Housing Finance and Monetary Policy*

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Abstract

We study how the structure of housing finance affects the transmission of monetary policy shocks. We document three main facts: first, the features of residential mortgage markets differs markedly across industrialized countries; second, and according to a wide range of indicators, the transmission of monetary policy shocks to residential investment and house prices is significantly stronger in those countries with larger flexibility/development of mortgage markets; third, the transmission to consumption is stronger only in those countries where mortgage equity release is common and mortgage contracts are predominantly of the variable-rate type. We build a two-sector DSGE model with price stickiness and collateral constraints and analyze how the response of consumption and residential investment to monetary policy shocks is affected by alternative values of two institutional features: (i) down-payment rate; (ii) interest rate mortgage structure (variable vs. fixed rate). In line with our empirical evidence, the sensitivity of both variables to monetary policy shocks increases with lower values of (i), and is larger under a variable-rate mortgage structure.

Keywords: Housing finance, mortgage markets, collateral constraint, monetary policy.

JEL: E21, E44, E52.

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1 Introduction

The role of housing wealth on economic activity has recently attracted considerable attention among academic researchers, policy-makers and press commentators.[1] This attention is partly explained by the sizeable rises in property prices and household indebtedness in several industrialized countries over the recent years (Debelle 2004, Terrones and Otrok 2004), and the need to understand both the determinants of such rises and their potential implications for monetary policy and financial stability. The recent global financial turmoil allegedly originating from the residential property market in the US has strengthened the interest in these matters even further. Beyond the policy considerations, there is a growing interest in assessing the effects of changes in property prices on consumption decisions, given the predominance of housing in total household wealth (Campbell and Cocco 2003, Muellbauer and Murphy 2008).

This paper studies the relationship between the structure of *housing finance* and the monetary transmission mechanism in several industrialized countries. We first show that there is significant heterogeneity in the institutional characteristics of national mortgage markets across the main industrialized countries, and especially within the EU. Examples of such institutional characteristics include the typical duration of mortgage contracts, the required levels of down-payment (or inverse loan-to-value ratios), the existence (or lack thereof) of equity release products. We interpret these indicators as alternative measures of the degree of development/flexibility of mortgage markets. There is in fact one channel, working from housing finance to the macroeconomy, that we aim at capturing by means of these indicators: the extent to which mortgage contracts allow to translate the value of housing as a collateral into current availability of credit for households. In turn, this credit can be used not only to finance new housing expenditure but also (non-housing) consumption.

In addition to the aforementioned indicators we also classify countries according to the prevailing interest-rate structure of mortgage contracts, namely flexible vs. fixed interest rate contracts. We treat this indicator separately for it does not necessarily reflect a higher

[1] For recent academic contributions see Aoki, Proudman and Vlieghe (2004), Davies and Heathcote (2005), Iacoviello (2005) and the literature review by Leung (2004); for contributions from a policy perspective see ECB (2003), Catte et al. (2004), Girouard and Blöndal (2001), BIS (2004) and IMF (2005, 2008); for a press account see The Economist (2003).

or lower degree of development of mortgage markets.[2] We believe this channel may be particularly important for the transmission of monetary policy, especially on consumption, for it represents a direct channel through which monetary policy, by altering the service cost of debt, can affect current disposable income.

We then conduct a VAR-based analysis of the effects of monetary policy shocks on consumption, house prices and residential investment in a sample of industrialised countries. We classify the countries into two groups, according to their degree of development of mortgage markets. Those belonging to the first (second) group are countries where LTV ratios are low, mortgage equity release is common (absent or partial) and the ratio of mortgage debt to GDP is high (low). We then also classify countries according to their prevailing interest rate structure of mortgage contracts (fixed vs. variable rate).

