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Demary, Markus
Institut der deutschen Wirtschaft Koeln

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Markus Demary[1]
Research Center for Real Estate Economics, Institut der deutschen Wirtschaft Köln, Germany

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Abstract: This study analyses empirically the link between real house prices and key macro variables like prices, output and interest rates for ten OECD countries. We find out that a monetary policy shock lowers real house prices in all ten countries, where the interest rate shock explains between 12 and 24 percent of the fluctuations in house prices. Impulse responses indicate that house prices rise after an output shock in nine of ten countries. But we also find evidence that real estate prices have a large impact on these key macroeconomic variables. We find out that the house price shock is a germane aggregate demand shock because it raises output and prices and leads to increasing money market rates in all countries. The story behind this finding is that increasing house prices lead to an increase in households' net worth which leads to increasing consumption expentitures and thereby stimulates aggregate demand. This stimulus on aggregate demand leads to increasing output and inflationary pressures on which the central bank reacts by tightening monetary policy. We find out that 12 to 20 percent of output fluctuations and around 10 to 20 percent of price fluctuations can be traced back to the housing demand shock. Moreover, we find that these housing demand shocks are a key driver of money market rates. We conclude that this channel is empirically relevant.

Key words: *Inflation, Monetary Policy, Housing Prices, Vectorautoregressions*

JEL Classification: *C32, E31, E32, E44*

[1]Authors contact details: Institut der deutschen Wirtschaft Köln, Gustav-Heinemann-Ufer 84-88, 50968 Köln, Germany, demary@iwkoeln.de, phone: 49-221-4981-744

1 Introduction

The recent months showed that fluctuations in real estate prices can have important implications for business cycle dynamics and economic stability. Despite social aspects like giving shelter housing is also of economic importance. A large fraction of households' net worth is invested in housing. Moreover, housing has the important part to be collateral for mortgage financing. And a large fraction of private liabilities are mortgages. When real estate prices change they change households' credit constraints. If, for example, house prices increase the value of collateral increases, too. Therefore, financial institutions have the possibility to lend to people to whom they did not before. Thus, rising house prices might lead to an increase in credit supply. Increases in real estate lead to an increase in households' net worth and thereby pushing the demand for consumption goods and thereby pushing aggregate demand. It seems that housing might therefore play a significant role in the transmission process of monetary policy onto the real economy and also in the transmission of business cycle fluctuations. If the central bank tightens monetary policy by raising the federal funds rate, this rise in money market rates will transmit to the mortgage market. Mortgage rates will thereby increase which expenses the costs of housing finance, which pulls the demand for housing and thereby housing prices. This will lower the value of collateral which results in a tightening of the supply of credit, which amplifies the effect of the central bank's interest rate hike on other interest rates.

This study analyses the impact of technology shocks, inflation and monetary policy on house prices as well as the impact of the housing market on the business cycle, inflation and money market rates by structural vectorautoregressions for ten OECD countries. Earlier papers, which study this impact with different methodologies are Iacoviello (2004), Assenmacher-Wesche and Gerlach (2008), Rubio (2008), McQuinn and O'Reilly (2007), Iacoviello (2000), Iacoviello and Neri (2008), Iacoviello and Minetti (2006), Bharat and Zan (2002) and Baffoe-Bonnie (1998), Piazzesi et al. (2007), Jäger and Voigtländer (2006) and Goodhard and Hofmann (2008). Iaccoviello (2004) derives and estimates a consumption Euler equation with housing. He assumes that house prices are part of the households' intertemporal optimization problem if the borrowing capacity of indebted households is assumed to be connected with the value of their home. By estimating the consumption Euler equation he finds a strong empirical support for the hypothesis that house prices are a key driver of aggregate consumption expenditures. Assenmacher-Wesche and Gerlach (2008) study the relationship between inflation, output, monetary policy, residential property and equity prices by means of a panel vectorautoregression for 17 OECD countries. They find that shocks to asset prices have a significant effect on output and credit after aproximately one year, where the price level increases with a larger lag. Rubio (2008) studies the relevance of fixed versus variable mortgage rates for the business cycle and monetary policy by means of a stochastic dynamic general equilibrium model with a housing market and households which are credit constraint and therefore need housing collateral in order to get loans. Borrowing is allowed either at a variable mortgage rate or at a fixed rate. She finds out that when monetary policy tightens households which borrowed at variable mortgage rates reduce consumption expenditures and housing demand by more than households who borrowed at fixed rates. McQuinn and O'Reilly (2007) apply country-by-country and panel cointegration techniques to a panel dataset consiting of 16 OECD countries spanning the time period from 1980 to 2005. The find a long-run cointegration relationship between house prices, income and interest rates, which is robust to seven out of eight cointegration test which they apply. Iacoviello and Neri (2008) explain the upward trend in real house prices of the last 40 years by slow technological progress in the housing sector. Moreover, they find that housing demand and housing supply shocks contribute to 25 percent of the volatility of house prices and housing investment, while monetary factors contribute with 20 percent. Iacoviello and Minetti (2006) also state that housing plays an important role in business cycle dynamics. They name that housing investment is a very volatile component of aggregate demand as well as that there are important wealth effects from changes in house prices on consumption. Bharat and Zan (2002) also find evidence of a stable long-term relationship between house prices, income and interest rates for Sweden and the United Kingdom (UK). By means of Granger-causality test they find that income Granger-causes house prices in

Sweden, while they find a feedback from income to house prices as well as a feedback from house prices to income for the UK. Baffoe-Bonnie (1998) estimates vectorautoregressions and finds that shocks to macroeconomic variables result in cyclical movements in housing prices. Moreover he finds that the housing market responds very sensitive to shocks in the employment growth and the mortgage rate. He concludes that regional house prices reflect regional employment growth as well as national mortgage rates. Piazzesi and Schneider (2009) want to explain the observation that in the 1970s U.S. asset markets experienced a 25 percent decrease in the wealth to GDP ratio and a negative comovement of house and stock prices that resulted in a portfolio shift from equity to real estate by 20 percent. They contribute the drop in wealth to the entry of the baby boom generation into asset markets and to the erosion of bond portfolios by inflation which resulted in a decreasing propensity to save. Jäger and Voigtländer (2006) compare the impulse responses of real house prices to a monetary policy shock within a structural VAR framework for ten OECD countries. They classify them into three groups. The UK, Spain, Finland and Australia form group one. These countries are characterized by a mortgage market which is dominated by mortgage contracts with variable interest rates. Group two consisting of the USA, the Netherlands and Denmark is characterized by mortgage market where either fixed rate contracts or variable rate contracts are supplied. Finally, group three consists of Germany, France and Japan. In these countries there is a dominance of fixed rate contracts in the mortgage market. Their impulse response analysis indicates that the reaction of real house prices two years after the monetary policy shock hit the economy is stronger in the countries with a dominance of variable rate contracts, where it is weaker in the countries with a dominance of fixed rate contracts. Tsatsaronis and Zhu (2004) use a VAR model consisting of inflation-adjusted house prices, the growth rate of gross domestic product, the consumer price inflation rate, the real short-term interest rate, the term spread between a government bond with long maturity and the short-term interest rate and the growth rate of inflation adjusted bank credit. They identify inflation as the key driver of real house prices and that household income has very low explanatary power.

This paper wants to contribute to this literature by supporting the evidence that there is a strong link between the housing market and the macroeconomy. We analyse this link by applying a rigourous econometric analysis to the time series of real housing prices, the real gross domestic product, the deflator for the gross domestic product and the money market rate as a measure for the monetary policy stance. Our dataset consists of time series for ten OECD countries including Australia, Denmark, Finland, France, Germany, Japan, the Netherlands, Spain, the UK and the USA spanning the period from the first quarter of 1970 to the last quarter of 2005. This real house price dataset was also employed in Tsatsaronis and Zhu (2004), OECD (2005), Ahearne et al. (2005), Ceron and Suarez (2006), Jäger and Voigtländer (2006) and McKieran and O'Reilly (2007), where we differ in methodology. First we use the Hodrick-Prescott-filtered cyclical components of the time series and calculate cross correlations between the cyclical components of house prices and the cyclical components of prices, output and the interest rates for leads and lags of these variables, a methodology also applied in Stock and Watson (1999). After that we apply vectorautoregressions to the logarithmic levels of these time series and cacullate the usual VAR statistics like impulse responses, forecast error variance decompositions and Granger-causality tests. With the help of the results we get from applying these methods we want to gain more and robust insights about the empirical interplay between these variables and the transmission of shocks to these variables.