We find two main results. First, the size of the peak effect of a monetary policy shock on residential investment is positively and significantly related both to our indicators of flexibility in mortgage markets (with higher flexibility translating into larger sensitivity) and to the type of interest rate structure (with residential investment being significantly more responsive to policy innovations in those countries with a variable-rate mortgage structure). A similar pattern emerges for the response of house prices. Second, we find that the evidence for consumption is mixed. Namely, consumption is significantly more responsive only in those countries where mortgage equity release is common and, especially, where prevailing mortgage contracts are of the variable rate type. Other indicators of mortgage markets flexibility, such as the LTV ratio or the ratio of mortgage debt to GDP, turn out not to be relevant for the differential response of consumption across countries to monetary innovations.

Under frictionless financial markets, the structure of housing finance should in principle be immaterial for the effects of monetary shocks. To rationalize our evidence we build a model that extends the baseline monetary policy framework in three main directions.[3] First, it allows for two sectors, respectively producing consumption goods and new housing. Second, it features heterogeneity of preferences between impatient consumers and patient consumers (in equilibrium, borrowers and savers respectively). The former do not

[2] It remains true, though, that in several countries the introduction of variable rate mortgage contracts has paralleled the process of deregulation in mortgage markets.

[3] Such baseline framework, featuring perfect financial markets, is usually labelled as New Keynesian (see Clarida et al. 1999, Woodford 2003).

act as standard permanent-income agents, but exhibit preferences tilted towards current consumption. The borrowers may be thought of as that share of the population for which acquiring a loan/mortgage requires providing an asset, and housing in particular, as a form of collateral. Third, private borrowing is constrained by the value of the collateral. That value is endogenously tied to the evolution of the price of housing.

Thus, in a context where mortgage markets allow more easily to convert asset values into borrowing, and therefore spending, consumption and residential investment should be more responsive to underlying shocks. In our framework, the relevant institutional features of the mortgage market are summarized by two main parameters: (i) the down-payment rate, and (ii) the interest-rate structure of the contract. We calibrate and simulate the model based on our introductory evidence on the heterogenous characteristics of mortgage markets in industrialized countries. We find that both institutional features magnify the responses of consumption and residential investment to monetary policy shocks.

General equilibrium borrower-saver models build on the earlier analysis of Kiyotaki and Moore (KM) (1997) and Krusell and Smith (1998). Recently, Iacoviello (2005) extends the KM framework to include features more typical of the New Keynesian monetary policy literature, whereas Campbell and Hercowitz (2004) extend this category of models to a real business cycle framework and explore the role of credit market innovations in contributing to the so-called Great Moderation. The modelling section of our work is related to the former paper, but it differs in two main ingredients: first, it features a two-sector structure (so that residential investment is an endogenous variable); second, it models institutional characteristics of the mortgage market (such as variable vs. fixed-rate contracts) and analyzes how they shape the transmission of monetary policy shocks.

The paper is structured as follows. In Section 2 we document some key institutional differences in mortgage markets across industrialized countries. We conduct some VAR-based empirical analysis in Section 3, focussing on the impact of a monetary policy shock on housing market-related variables. The structural model is developed in Section 4 and discussed in Section 5. Section 6 presents some dynamic simulations. Section 7 concludes.

2 Housing finance in the industrialized countries

In this section we document that mortgage markets differ significantly across industrialized countries in terms of both size and key institutional characteristics, such as the prevailing contractual arrangements and the available product range. This heterogeneity is particularly evident within the euro area, where mortgage lending remains a predominantly domestic business activity, largely reflecting national traditions and cultural factors as well as the institutional settings of the local banking sector.

Table 1 summarizes some of the institutional indicators that have been identified in the literature as most likely to have a bearing on the relationship between housing wealth and consumption, as well as on the channels of monetary policy transmission (see e.g. MacLennan et al. 1998) and Debelle 2004). We report data for a total of nineteen countries, including nine euro area countries, some European countries outside the euro area, Japan and the main Anglo-Saxon countries.