Within this study the following results emerge. Cross correlations indicate a strong link between the cyclical components of real house prices and output at several leads and lags. We find out that a monetary policy shock lowers real house prices in all ten OECD countries, where the interest rate shock explains between 12 and 24 percent of the fluctuations in house prices. This finding is in line with our intuition that increasing interest rates increase the cost of financing real estate projects and thereby lower the demand for housing. We do not find evidence that rising prices lead to rising house prices, because inflationary pressures increase the demand for real estate for the sake of hedging inflation. A reason can be that inflation-indexed income from renting homes is not reflected in the OECD house price index and that it only measures the worth of the building. Our results give more support for the hypothesis that when the central bank raises interest rates to accomodate inflationary pressures which is the cause of falling house prices. This hypothesis is empirically supported by increasing interest rates and decreasing house prices after the inflationary shock. Impulse responses indicate that house prices rise after an output shock in nine of ten countries, which might be due to the fact that rising house prices increase households' net worth which gives them incentive to increase their consumption expenditures (see Piazzesi et al. 2007). But we also find evidence that real estate prices have a large impact on these key macroeconomic variables. We find out that the house price shock is a germane aggregate demand shock because it raises output and prices and leads to increasing money market rates. The story behind this finding is that increasing house prices lead to an increase in households' net worth which leads to increasing consumption expentitures and thereby stimulates aggregate demand. This stimulus on aggregate demand leads to increasing output and inflationary pressures on which the central bank reacts by tightening monetary policy which leads to higher money market rates. We find out that 12 to 20 percent of output fluctuations and around 10 to 20 percent of price fluctuations can be traced back to the housing demand shock. Moreover, we find that these housing demand shocks are a key driver of money market rates. We conclude that this channel is empirically relevant. However, we do not find evidence that a higher value of housing as a collateral has any impact on interest rates. Our results are in line with the results reported in Iacoviello (2000), who finds monetary policy shocks lower house prices and that the timing in the response of house prices matches that of output. Moreover, he finds that monetary shocks are a key driving force of house price fluctuations. Goodhard and Hofmann (2008) that there is a strong and multidirectional link between house prices, monetary varaibles and the macroeconomy.

The remainder of this paper is structured as follows. Section two tackles the transmission mechanisms, while section three presents the empirical model. Section four contains the empirical results, while section five concludes.

2 Transmission Channels

Within this section we want to derive theoretical transmission channels between these macroeconomic variables. We can use these intutions later on in order to interpret the results of our econometric analysis.

From our economic intuition we can identify the following transmission channels from inflation, output and interest rates on real estate prices:

(i) When the monetary authority tightens monetary policy, this will translate into an increase in the money market rate and thereby through the mortgage market into higher costs of financing real estate projects. Thus, the demand for real estate will decrease after a policy tightening and thereby real estate prices.

($ii\,a$) When a shock is increasing the price level unexpectedly, economic agents try to protect their wealth by investing in real estate, because they believe that real estate is a good hedge against inflation. Thus, this inflation induced demand for real estate increases real estate prices.

($ii\,b$) When inflation is rising, the monetary authority should respond by raising the Federal Funds Rate, which will lead to an increase in mortgage market rates and thereby housing finance will be more expensive. This will lower the demand for real estate and will lead to lower real estate prices.

(iii) When a shock pushes output above its long term steady-state, firms' demand for labor is increasing and thereby households decide to work more. This increase in households' labor income can either be consumed or invested into real estate. Note that having a job increases the chances to get a cheap loan for investing in homes. Thus, the demand for housing is increasing when the economy is experiencing a boom phase, which will translate into an increase in real estate prices. Moreover, firms need more office space, which will also trigger into an increase in office real estate prices.

But there are also feedbacks from the real estate sector onto the macroeconomy.

We identified the following transmission channels:

(*iv*) When a shock leads to rising housing prices, there will be a rise in households' net worth. This increase in wealth will lead to portfolio shifts and to increases in households' consumption expenditures (see Iacoviello 2004 and Piazzesi et al. 2007). This rise in the demand for consumption goods will push the gross domestic product above its long term steady-state level.

(*v*) When real estate prices are rising and thereby pushing consumption expenditures and thusly aggregate demand they will lead to inflationary pressures. Moreover, economic agents are trying to get higher rents, which raises the costs of living which are reflected in the increase in the price level.

(*vi a*) When real estate prices are rising and thereby households' net worth, the central bank committee might expect a future increase in aggregate demand which increases inflation risks. Central bankers might respond to increasing house prices by raising money market rates.

(*vi b*) When real estate prices are rising the value of collateral is increased and thus banks have the possibility to give credit to households to whom they did not before. Thus, a rise in real estate prices raises credit supply and thusly leads to lower interest rates.

The following sections contain information about the used dataset, the empirical methodology and empirical results in order to get a robust inference about which of these proposed channels is of empirical relevance and which one not.

3 Data and Methodology

The empirical analysis is based on the same dataset used in Jäger and Voigtländer (2006) consisting of the ten OECD countries Australia, Denmark, Finland, France, Germany, Japan, the Netherlands, Spain, the UK and the USA which they directly got from the OECD[2]. The same house price dataset is also used in Tsatsaronis and Zhu (2004), OECD (2005), Ahearne et al. (2006), Ceron and Suarez (2006) and McQuinn and O'REally (2007), where we differ in methodology here. The time series range from the first quarter of 1970 to the last quarter of 2005 making a total of 144 observations per time series. The time series used for the analysis are the OECD real house price index, the deflator for the gross domestic product as a measure of the aggregate price level, the gross domestic product as a measure of output and a short term interest rate as a measure of the monetary policy stance. In OECD (2005) one can find a description of the real house price time series. The house price index of Australia is an index of a weighted average of eight capital cities calculated by the Australia Bureau of Statistics. For Denmark it is the index of one-family houses sold which the OECD got from Statistics Denmark. Finland's version of the house price index consists of a basket of housing prices in metropolitan areas calculated by the Bank of Finland. For Germany is an index consisting of total resales which is originally supplied by th Bundesbank. In Japan it is a nationwide urban land price index which is supplied by the Japan Real Estate Insitute. The house price index for the Netherlands consists of existing dwellings calculated by the Nederlandsche Bank. The Spanish house price index is supplied to the OECD by the Banco de Espana. In the UK it is a mix-adjusted house price index supplied by ODPM, while for the USA is is the nationwide single family house price index supplied by OFHEO. Moreover one can read in OECD (2005) that they used data provided by the Bank for International Settlements which are based on national sources for the countries for the price indices in which the sample period was incomplete.

Because these house price data over this sample period are frequently used we find it useful to elaborate on this darta, too. In contrast to the other cited studies we differ a bit in methodology. The first part of our analysis is based on the Hodrick-Prescott-filtered cyclical components of the time series. In order to analyse how weak or strong they comove at business cycle frequencies we calculate cross correlations for serveral leads and lags of the variables. This

[2]Many thanks to Manfred Jäger and Michael Voigtländer for supplying me their dataset and Christophe André from OECD who supplied this dataset to them.

methodology is inspired by the work of Stock and Watson (1999) where they measure business fluctuations in U.S. time series. The second part of our analysis is based on the VAR-methodology which several of the here cited papers also applied. The VAR approach, originally introduced by Sims (1980), is a widely used approach for the empirical analysis of the monetary transmission process[3]. Christiano et al. (1996a, 1996b) suggest the VAR approach to get empirical robust results about the effects of monetary policy. In contrast to traditional econometric approaches VAR models do not concentrate on systematic movements, but concentrate on the dynamic time series effects of shocks to the economy. In contrast to the foregoing VAR papers on housing price dynamics (Tsatsaronis and Zhu 2004, Jäger and Voigtländer 2006) we use a simpler version of the VAR model here with just the price level, output, a short term interest rate and the house price index as macroeconomic variables. The reason is that we want to identify shocks that can be interpreted as an aggregate supply shock (one that moves output and prices in opposite directions), an aggregate demand shock (one which moves output and prices in the same direction), a monetary policy shock (one which increases the interest rate and which leads to decreasing output and decreasing prices) and a house price shock (about whose impact we want to learn more). In order to catch these dynamic responses we employ the usual recursive identification scheme via the Cholesky-decomposition of the variance-covariance matrix. The order of the variables is as usual in the literature on monetary policy shocks with prices ordered first, then output and the monetary policy instrument ordered last (see Favero 2001 for an overview over this methodology). This identification scheme assumes a kind of monetary policy reaction function a la Taylor (1993) where the policy maker reacts on all shocks immediatedly. Moreover, it implies that output does not react in the current period to the interest rate shock, which is justified by a lag in the monetary transmission process. Furthermore it implies that prices do not react to the output shock as well as the monetary policy shock in the current period. This restriction is justified by the assumption that

[3]See the contributions of Bagliano and Favero (1998), Bernanke and Blineder (1992), Bernanke and Mihov (1997, 1998a, 1998b), Christiano et al. (1996, 1998), Blanchard and Quah (1989), Gali (1992), Sims (1992), Strongin (1995), Uhlig (1997) and the textbook treatments Amisano and Giannini (1997) and Favero (2001).

prices are sticky in the short-run, so that monetary policy affects output before it affects prices. Note that this view of the monetary transmission process is in line with the inflation targeting model introduced by Svensson (1999a, 1999b). Last but not least, we model house prices last because we assume that the monetary policy maker might not react contemporaneously to developments in the housing market, while the housing market reacts directly to all shocks.

Summing up, the VAR model assumes joint dynamics of the logarithms of the price level p_t, output y_t, the short-term interest rate i_t and the house price index h_t. If we stack all four variables into the vector $x_t = [p_t, y_t, i_t, h_t]'$ the VAR model in reduced form of order k can be written as

$$x_t = A_1 x_{t-1} + ... + A_k x_{t-k} + u_t, \quad (1)$$

where u_t is the VAR 4×1 residual vector with mean zero and 4×4 variance-covariance matrix Ω, where the A_j are 4×4 coefficient matrices, which can be estimated using the reduced form VAR. Because the VAR residuals are contemporaneously correlated we cannot interpret them as primitive shocks and cannot trace their isolated impact onto the variables of the VAR systems. Because we need independent (or at least uncorrelated) shocks, which are up to now unobservable to us, we have to ortogonalize them by identifying restrictions. The VAR model in structural form (that means with identified orthogonal shocks) looks as follows

$$x_t = A_1 x_{t-1} + ... + A_k x_{t-k} + B\varepsilon_t, \quad (2)$$

where the structural shocks summarized in the 4×1 vector ε_t have also zero mean, however, they are contemporaneously uncorrelated and have unit variance by construction, thus, their variance covariance matrix is the identity matrix. From equations (1) and (2) follows that the relationship between the VAR residuals and the unobservable structural shocks is

$$u_t = B\varepsilon_t, \quad (3)$$

while the relationship between their variance-covariance matrices is

$$\Omega_t = E[u_t u_u'] = E[B\varepsilon_t \varepsilon_t' B'] = BB'. \tag{4}$$

This relationship places 10 restrictions on the matrix B, thus we need additional 6 restrictions in order to calculate all elements in B and thus identify the structural shocks. Often one uses the Cholesky-decomposition in order to identify the shocks. The Cholesky-identification scheme is a lower triangular matrix B

$$\begin{bmatrix} u_t^p \\ u_t^y \\ u_t^i \\ u_t^h \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix} \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^y \\ \varepsilon_t^i \\ \varepsilon_t^h \end{bmatrix}. \tag{5}$$

This identification scheme assumes that the price level reacts with a lag to the output shock, the interest rate shock and the housing price shock. The output reacts with a lag to the inflation shock, the interest rate shock and the housing price shock. The central bank reacts only to the inflation shock and the output shock and has its own shock which represents a deviation from the monetary policy rule. House prices are assumed to react directly to all shocks as already mentioned. Now that shocks are identifies we can start with the empirical analysis. This is done first by caculating the impulse responses $\alpha_s(i,j)$ to an isolated one-time shock at time t to the system

$$\alpha_s(i,j) = \frac{\partial x_{i,t+s}}{\partial \varepsilon_{j,t}}, \text{ for time } s = 0, ..., \tag{6}$$

which is nothing else than the expected future path of a variable $x_{i,t}$ after the shock $\varepsilon_{j,t}$ hit the VAR-system (see Favero 2001, pp. 174-175). The forecast error variance decomposition can be calculated by first forecasting x_t and calculating the VAR-forecast errors as

$$x_{t+s} - E_t x_{t+s} = C_0\varepsilon_t + C_1\varepsilon_{t-1} + ... + C_s\varepsilon_{t-s}, \tag{7}$$

where matrixces C can be calculated from the VAR-coefficient matrices and the shock impact matrix B (see Favero 2001, pp. 174-175). The forecast error variance can now be calculated as

$$Var(x_{t+s} - E_t x_{t+s}) = C_0 C_0' + C_1 C_1' + ... + C_s C_s', \tag{8}$$

because the structural shocks have a variance-covariance matrix equal to the identity matrix by construction. Note, that all shocks contribute to the forecast error variance of each varaible. By deviding this system of equation through the forecast error variance $Var(x_{t+s} - E_t x_{t+s})$, we get the percentage contribution of each shock to the forecast error variance of each variable. This statistic measures the importance of one particular shock for the fluctuations of a variable in the VAR system. Finally, one can test on Granger-causality (or more precisely on Granger-non-causality, see Granger 1987). The Granger-causality test the null hypothesis that the past of the variable $x_{i,t}$ has no impact on the present or future of the variable $x_{j,t}$ in the VAR-system. This test can be performed as zero coefficient restrictions on the pertinent elements (i, j) of the coefficient matrices A_1 to A_k. If we can reject the null hypothesis of Granger-non-causality of one variable, this means that the past of this variable determines the present of another varaible in the VAR-system.

4 Empirical Results

This section contains the empirical results. First of all we calculate cross correlations between the Hodrick-Prescott-filtered cyclical components of the time series for several leads and lags. After that we present the results of the impulse response analysis, the forecast error variance decomposition and the Granger-causality tests which we perform by applying a VAR-model to the logarithmic levels of the data.

4.1 Volatilities and Cross Correlations

In this subsection we analyze statistical properties of the business cycle components of the data series. We extract the cyclical components by applying the

Hodrick-Prescott filter to the logarithms of the data series. The resulting cyclical components are measured as the percentage deviation from the Hodrick-Prescott-trend. Following the methodology apllied in Stock and Watson (1999) we calculate volatilities, autocorrelations and cross correlations on these cyclical components in order to get insights about the volatility, the persistence and comovements between house prices and the other three macroeconomic variables at business cycle frequencies.

Table 1 contains the standard deviations of the cyclical components of the time series. From this table we can infer that the business cycle component of real housing prices is more volatile than the cyclical components of inflation, output and interes rates. The reason for the higher volatility might be the fact that housing supply is inelastic at this frequencies, which has the effect that changes in the demand for housing translate into volatility of housing prices.

Table 1: Volatilities

	Volatilities			
	Inflation	Output	Interest Rate	House Prices
Australia	0.017	0.013	0.019	0.042
Denmark	0.011	0.014	0.016	0.057
Finland	0.019	0.021	0.016	0.070
France	0.010	0.009	0.015	0.155
Germany	0.007	0.018	0.016	0.018
Japan	0.017	0.014	0.016	0.044
Netherlands	0.010	0.013	0.017	0.059
Spain	0.014	0.011	0.019	0.053
UK	0.023	0.015	0.018	0.069
USA	0.009	0.016	0.017	0.021

Volatilities are calculated as the standard deviations of the Hodrick-Prescott-filtered cyclical components of the time series. The cyclical components are measured as percentage deviations from the Hordrick-Prescott-trend. The dataset spans the period from 1970Q1 to 2005Q4.

Table 2 panel (a) shows autocorrelation coefficients of the cyclical component of house prices for up to five lags. As one can see, all house price cycles display similar degrees of persistence. Autocorrelation coefficients to lag one are in a range between 0.884 (Australia) and 0.974 (France), while autocorrelations to lag two range between 0.675 (Australia) and 0.894 (France). This finding indicates that house price cycles are quite persistent. We can compare these autocorrelations with the autocorrelations of the cyclical component of the price level which is given by panel (b) of table 2. What can be found here is that the cyclical component of the price level is characterized by similar degrees of persistence as house prices have. The autocorrelations of prices to their first lag are in a range between 0.800 (Germany) and 0.902 (Japan), where autocorrelations to their second lag are in a range between 0.633 (Netherlands) and 0.811 (USA). If we compare these values to the autocorrelations of the cyclical component of output (table 3 panel (3)), we see that they lie in a range between 0.541 (Netherlands) and 0.905 (Finland) for the first lag, where the autocorrelations to the second lag range between 0.387 (Netherlands) and 0.788 (Finland) indication that the house price cycle is more persistent compared to the business cycle. Last, but not least, the persistence of the cyclical component of interest rates lie in a range between 0.516 (Spain) and 0.878 (Denmark and Germany) for the first lag and between 0.013 (Spain) and 0.656 (Denmark and Germany). Thus, indicating that the cyclical movements of house prices and the price level are more persistent compared to the cyclical movements of output and interest rates. In order to get an inference about how these cycles comove, we have to calculate cross correlations between them for several leads and lags. Results from this excercise can be found in table 4.