The indicators included in *Table 1* are: (i) mortgage-debt to GDP ratio; (ii) typical LTV ratio; (iii) type of interest-rate structure; (iv) typical mortgage contract duration, (v) diffusion of home equity release products, and (vi) the IMF (2008) index of mortgage market development and completeness.

Cross-country heterogeneity is pervasive in all indicators considered. Mortgage-to-GDP ratios vary widely across countries: values range between 13% in Italy and 116% in Switzerland. Among the large countries, Italy and France have the lowest ratios, while the ratios in the UK and the US are relatively high. Also typical LTV ratios vary significantly across countries, ranging between 50% in Italy and 90% in the Netherlands and UK.[4] Cross-country variations in these ratios partly reflect differences in legal and regulatory frameworks.[5] Hence, they reflect - at least to some extent - institutional factors which are largely exogenous.

The heterogeneity in terms of interest rate adjustment is also substantial across coun-

[4]Data from the Council of Mortgage Lenders shows that during the past housing boom LTV ratios above 90% were fairly common in the UK.

[5]For instance, it has been argued (e.g., MacLennan et al. 1998, and Ahearne et al. 2005) that the reason why the LTV ratio has been historically low in Italy lies in the difficulty for the lender to enforce repossession in case of default of the borrower, given the country's slow and costly judicial proceedings. In Japan, the mortgage market has been historically dominated by a public agency that kept LTV ratios low and focused on financing purchases of new rather than used housing (Seko 1994).

tries. Conceptually, mortgage contracts can be distinguished between *variable* and *fixed* rate mortgages: variable rate contracts are those in which the lending rate floats with, or is frequently adjusted to, a short-term market interest rate; fixed rate contracts are those in which the lending rate remains constant throughout the duration of the contract. In practice, contracts do not always fully conform to these conceptual types and often fall under intermediate categories (Borio 1996). Among the EU countries, the UK, Spain and Italy mainly have variable or adjustable rate mortgages, although for the latter two countries this reflects a relatively recent development.[6] By contrast, Germany, France, Austria, Belgium, Denmark and the Netherlands are mainly characterized by fixed rate mortgages, similar to the US and Canada.

An additional element of divergence among national mortgage markets is the extent of the recourse to *home equity release*. Following changes in house prices and mortgage interest rates, collateral constrained agents may wish to adjust their net borrowing positions or to refinance the terms of their existing mortgages according to the changed conditions. For instance, in light of a run-up in house prices (and especially if that run-up is expected to continue into the future), borrowers may increase the amount of their mortgage loans or apply for a second mortgage against the increased value of their collateral. The released mortgage equity may be subsequently used for a variety of purposes, such as debt refinancing, acquisition of durable goods, purchase of financial assets or home improvements. When mortgage interest rates decrease, agents may be willing to re-finance their mortgages to take advantage of lower interest payments in order to free liquidity for other expenditures or, alternatively, they may want to increase their borrowing to reflect their increased debt servicing capacity. Alternatively, and mostly in countries with highly flexible and developed mortgage markets, lenders may be more willing to extend so-called home equity lines of credit (or, broadly speaking, home equity loans) when they observe an increase in house prices. Conversely, during a downturn in house prices, as in the recent financial turmoil, such equity lines of credit are often the first ones to be scaled back by lenders. At the same time, in those instances, lenders may find it convenient to walk away from delinquent home equity loans rather than pushing borrowers into foreclosure on the primary mortgage.[7] All these margins are likely to have significant consequences on

[6] Japan also has mainly variable rate mortgages.

[7] See, for instance, Wall Street Journal, January 16, 2008.

current disposable income, and therefore on current consumption for liquidity constrained individuals.