Table 4 contains cross correlations of the Hodrick-Prescott-filtered time series of house price with leads and lags of the business cycle components of output, inflation and interest rates. Panel (a) of this table contains the cross correlations of real house prices and output. In nine of ten countries we find a strong contemporaneous correlation between house prices and output ranging from 0.317 (Germany) to 0.797 (Finland). The only exception is France with just a correlation of 0.060. Moreover we find strong correlations of house prices with past output even for France. With respect to the one quarter lagged output these correlations range from 0.090 (France) to 0.777 (Finland), while the correlations between house prices and the two quarter lagged output range from 0.038 (Germany) to 0.719 (Finland). The strong correlations between the cyclical components of house prices and output inidcate that the housing market is strongly moving with the business cycle. Or more precisely, that

Table 2: Autocorrelations

Lag	(a) Autocorrelation of House Prices 1	2	3	4	5
Australia	0.884	0.675	0.410	0.143	-0.087
Denmark	0.899	0.763	0.555	0.383	0.239
Finland	0.952	0.843	0.688	0.506	0.316
France	0.974	0.894	0.841	0.788	0.736
Germany	0.925	0.802	0.660	0.513	0.372
Japan	0.942	0.825	0.670	0.479	0.283
Netherlands	0.945	0.850	0.716	0.548	0.380
Spain	0.915	0.744	0.542	0.346	0.176
UK	0.941	0.813	0.631	0.421	0.211
USA	0.912	0.796	0.655	0.472	0.304

Lag	(b) Autocorrelations of the Price Level 1	2	3	4	5
Australia	0.872	0.731	0.596	0.448	0.251
Denmark	0.864	0.711	0.558	0.388	0.209
Finland	0.867	0.701	0.505	0.309	0.104
France	0.901	0.753	0.594	0.437	0.277
Germany	0.800	0.657	0.505	0.373	0.226
Japan	0.902	0.726	0.493	0.239	0.008
Netherlands	0.818	0.633	0.523	0.415	0.264
Spain	0.875	0.723	0.571	0.431	0.285
UK	0.896	0.748	0.572	0.352	0.135
USA	0.933	0.811	0.661	0.483	0.276

Autocorrelations are calculated on the Hodrick-Prescott-filtered cyclical components of the time series. The cyclical components are measured as percentage deviations from the Hordrick-Prescott-trend. The Dataset spans the period from 1970Q1 to 2005Q4.

output is a key driver of the housing cycle at business cycle frequencies. Correlations of house prices with future output display also high values indicating that past house prices have a significant impact on the business cycle. These correlations range from 0.040 (France) to 0.679 (Denmark). Thus, there is evidence that the housing market and aggregate output influence each other during the business cycle, where causality might run in both directions. The high correlations between past output and housing prices can be explained as follows. If output is above its long-term average more workers are employed and thus household income is increases. People want to invest these additional funds, where they prefer investing in real estate because housing has also the character of shelter. Because having a job increases the chances to get a cheap

Table 3: Autocorrelations

	(a) Autocorrelation of Output				
Lag	1	2	3	4	5
Australia	0.714	0.481	0.329	0.072	-0.044
Denmark	0.805	0.644	0.393	0.145	-0.048
Finland	0.905	0.788	0.644	0.480	0.321
France	0.853	0.668	0.456	0.245	0.093
Germany	0.619	0.403	0.266	0.170	0.059
Japan	0.805	0.627	0.457	0.213	0.009
Netherlands	0.541	0.387	0.251	0.127	0.113
Spain	0.825	0.719	0.551	0.360	0.254
UK	0.806	0.647	0.503	0.310	0.165
USA	0.870	0.697	0.489	0.288	0.086
	(b) Autocorrelations of Interest Rates				
Lag	1	2	3	4	5
Australia	0.736	0.470	0.282	0.092	-0.196
Denmark	0.878	0.665	0.434	0.231	0.035
Finland	0.717	0.462	0.286	0.157	-0.010
France	0.813	0.531	0.260	0.036	-0.131
Germany	0.878	0.665	0.434	0.231	0.035
Japan	0.835	0.624	0.395	0.141	-0.113
Netherlands	0.744	0.435	0.247	0.051	-0.154
Spain	0.516	0.013	0.038	-0.012	-0.280
UK	0.801	0.569	0.327	0.144	-0.040
USA	0.784	0.525	0.397	0.280	0.138

Autocorrelations are calculated on the Hodrick-Prescott-filtered cyclical components of the time series. The cyclical components are measured as percentage deviations from the Hordrick-Prescott-trend. The Dataset spans the period from 1970Q1 to 2005Q4.

loan in the mortgage market agents want to invest in real estate when employment is high. The strong correlation between house prices and future output can be explained as follows. If house prices rise above their long-term average households wealth increases. This increase in wealth leads to higher consumption which translates into higher output. Empirical evidence for these wealth effects on consumption can be found in ...

Panel (b) of table 4 contains cross correlations of house prices with leads and lags of the business cycle components of inflation. For the contemporaneous correlations we find that they are strong if they are negative ranging from -0.224 (Japan) to -0.706 (USA), while they are small if they are positive ranging from 0.011 (France) to 0.288 (Finland). If we consider only correlations to past inflation we find strong and negative correlations for most of the countries considered. If we consider correlations with the 1 quarter lagged inflation rate we find negative correlations ranging from -0.024 (France) to 0.744 (USA), where if we consider correlations to the two quarter lagged inflation rate we will find negative correlations ranging from -0.061 (France) to 0.809 (USA). Finland and Spain are the exceptions having positve correlations ranging from 0.156 and 0.021 (France) to 0.246 and 0.220 (Spain). What is the explanation of the negative relationship between house prices and past inflation? Consider inflation is above its long-term average (e. g. the inflation target of the central bank). The central bank will react by pushing interest rates, which will increase the costs of financing homes. Therefore, housing demand declines which will lead to the decline in housing prices. If we compare the correlations of house prices with future inflation we find a positve correlation to the one quarter ahead inflation rate for six countries ranging from 0.014 (Japan) to 0.400 (Finland), while we find negative correlations for four countries ranging from -0.292 (Netherlands) to -0.551 (Denmark). Again correlations seem to be higher in magnitude if they are negative indicating that the negative relationship might be stronger than the positve. A positve realtionship between house prices and future inflation can be explained as follows. Assume that house prices are above their long-term average. This increase in wealth increase households' demand for consumption goods and thereby aggregate demand. The increase in aggregate demand pushes the inflation rate above its long-term average. But what explains the negative correlation between house prices and future inflation which seems to be stronger than the positive one? Suppose house prices rise above their long-term average which pushes aggregate demand. Homeowners may want higher rents for supplying housing which increases to cost of living and thereby inflation.

Panel (c) of table 5 contains cross correlation between house prices and leads and lags of money market rates. If we compare the contemporaneous correlations we find positive correlations for eight countries ranging from 0.072 (France) to 0.551 (UK), while we find negative correlations for Denmark (-0.407) and the Netherlands (-0.140). If we compare the positive correlations to past interest rates we find correlations ranging from 0.017 (Finland) to 0.443

(Germany) for the one period lagged interest rate, while we find positive correlations ranging from 0.015 (France) to 0.415 (Germany). The negative correlations of Danish house prices to lagged interest rates are -0.383 and -0.336, while the are -0.233 and -0.307 for the Netherlands. The negative relationship between past interest rates and housing demand is straightforward. If interest rates rise above their long-term average housing finance will become more costly. In response to increasing interes rates housing demand will decline which will lead to decreasing house prices. We also expects this link to be strong, as mirrored by the strong negative correlations of Denmark and the Netherlands. But these positive correlations are still puzzling. We find strong positve cross correlations between house prices and future interest rates ranging from 0.094 (France) to 0.671 (UK) in eight countries. Why are interest rates increasing in response to higher house prices? If the increase in house prices triggers aggregate demand central bankers will expects higher future output and higher future inflation (see panels (a) and (b)) and react by tightening monetary policy which will lead to increasing interest rates. The only exceptions are Denmark and the Netherlands which have also negative correlations between house prices and future inflation.

4.2 Impulse Responses

A more detailed picture about the interaction of the four time series can be given by calculating impulse respones. Thus, we can trace out the dynamic impact of a well defined shock onto the time series behavior of the four variables.