Overall, the use of home equity release remains limited in some countries as reported in *Table 1*, though mortgage equity extraction and refinancing have become significant at the aggregate level in a few of them (e.g., US, UK and the Netherlands). In some cases, the limited recourse to home equity release may reflect scarce availability of suitable mortgage contracts (e.g., due to regulatory constraints). However, in most countries borrowers are deterred from refinancing their contracts by administrative obstacles and prohibitive transaction costs.[8] In such countries, mortgage lending is likely to interact with interest rate and house price developments only to a very limited extent (namely only for the new mortgage contracts and not for the existing ones, which mostly reflect market conditions prevailing at the time they were signed rather than current conditions). The US has been historically one of the main exceptions to this pattern, with the exceptional nature of its national mortgage market becoming particularly evident in recent years as US borrowers have taken advantage of low interest rates, rising house prices and a dramatic decline in transaction costs to engage in a wave of mortgage refinancing and equity extraction commonly thought to have been large enough to influence aggregate spending.

IMF (2008) compiles a synthetic indicator of the degree of development and completeness of national mortgage markets. In particular, the value of the index for each country is a function of various indicators, such as LTV ratios, the ability to extract mortgage equity or to refinance without incurring fees, the development of secondary markets for mortgage loans, etc. Higher values of the index (which lies between 0 and 1) indicate a more developed and advanced national mortgage market. With the exception of the Netherlands, European countries tend to have relatively low values. In particular, the three largest euro area economies (Germany, France and Italy) are those with the lowest values in the sample. Similarly, the value of the index is low for Japan. By contrast, the index assigns relatively high values to the Anglo-Saxon economies, with the US scoring almost the maximum level.

[8] For instance, Borio (1996) documents the penalties and administrative costs that borrowers willing to repay in advance their medium- and long-term (not necessarily mortgage) loans face in a number of countries.

3 Housing finance and monetary policy transmission: the evidence

Institutional differences across mortgage markets are often cited as a likely source of cross-country differences in the speed and strength of the transmission of monetary policy impulses to the economy. The size and distribution of household mortgage debt, average maturity of contracts and type of interest rate adjustment are usually listed among the characteristics likely to determine the extent of the income and collateral effects induced by changes in interest rates (Debelle (2004)).

BIS (1995) concludes that monetary policy could be expected to have comparatively stronger effects in Anglo-Saxon countries than in continental Europe (with the possible exception of Italy, where variable-rate mortgages predominate). Borio (1996) notes that this split coincides with that between countries with more or less developed financial structures, though this does not amount to conclusive evidence. Iacoviello (2002) relates variations in the magnitude of output responses to monetary policy shocks across European countries to differences in financial systems. Likewise, Angeloni et al. (2003) refer to institutional differences in housing finance as one possible explanation for the more muted response of private consumption to monetary policy shocks in the euro area compared with the US. In recent years, the remarkable heterogeneity in private consumption developments between some continental European countries and most Anglo-Saxon countries at a time of (common) worldwide low interest rates has seemed to provide further confirmation about the importance of structural differences in mortgage markets across countries in determining the strength of the housing channel of monetary policy.

In this section we estimate a baseline VAR model in 19 advanced countries for which we have sufficiently reliable house price data.[9] The model is specified as follows,

$$A_0^i Y_t^i = k^i + \gamma^i t + A^i(L) Y_{t-1}^i + B^i(L) z_t + \varepsilon_t^i \tag{1}$$

for each country i and time t; z_t is a vector of common exogenous variables. The vector of the endogenous variables, Y_t^i, includes (in this order) private consumption, residential investment, the consumer price index (CPI), the real house price, a 3-month interbank

[9]The list of countries includes: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States. The source of data is the OECD Economic Outlook Database.

interest rate, and the real effective exchange rate. We include the real effective exchange rate to cater for open economy influences that, while arguably secondary for the US economy, are likely to matter considerably for the small open economies in our group of countries. Moreover, for all countries except the US we include up to 2 lags of the US log consumption, the US log price level, the US 3-month interest rate and the oil price in USD as exogenous variables; for the US, we only include the last variable. The exogenous variables are a parsimonious way to cater for cross-country spillovers and in fact we find that the correlations between residuals in country pairs are typically very small. The identification of the VAR is achieved by assuming that the A_0^i matrix has a Choleski structure in each country.[10]