4.2.1 Impulse Responses to an Inflationary Shock

In eight of ten countries the inflationary shock pulls output below its long-term average (see table 5, panel (b)). Because in all countries it pushes prices and output on impact opposite directions, this shock can be interpreted as an aggregate supply shock. Denmark and Spain are the only counries where output rise to positive levels in the subsequent quarters. Aggregate supply

Table 4: Cross-Correlations

	(a) Cross Correlation with House Prices				
	Output(-2)	Output(-1)	Output	Output(+1)	Output(+2)
Australia	0.381	0.473	0.485	0.433	0.340
Denmark	0.447	0.545	0.633	0.679	0.675
Finland	0.719	0.777	0.797	0.772	0.703
France	0.112	0.090	0.060	0.040	0.031
Germany	0.038	0.035	0.317	0.223	0.156
Japan	0.674	0.660	0.605	0.478	0.306
Netherlands	0.187	0.266	0.329	0.329	0.349
Spain	0.510	0.528	0.512	0.483	0.388
UK	0.660	0.657	0.616	0.498	0.343
USA	0.648	0.671	0.660	0.627	0.532

	(b) Cross Correlation with House Prices				
	Inflation(-2)	Inflation(-1)	Inflation	Inflation(+1)	Inflation(+2)
Australia	-0.045	-0.001	0.054	0.119	0.171
Denmark	-0.271	-0.383	-0.477	-0.551	-0.598
Finland	0.021	0.156	0.288	0.400	0.488
France	-0.061	-0.024	0.011	0.042	0.067
Germany	-0.180	-0.070	0.047	0.181	0.259
Japan	-0.603	-0.435	-0.224	0.014	0.245
Netherlands	-0.107	-0.200	-0.263	-0.292	-0.305
Spain	0.220	0.246	0.237	0.218	0.198
UK	-0.506	-0.482	-0.429	-0.327	-0.193
USA	-0.809	-0.774	-0.706	-0.568	-0.402

	(c) Cross Correlation with House Prices				
	Interest(-2)	Interest(-1)	Interest	Interest(+1)	Interest(+2)
Australia	-0.093	0.143	0.379	0.555	0.612
Denmark	-0.336	-0.383	-0.407	-0.294	-0.128
Finland	-0.122	0.017	0.172	0.339	0.476
France	0.015	0.047	0.072	0.094	0.110
Germany	0.415	0.443	0.461	0.477	0.479
Japan	0.063	0.238	0.419	0.598	0.694
Netherlands	-0.307	-0.233	-0.140	-0.062	0.036
Spain	0.203	0.254	0.278	0.276	0.217
UK	0.184	0.374	0.551	0.671	0.728
USA	-0.060	-0.063	0.234	0.408	0.504

Cross correlations are calculated on the Hodrick-Prescott-filtered cyclical components of the time series. The cyclical components are measured as percentage deviations from the Hordrick-Prescott-trend. The Dataset spans the period from 1970Q1 to 2005Q4.

shocks confront central bankers with a trade-off between stabilizing inflation (tightening monetary policy) and stabilizing output (cutting interest rates). This trade-off can be seen in panel (c). In six countries interest rates rise in response to the aggregate supply shocks indicating that the central bank will fight inflation, while interest rates drop in four countries indicating that the central bank tries to stimulate output. One interesting result emerges. In countries, where the aggregate supply shock drops the output below its long-term level house prices decrease below their long-term level, while in the two countries where the inflationary shock leads to increasing output, house prices increase. This result is in favor of the strong link between output movements and house price movements which we already saw in table 2. As already said, output declines on impact ranging from -0.01 (Denmark) to -0.60 (Germany). After one year the output gap ranges from -0.02 (France) to -0.52 (Japan), while it is 0.12 in Denmark and 0.09 in Spain. This pattern is persistent for the next years as can be infered from the impluse responses up to four years after the shock hit the economy. In response to the aggregate supply shock house prices behave differently on impact. In six countries house prices decline on impact, while they rise in four countries. But note that the positive impulse responses are only small in magnitude. In the subsequent quarters we can inspect a tendency for house prices to decline. In five countries the inflationary shock is destabilizing because of its persistent nature which leads to a gradual decline in house prices. In three countries the response is hump-shaped having its through after four quarters in Germany, eight quarters in Japan and twelve quarters in the UK.

4.2.2 Impulse Responses to an Output Shock

The output shock increase the price level in all ten countries (see table 6 panel (b)). Because it moves prices and output into the same direction, it can be interpreted as an aggregate demand shock. In light of the aggegate demand shock the central banker does not have to face a trade-off, because monetary policy can smooth both, output and inflation. Thus, in response to the aggregate demand shock the central bank has to tighten monetary policy. As can be seen from panel (c) this reaction can only be found in six out of ten countries, where money market rates increase. Exceptions are Australia, Denmark, Spain and the UK. As can be seen from panel (a) house prices rise

Table 5: Impulse Responses to an Inflationary Shock

Quarters after Shock	(a) House Prices 0	4	8	12	16
Australia	-0.02	0.22	-0.10	-0.38	-0.54
Denmark	0.04	0.48	0.46	0.42	0.39
Finland	0.09	-0.20	-0.63	-0.99	-1.22
France	0.01	0.07	-0.22	-0.55	-0.81
Germany	-0.13	-0.23	-0.20	-0.14	-0.07
Japan	-0.36	-1.80	-2.13	-1.82	-1.41
Netherlands	0.01	-0.01	-0.17	-0.37	-0.56
Spain	-0.23	0.68	0.89	0.75	0.53
UK	-0.41	-1.04	-1.33	-1.38	-1.30
USA	-0.35	-0.87	-1.11	-1.28	-1.37
Quarters after Shock	**(b) Gross Domestic Product 0**	**4**	**8**	**12**	**16**
Australia	-0.26	-0.07	-0.14	-0.18	-0.18
Denmark	-0.01	0.12	0.14	0.14	0.15
Finland	-0.14	-0.19	-0.33	-0.42	-0.46
France	-0.01	-0.02	-0.13	-0.19	-0.21
Germany	-0.60	-0.50	-0.42	-0.33	-0.25
Japan	-0.12	-0.52	-0.46	-0.15	-0.27
Netherlands	-0.26	-0.14	-0.15	-0.17	-0.19
Spain	-0.05	0.09	0.11	0.09	0.06
UK	-0.21	-0.31	-0.35	-0.33	-0.29
USA	-0.10	-0.21	-0.30	-0.28	-0.19
Quarters after Shock	**(c) Money Market Rates 0**	**4**	**8**	**12**	**16**
Australia	0.18	0.36	0.28	0.20	0.16
Denmark	0.06	-0.10	-0.06	-0.05	-0.05
Finland	0.25	0.41	0.33	0.27	0.20
France	0.18	0.38	0.27	0.19	0.14
Germany	-0.03	-0.00	-0.02	-0.01	0.01
Japan	0.16	0.15	-0.11	-0.10	-0.01
Netherlands	-0.16	-0.02	0.03	0.04	0.05
Spain	0.17	0.09	0.05	0.04	0.02
UK	0.22	0.22	0.13	0.09	0.07
USA	0.18	0.28	0.16	0.03	-0.06

Estimated impulse responses to an inflationary shock based on the Cholesky identification scheme. Entries from panels (a) and (b) are measured as percentage deviations from steady-state, while the entries from panel (c) are measured as percentage point deviations from the steady-state level. All impulse responses were multiplied by 100 percent.

in all countries but France in response to the aggregate demand shock. This increase ranges from 0.08 (Spain) to 1.57 (Finland) one year after the shock hit the economy, while it ranges from 0.01 (USA) to 2.00 (Finland) two years after the shock hit the economy. In seven countries we can find a hump-shaped response which has its maximum after four quarters in Denmark, Germany and Japan, while it has its maximum after eight quarters in Australia and Finland. In the Netherlands and in the UK the house price hike reaches its maximum three years after the shock hit the economy. The economics behind these responses are the following. The demand shock increases output and inflation. The output stimulus leads to an increasing demand for real estate because more people are at work and thus it is easier for them to get a mortgage loan when being employed. This response is in line with the strong cross correlations between house prices and current and past output which we already saw in table 4.

4.2.3 Impulse Responses to a Monetary Policy Shock

Table 7 contains estimated impulse responses to a shock to the money market rate. We interpret this shock as a monetary policy shock. As a monetary policy shock usually does, this shock leads to a drop in output in all ten OECD cour- tries. This drop in output reaches from -0.01 (Germany) to -0.79 (UK) eight quarters after the realization of the shock. The price level rises in response to the monetary policy shock in most of the countries. This counterintuitive finding is called "price puzzle" and results from ommiting oil prices in the VAR system (see Favero 2001). As expected the monetary policy shock leads to declining house prices in the long run. Twelve quarters after the shock hit the economy this drop in house prices ranges from -0.04 (Germany) to -2.91 (Netherlands). The deline in house prices is larger compared to the decline in output in all countries. This corresponds to the finding that the volatility of house prices is larger compared to the volatility of output, inflation and interest rates. The decline in real house prices after a monetary tightening has the following implications. When monetary policy tightens, interest rates in the mortgage market will also tighten leading to higher costs of financing houses. Higher costs of financing means that the demand for housing will decline leading to a drop in house prices. Because the drop in house prices

Table 6: Impulse Responses to an Output Shock

Quarters after Shock	(a) House Prices 0	4	8	12	16
Australia	0.19	0.98	1.00	0.94	0.91
Denmark	0.54	1.50	1.47	1.41	1.35
Finland	0.39	1.57	2.00	1.88	1.50
France	-0.05	-0.07	-0.19	-0.18	-0.10
Germany	0.14	0.28	0.23	0.10	-0.01
Japan	0.31	0.36	0.11	-0.11	-0.25
Netherlands	0.42	0.55	0.70	0.92	1.15
Spain	-0.21	0.08	0.40	0.67	0.86
UK	0.47	1.10	1.34	1.41	1.37
USA	-0.01	0.07	0.01	-0.02	-0.04
Quarters after Shock	**(b) Price Level 0**	**4**	**8**	**12**	**16**
Australia	0.00	0.22	0.29	0.32	0.32
Denmark	0.00	-0.07	0.01	0.08	0.14
Finland	0.00	0.24	0.31	0.34	0.34
France	0.00	0.10	0.17	0.16	0.11
Germany	0.00	0.13	0.19	0.20	0.18
Japan	0.00	0.10	0.10	0.03	-0.06
Netherlands	0.00	0.16	0.21	0.24	0.28
Spain	0.00	0.02	0.07	0.11	0.16
UK	0.00	0.06	0.11	0.16	0.19
USA	0.00	0.06	0.13	0.16	0.16
Quarters after Shock	**(c) Money Market Rates 0**	**4**	**8**	**12**	**16**
Australia	-0.24	0.02	-0.03	-0.08	-0.11
Denmark	-0.12	-0.19	-0.10	-0.10	-0.09
Finland	0.18	0.00	0.02	0.05	0.07
France	0.47	0.40	0.32	0.30	0.31
Germany	1.45	1.23	1.07	0.93	0.83
Japan	-0.16	0.09	0.00	-0.08	-0.12
Netherlands	0.32	0.04	-0.05	0.07	-0.08
Spain	-0.25	-0.20	-0.17	-0.16	-0.15
UK	-0.09	-0.09	-0.08	-0.07	-0.07
USA	0.30	0.31	0.12	0.05	0.01

Estimated impulse responses to an output shock based on the Choleski identification scheme. Entries from panels (a) and (b) are measured as percentage deviations from steady-state, while the entries from panel (c) are measured as percentage point deviations from the steady-state level. Note that all impulse responses are multiplied by 100 percent.

leads to a lower wealth of households it will have direct effects on households consumption expenditures and thereby on the business cycle. Moreover, if house prices drop the value of collateral in the housing market declines which shortens households' credit constraints. Banks will only supply loans to households in exchange of higher risk premiums on the mortgage rate. Thus, tighter monetary policy may lead to an large increase in mortage rates.

4.2.4 Impulse Responses to a House Price Shock

Table 8 contains impulse responses of the price level, of gross domestic product and money market rates to an unexpected increase in housing prices. We find out that a shock to house prices leads to an increasing price level, in all of the countries, an increasing gross domestic product in seven of ten countries and to increasing money market rates in nine of ten countries. Eight quarters after the house price shock the price level rises in a range of 0.01 (Denmark) to 0.81 (Australia), while it rises to 0.07 (Spain) to 0.99 (Australia) 16 Quarters after the shock. Thus, the housing price shock has a persistent effect on goods prices. The rise in output ranges from 0.10 (Japan) to 0.30 (Finland) in the countries where it rises eight quarters after the shock hit the economy. The money market rates rise in a range of 0.28 (Spain) to 0.52 (Finland) after the increase in house prices. The economics behind these impulse responses might be the following. Because the house price shock increases prices and output it can be interpreted as a germane aggregate demand shock. Thus, the increase in house prices leads to a higher wealth of households which translates into a higher demand for goods and services. This increase in aggregate demand leads to inflationary pressures on which the central bank reacts by tightening monetary policy.

4.3 Forecast Error Variance Decompositions

Table 9 contains the forecast error variance decompositions of house prices (panel (a)) and output (panel (b)) with respect to the four shocks. These forecast error variance decompositions are measured in percentage fraction of the total variance of house prices and output, respectively, and indicate the contribution of the pertinent shocks to the variation in output and house prices.

Table 7: Impulse Responses to a Monetary Policy

Quarters after Shock	(a) House Prices 0	4	8	12	16
Australia	-0.05	-0.70	-1.19	-1.36	-1.36
Denmark	-0.66	-0.49	-0.39	-0.40	-0.41
Finland	-0.29	-0.67	-0.53	-0.58	-0.83
France	-0.01	-0.72	-1.61	-2.11	-2.42
Germany	-0.05	0.07	0.03	-0.04	-0.06
Japan	-0.32	-1.51	-2.02	-1.95	-1.71
Netherlands	0.02	-1.52	-2.51	-2.91	-3.01
Spain	-0.15	-0.59	-0.71	-0.64	-0.53
UK	0.21	-1.32	-2.32	-2.63	-2.58
USA	-0.09	-0.72	-1.06	-1.32	-1.52
Quarters after Shock	(b) Gross Domestic Product 0	4	8	12	16
Australia	0.00	-0.28	-0.51	-0.59	-0.59
Denmark	0.00	-0.27	-0.25	-0.23	-0.21
Finland	0.00	-0.37	-0.56	-0.66	-0.78
France	0.00	-0.30	-0.53	-0.58	-0.56
Germany	0.00	0.10	-0.01	-0.04	-0.01
Japan	0.00	-0.31	-0.26	-0.17	-0.11
Netherlands	0.00	-0.45	-0.65	-0.70	-0.68
Spain	0.00	-0.22	-0.21	-0.19	-0.17
UK	0.00	-0.50	-0.79	-0.84	-0.80
USA	0.00	-0.50	-0.76	-0.80	-0.74
Quarters after Shock	(c) Price Level 0	4	8	12	16
Australia	0.00	0.51	0.67	0.69	0.66
Denmark	0.00	-0.02	-0.04	-0.06	-0.07
Finland	0.00	0.28	0.36	0.41	0.42
France	0.00	0.36	0.67	0.72	0.65
Germany	0.00	0.26	0.38	0.38	0.35
Japan	0.00	0.38	0.10	-0.14	-0.27
Netherlands	0.00	0.29	0.28	0.17	0.02
Spain	0.00	0.09	0.06	0.03	0.01
UK	0.00	0.67	1.20	1.28	1.21
USA	0.00	0.24	0.32	0.28	0.15

Estimated impulse responses to a shock to the money market rate based on the Cholesky identification scheme. Entries from panels (a), (b) and (c) are measured as percentage deviations from steady-state. Note, that all impulse responses are multiplied by 100 percent.

The reported numbers indicate the contribution of the shocks eight quarters after they hit the economy. As one can see, most of the variation in house prices is due to the house price shock. This contribution ranges from 42.75

Table 8: Impulse Responses to a House Price Shock

Quarters after Shock	(a) Price Level 0	4	8	12	16
Australia	0.00	0.46	0.81	0.95	0.99
Denmark	0.00	-0.04	0.01	0.08	0.12
Finland	0.00	0.29	0.43	0.42	0.35
France	0.00	0.21	0.38	0.56	0.75
Germany	0.00	0.12	0.25	0.35	0.40
Japan	0.00	0.37	0.76	0.89	0.92
Netherlands	0.00	0.04	0.12	0.23	0.32
Spain	0.00	0.00	0.05	0.07	0.07
UK	0.00	-0.05	0.29	0.59	0.72
USA	0.00	0.17	0.40	0.60	0.76
Quarters after Shock	(b) Gross Domestic Product 0	4	8	12	16
Australia	0.00	-0.01	-0.26	-0.40	-0.45
Denmark	0.00	0.34	0.28	0.18	0.10
Finland	0.00	0.57	0.30	-0.22	-0.67
France	0.00	0.01	-0.01	-0.08	-0.17
Germany	0.00	0.25	0.19	0.02	-0.15
Japan	0.00	0.18	0.10	0.05	0.03
Netherlands	0.00	-0.01	-0.03	-0.13	-0.25
Spain	0.00	0.35	0.29	0.06	-0.11
UK	0.00	0.12	-0.15	-0.40	-0.53
USA	0.00	0.12	-0.11	-0.26	-0.36
Quarters after Shock	(c) Interest Rates 0	4	8	12	16
Australia	0.00	0.60	0.41	0.26	0.19
Denmark	0.00	-0.29	-0.04	-0.02	-0.02
Finland	0.00	0.36	0.52	0.54	0.48
France	0.00	0.16	0.32	0.38	0.42
Germany	0.00	0.34	0.44	0.37	0.27
Japan	0.00	0.50	0.49	0.28	0.13
Netherlands	0.00	-0.28	-0.07	0.05	0.10
Spain	0.00	0.40	0.28	0.21	0.16
UK	0.00	0.54	0.50	0.34	0.21
USA	0.00	0.36	0.29	0.27	0.27

Estimated impulse responses to a house price shock based on the Cholesky identification scheme. Entries from panels (a) and (b) are measured as percentage deviations from steady-state, while the entries from panel (c) are measured as percentage point deviations from the steady-state level. Note, that all impulse responses are multiplied by 100 percent.