The model in (1) is estimated on quarterly data, seasonally adjusted whenever appropriate, on a sample period between 1980:1 and 2008:4. For two countries, the starting date is later due to data availability (1981 for Switzerland, 1988 for Austria).[11] The VAR models are specified in levels and, with the exception of the interest rates, all variables are in expressed in logs. Based on the Schwartz information criterion, a lag order of two (in levels) is found to be optimal for this model across almost all countries.[12]

After estimating the VAR model for each country, we run the pooling test (based on a Wald test of equal coefficients) to check whether a panel specification with pooled cross sections could be preferable. However, we find that the data overwhelmingly reject the null that the coefficients in model (1) are the same across countries.[13] Therefore, rather than estimating a pooled panel which would in this case likely lead to biased estimates, we estimate the model country-by-country and then consider the average impulse response of the endogenous variables to a standardised contractionary monetary policy shock (i.e.,

[10] See, for instance, Christiano et al. (1999). Our results are not sensitive to alternative orderings of the variables: for instance, whether consumption is ordered before or after residential investment (although it may seem plausible that residential investment reacts more quickly to monetary impulses than real consumption), the house price ordered before or after the CPI, or the real exchange rate ordered before or after the short-term nominal interest rate.

[11] Notice that, due to data limitations, we have not included another possibly relevant variable in the VARs, i.e., mortgage debt. Also, the lack of harmonized data on house prices has to be emphasized; even within the euro area house price data are not fully comparable. For this reason, the results on house prices have to be interpreted with relatively more caution.

[12] Giuliodori (2004) conducts a similar analysis for EU countries, finding broadly similar results as in this study. **(WHAT WE DO THAT HE DOES NOT DO)**

[13] For the sake of brevity we do not report the results of the tests, but those results are available upon request from the corresponding author.

a shock of the same magnitude to the equation for the 3-month interest rate).

We aggregate the cross-sectional information based on the 'stochastic pooling' Bayesian approach proposed by Canova and Pappa (2007). Let $dX^i(k)$ be the estimated impulse response (to a unit size monetary policy shock) of variable X at horizon k for country i. Similar to Canova and Pappa[14], we assume that the prior distribution is

$$dX^i(k) = \mu_k + v_k^i \tag{2}$$

where μ_k is the cross-country average and

$$v_k^i = N(0, \frac{\tau_x}{k^{\gamma_x}}) \tag{3}$$

$\tau_x, \gamma_x > 0$, represents the assumed degree of dispersion across countries for each variable X. We choose τ_x so as to allow for a significant degree of dispersion across units. The dispersion across countries decays over time at a rate dictated by the parameter γ_x.[15] We choose a very diffuse prior for μ_k, so that the average impulse responses are practically entirely driven by the data. As shown by Canova and Pappa, the posterior mean for μ_k - i.e. the variable which we are interested in in our analysis - is a weighted average of the OLS estimates across countries, with weights given by the precision of the estimates, i.e. the inverse of their variances; the posterior precision is also a linear combination of the τ_x parameters as well as the weighted precision of the OLS estimates. Since the posterior distribution for μ_k is Normal, we can plot ranges at various significance levels.

Figure 1 reports the group average impulse responses of the CPI, private consumption, the real effective exchange rate, residential investment and the real house price to a monetary policy shock. The impulse responses generally accord well with the conventional wisdom on the effects of a monetary policy shock. Private consumption, residential investment fall temporarily after the shock in the usual hump-shaped manner, and ultimately go back to the baseline. The effect on residential investment is, in average, quicker and

[14] We refer in particular to their procedure for US states. Note that we specify our prior on the impulse response functions directly, rather than on the coefficients of the structural MA representation as in Canova and Pappa (2007). Since shocks are of unitary size there is a direct linear mapping between the two concepts, and the two approaches are therefore equivalent.