(USA) percent to 95.75 (Spain) percent. In five countries the money market shock has explanatory power for the variation in house prices. In the USA it explains 24.18 percent of the variation, while it explains 21.65 percent in Japan. In Spain only 1.66 percent of the variation in house prices can be explained by the money market shock. In Australia, Denmark and Finland around 13 percent of the house price variation can be explained by the output shock. Different are Japan and the USA. Here 27.89 percent (Japan) and 32.84 percent (USA) of the total variation in house prices can be explained by the inflation shock. Summing up, one can conclude that it is house price shocks and to some degree interest rate shocks that drive housing price dynamics. Shocks to the price level and shocks to output play only a minor role. Note, that these findings stand in contrast to Tsatsaronis and Zhu (2004), who find that inflation has a large effect on house prices.

Panel (b) of table 9 contains the decomposition of the variation in output. Here, a large degree of output fluctuations are due to aggregate demand shocks. The contribution of these shocks range from 56.99 (UK) to 85.89 (Australia). Exception is the USA, where only 1.63 percent of the variation of output is due to aggregate demand shocks. Here a lot of variation in output is contributed to aggregate supply shocks (71,06 percent), money market shocks (14.09 percent) and housing market shocks (13.22 percent). As expected the monetary policy shock has strong explanatory power for the output variation in most of the countries. The contribution of housing demand shocks are either low like in Australia (1.66 percent), Germany (2.36 percent) or Japan (2.37 percent) or it is high like in Denmark (12.79 percent), Finland (14.98), Spain (19.87 percent) and the USA (13.22 percent). This high contribution in the USA and Spain leads to the conclusion that there is a strong influence of the housing market to output fluctuations.

Table 9: Forecast Error Variance Decomposition

	(a) House Prices			
	Price Level	Output	Interest Rate	House Prices
Australia	0.39	12.24	9.43	77.94
Denmark	1.20	12.94	2.12	83.74
Finland	0.67	13.88	2.05	83.40
France	0.25	0.25	18.74	80.76
Germany	2.32	3.15	0.15	94.38
Japan	27.89	0.99	21.65	49.48
Netherlands	0.04	2.08	17.21	80.67
Spain	2.34	0.25	1.66	95.75
UK	6.08	6.72	12.76	74.43
USA	32.84	0.22	24.18	42.75

	(b) Gross Domestic Product			
	Price Level	Output	Interest Rate	House Prices
Australia	1.67	85.89	10.78	1.66
Denmark	1.90	77.40	7.90	12.79
Finland	3.87	69.96	11.18	14.98
France	1.58	59.06	39.33	0.02
Germany	13.87	83.33	0.44	2.36
Japan	22.46	67.20	7.97	2.37
Netherlands	2.01	73.85	23.20	0.04
Spain	1.68	70.25	8.20	19.87
UK	10.36	56.99	31.43	1.22
USA	71.06	1.63	14.09	13.22

Forecast error variance decompositions based on the Choleski identification scheme. Entries from panels (a) and (b) are measured as the percentage contribution which each of the four shocks (inflation shock, output shock, money market shock, house price shock) has to the forecast error variance of the pertinent variable indicated in panel (a) and (b) eight quarters after the shock has hit the economy. Note that the contribution of the four shocks sum to 100 percent.

Table 10 contains the forecast error variance decomposition of the money market rate (panel (c)) and the price level variation (panel (d)). Surprisingly, the housing demand shock has a strong impact on the fluctuations in the money market rate indicating a strong link between the mortgage market and the money market. The contribution of the housing market shock to the variation in interest rate ranges from 5.65 (France) to 40.24 (Japan). Compared to these numbers the contribution of inflation shocks in Japan are only 8.05 percent, while the contribution of the output shock is only 1.44 percent. As another example the contribution of housing price shocks is 18.04 percent in

Germany, while the contribution of perice level shocks is just 0.07 percent and 6.79 percent here.

Table 10 panel (d) contains the contribution of these shocks to the price level variation. In four countries the housing demand shock has a strong impact on the price level like in Australia (14.25 percent), Germany (10.48 percent), Japan (19.38 percent) and the USA (13.22 percent), while it plays only a minor role in the remaining six countries. This strong contribution of housing price fluctuations to price level fluctuations can be due to the fact that housing plays a signnificant role in the goods basket on which the price index is constructed in these countries and therefore plays a major role in the determination of the costs of living.

4.4 Granger-Causality Tests

Granger-causality is given if the inclusion of a variable included in the vectorautoregressive model significanty increases the forecasting performance of one variable of the model. Thus, Granger-causality is given if the past of one variable has a significant impact on the future of another variable. Table 11 contains the tests on Granger-causality for house prices (panel (a)) and the price level (panel (b)). In panel (a) we test the null hypothesis that either the price level, output or money market rates have no forecasting power for house prices. For only two out of ten countries (Japan and Spain) we can reject that inflation has no forecasting power for house prices, while we can reject that output has no forecasting power just for the USA and Japan. But we can reject that the money market rate has no forecasting power for house prices for France, the Netherlands, the UK and the USA.

In panel (b) of table 11 we test the null hypothesis that house prices, output and the money market rate have no forecasting power for the price level. In only two cases (Netherlands and USA) we find that the inclusion of house prices enhances the forecasting performance of prices. The link between past interest rates and prices seems to be stronger here (seven rejections).

Table 12 contains results of the tests of Granger causality for output (panel

Table 10: Forecast Error Variance Decomposition

	(c) Interest Rate			
	Price Level	Output	Interest Rate	House Prices
Australia	7.77	0.62	71.67	19.94
Denmark	1.20	5.53	68.56	24.71
Finland	14.69	0.37	71.31	13.62
France	16.00	1.78	76.57	5.65
Germany	0.07	6.79	75.10	18.04
Japan	8.05	1.44	50.27	40.24
Netherlands	0.84	3.65	88.86	6.66
Spain	2.16	7.34	75.88	14.61
UK	5.96	1.02	67.36	25.66
USA	9.18	12.47	66.61	11.74

	(d) Price Level			
	Price Level	Output	Interest Rate	House Prices
Australia	69.97	2.65	13.12	14.25
Denmark	97.18	1.84	0.61	0.37
Finland	88.72	2.86	3.81	4.61
France	80.54	1.00	14.06	4.41
Germany	47.98	8.49	33.05	10.48
Japan	72.55	0.74	7.32	19.38
Netherlands	2.91	73.85	23.20	0.04
Spain	97.48	0.47	1.82	0.23
UK	78.83	0.16	20.44	0.57
USA	71.06	1.63	14.09	13.22

Forecast error variance decompositions based on the Choleski identification scheme. Entries from panels (c), and (d) are measured as the percentage contribution which each of the four shocks (inflation shock, output shock, money market shock, house price shock) has to the forecast error variance of the pertinent variable indicated in panel (c) and (d) eight quarters after the shock has hit the economy. Note that the contribution of the four shocks sum to 100 percent.

(c)) and the money market rate (panel (d)). We find out that the inclusion of house prices into the VAR system improves the forecasting performance of output in six of ten countries (Denmark, Finland, Japan, Spain and the USA). But we also found out that inflation and the money market rate have significant forecasting power for output in most of the countries. This link between the housing market and output was already found in cross correlations and impulse responses. In panel (d) we find that the inclusion of inflation does only Granger-cause the money market rate in two countries (Japan and the USA), while the inclusion of output has only significant forecasting power in

Table 11: Granger-Causality Tests

	(a) ... does not Granger-Cause House Prices		
	Inflation	Output	Interest Rate
Australia	3.18 (0.20)	4.92 (0.08)	3.79 (0.15)
Denmark	0.62 (0.73)	2.15 (0.34)	1.70 (0.42)
Finland	3.87 (0.14)	4.69 (0.10)	0.52 (0.77)
France	0.91 (0.64)	1.94 (0.38)	8.19 (0.02)
Germany	0.69 (0.71)	3.39 (0.18)	3.24 (0.20)
Japan	8.12 (0.02)	8.07 (0.02)	1.04 (0.59)
Netherlands	3.16 (0.21)	3.99 (0.14)	9.23 (0.01)
Spain	6.27 (0.04)	3.41 (0.18)	0.27 (0.87)
UK	1.15 (0.56)	2.03 (0.36)	12.41 (0.00)
USA	5.66 (0.06)	7.33 (0.03)	11.83 (0.00)
	(b) ... does not Granger-Cause the Price Level		
	House Prices	Output	Interest Rate
Australia	3.95 (0.14)	4.92 (0.09)	14.68 (0.00)
Denmark	0.60 (0.74)	6.41 (0.04)	2.66 (0.26)
Finland	0.65 (0.72)	1.50 (0.47)	4.69 (0.10)
France	3.23 (0.20)	1.89 (0.39)	12.32 (0.00)
Germany	2.50 (0.29)	2.87 (0.24)	22.59 (0.00)
Japan	5.25 (0.07)	0.45 (0.80)	32.21 (0.00)
Netherlands	9.36 (0.01)	4.38 (0.11)	9.97 (0.01)
Spain	0.26 (0.88)	6.13 (0.05)	1.06 (0.59)
UK	1.17 (0.56)	4.28 (0.12)	13.27 (0.00)
USA	13.70 (0.00)	1.79 (0.41)	16.47 (0.00)

Results of the Granger-causality tests on the null-hypothesis that one of the three variables in columns (inflation/house prices, output, interest rate) does not Granger-cause house prices (panel (a)) and output (panel (b)). The reported numbers are the values of the test statistic which are under the null χ^2-distributed with the number of of degrees of freedom equal to the number of lags of the VAR-system (here: 2). P-values corresponding to the null of no Granger-causality are reported in parenthesis.

three countries (Finland, France and Spain). But we find that the inclusion of house prices have a significant impact in forecasting interest rates in all countries despite Finland, France and the Netherlands. This strong link between the housing market and money market rates via the mortgage market was also found earlier in cross correlations and impluse responses.

Table 12: Granger-Causality Tests

	(c) ... does not Granger-Cause Output		
	Inflation	House Prices	Interest Rate
Australia	6.30 (0.04)	1.42 (0.49)	11.98 (0.00)
Denmark	2.26 (0.32)	7.98 (0.02)	5.36 (0.07)
Finland	1.21 (0.55)	23.98 (0.00)	8.91 (0.01)
France	7.22 (0.03)	0.98 (0.61)	21.69 (0.00)
Germany	2.35 (0.31)	2.12 (0.35)	1.54 (0.46)
Japan	3.52 (0.17)	8.79 (0.01)	5.51 (0.06)
Netherlands	0.65 (0.72)	4.11 (0.13)	11.73 (0.00)
Spain	8.09 (0.02)	26.12 (0.00)	4.50 (0.11)
UK	9.19 (0.01)	2.97 (0.23)	18.16 (0.00)
USA	13.30 (0.00)	9.12 (0.01)	21.98 (0.00)
	(d) ... does not Granger-Cause Money Market Rate		
	Inflation	Output	House Prices
Australia	4.35 (0.11)	4.82 (0.09)	12.32 (0.00)
Denmark	3.70 (0.16)	3.00 (0.22)	20.68 (0.00)
Finland	3.82 (0.15)	6.29 (0.04)	7.57 (0.02)
France	5.52 (0.06)	7.29 (0.03)	3.99 (0.14)
Germany	4.25 (0.12)	44.48 (0.11)	6.85 (0.03)
Japan	14.73 (0.00)	5.77 (0.06)	16.12 (0.00)
Netherlands	0.48 (0.79)	1.58 (0.46)	4.90 (0.09)
Spain	1.36 (0.51)	15.79 (0.00)	11.62 (0.00)
UK	3.35 (0.19)	5.13 (0.08)	12.48 (0.00)
USA	7.31 (0.03)	5.48 (0.06)	7.24 (0.03)

Results of the Granger-causality tests on the null-hypothesis that one of the three variables in columns (inflation, house prices, interest rate/output) does not Granger-cause output (panel (c)) and interest rates (panel (d)). The reported numbers are the values of the test statistic which are under the null χ^2-distributed with the number of of degrees of freedom equal to the number of lags of the VAR-system (here: 2). P-values corresponding to the null of no Granger-causality are reported in parenthesis.

5 Conclusion and Outlook

Within this paper we wanted to highlight the empirical relevance of the interplay between the housing market and key macroeconomic variables like prices, output and interest rates. For conducting this research goal we employed lots of econometric methods like analysing cross correlations at different leads and lags and VAR-based inference like impluse responses, forecast error varaince decompositions and Granger-causality tests.

Within this paper the follwing results emerge.

(*i*) We suspected that a monetary tightening leads to lower real estate prices, because higher interest rates increase the costs of financing real estate projects and thereby lower housing demand. We find empirical evidence for this proposition by finding out that a monetary policy shock lowers real house prices in all ten OECD countries. Moreover we found out that money market rates Granger-cause house prices in France, the Netherlands, the UK and the USA. In half of the countries considered the interest rate shock explains between 12 and 24 percent of the fluctuations in house prices.

(*ii a*) We expected that an inflationary shock should lead to higher real estate prices because economic agents rise their demand for real estate in order to protect their wealth against future inflation. Impulse responses indicate that house price decline in eight of ten countries, while we only find support of our hypothesis in Denmark and Spain. Forecast error variance decompositions indicate that only a minor fraction of the volatility in house prices can be explained by the inflationary shock. Moreover, we only find for Japan and Spain that prices Granger-cause house prices. Reasons might be that rent income is not reflected in the OECD house price indices so the indices only measure the worth of the building as a consumption good because inflation protection through real estate is only possible through inflation indexation of rents.

(*ii b*) We supposed that if prices are rising the monetary authority will respond by raising their interest rate and thereby increasing the costs of financing real estate projects. This will result in a decline in housing demand and thereby in declining house prices. We find empirical support for this hypothesis because impulse responses indicate that after an inflationary shock money market rates increase and house prices decline.

(*iii*) The hypothesis that a shock to output raises households' income and thereby their demand for housing and thereby leads to increasing house prices can be empirically veryfied. Impulse responses indicate that house prices increase in nine of ten OECD countries after an output shock hit the economy. Moreover, cross correlations indicate a high correlations between the cyclical components of house prices and output at several leads and lags. Despite this high correlations the house price shock explains only a small fraction of house price volatility.

(*iv*) We suspected that a shock to real estate prices leads to an increase in households' net worth through which they increase their demand for consumption goods. This increase in aggregate demand pushes output above its long-term steady-state level. Impulse responses indicate that output increases in seven of ten OECD countries after a house price shock hit the economy. Moreover, we find strong cross correlations between the cyclical components of house prices and output at several leads and lags. Furthermore, house prices Granger-cause output in half of the OECD countries. Forecast error variance decompositions indicate that a significant fraction of output fluctuations (12 to 20 percent) can be traced back to housing demand shocks. We conclude that this channel is empirically relevant.

(*v*) We supposed that a hike in real estate prices lead to inflationary pressures. Impulse responses indicate that the price level rises in all ten OECD countries after a housing demand shock. Moreover, we found that around 10 to 20 percent of the fluctuations in the price level can be traced back to housing demand shocks in four countries.

(*vi a*) We supposed that the central bank reacts to a housing price shock by raising her policy rate because the housing demand shock pushed aggregate demand. Impulse responses indicate that in seven out of ten countries the housing demand shock raises both prices and output which means that it raises aggregate demand. Moreover, the impulse responses indicate that the central bank reacts to this shock by raising the money market rate. Forecast error variance decompositions indicate that the housing demand shock is a key driver of interest rates in eight of ten countries. Futhermore, we find that house prices Granger-cause the money market rate in eight of ten countries. Thus, we conclude that this channel is empirically relevant.

(*vi b*) We supposed that a rise in real estate prices raises the value of collateral which gives incentives to banks to raise their credit supply. Thus interest rates should fall in response to increasing house prices. We do not find evidence for this collateral channel because interest rates rise in nine countries after the house price shock. We conclude that this channel is only of minor importance and maybe superimposed by the inflation targeting policy of the central bank (see (*via*)).

All in all, we find a lot of empirical support that house prices are a key element of the interplay between macroeconomic variables. A new and robust result is that unexpected increses or decreases in real house prices can be interpreted as germane aggregate demand shocks. This result has the following implications for the conduct of monetary policy. Because unexpected house price changes lead to changes in aggregate demand they can be used as an indicator of future inflation. Future research should elaborate on the abbility of real house prices as an inidcator of demand driven inflation. Further research might also use this information for building models that connect housing and the macroeconomy (see Rubio 2007 and Iacoviello and Neri 2008).

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