[15] **In Canova and Pappa $\gamma_x = 1$ while we take $\gamma_x = 0.25$ in order to allow for a slower decay in the cross country differentiation with respect to the horizon, which appears to be more realistic. We calibrate τ_x (i.e. the degree of heterogeneity after 1 period) to be of the same order of magnitude of the peak average impulse response for each variable, thereby allowing for a significant degree of cross country heterogeneity.**

about ten times larger at the peak than the effect on private consumption, a result which has been already emphasised in the literature, especially on US data (see e.g. Erceg and Levin, 2006). In addition, real house prices fall in response to the shock, with this response also displaying an inertial behavior. Finally, the CPI falls over time (though displaying a price puzzle in the short term), and the real effective exchange rate appreciates.

We then turn to the key objective of this analysis, namely establishing whether the transmission of monetary policy shocks is different across countries according to the degree of development in their mortgage markets. In order to shed some light on this question we divide the full group of 19 countries in two sub-groups according to several indicators of mortgage market development. First, we rank the countries according to their mortgage debt to GDP ratio and to the typical LTV ratio. In this way, we classify countries below the median country in the ranking as "low development" countries, and the remaining ones as "high development". As to the ability of engaging in mortgage refinancing and mortgage equity withdrawal (MEW), we divide the countries between those where this is possible (high development) and those where this is not possible (low development). Finally, we classify countries according to whether their mortgage debt structure is predominantly fixed rate or variable rate. Table 2 reports the chosen classification for all countries in our group. We choose to report results for a classification based on alternative indicators for this should arguably increase the robustness of our results.

Based on this classification of the countries in 2 sub-groups, we then study whether the transmission of a monetary policy shock is significantly different across sub-groups. We therefore compute the average impulse response to a standardised monetary policy in the sub-groups, using the same 'stochastic pooling' approach used before the whole group of countries within each sub-group. These are reported in Figure 2 for private consumption, Figure 3 for residential investment and Figure 4 for the real house price (standard errors are again computed based on the bootstrapping procedure described above). The thick, blue lines refer to countries with highly developed mortgage markets, and the thin, purple line to countries with less developed markets. The general message is that there appears to be a strong difference between the two sub-groups as regards the response of the housing market-related variables, namely residential investment and the real house price. This is particularly evident for two institutional parameters: the possibility of mortgage refinancing and MEW, and the interest rate adjustment (fixed or variable). Overall,

there is significant evidence that monetary policy exerts more powerful effects on housing markets in countries where the underlying mortgage market is more developed (according to our classification), and mortgages are mostly of the variable rate type. As regards consumption, the results are more mixed. On the one hand, countries where MEW is practiced and where the interest rate adjustment is predominantly variable rate continue to show a significantly stronger impact of monetary policy on private consumption as well. On the other hand, the results for the loan to value ratio index and for the mortgage debt to GDP ratio do not show any significant effect.

POSSIBLE COMMENT ON OUTLIERS??

In order to formally test for the statistical significance of the differences in the mean impulse responses across the sub-groups, Table 3 reports such differences for consumption, residential investment and the real house price at 4, 8, 12 and 24 quarters ahead, together with a formal test of statistical significance, again derived using a bootstrapping procedure. Each entry in the upper panel of Table 3 reports $dX(k)_{low} - dX(k)_{high}$ or $dX(k)_{fix} - dX(k)_{var}$, where, respectively, "low" and "high" stands for highly and lowly developed mortgage markets (with the degree of development measured across different indicators), and "fix" and "var" for fixed rate and variable rate contracts respectively. In the lower panel of Table 3 the same values are reported for accumulated impulse response functions. As can be seen in the Table, most of the differences between sub-group mean responses are negatively signed and often statistically significant, which - given the ordering of the two sub-groups - shows that on the whole monetary policy is relatively more powerful in countries with more developed mortgage markets and variable rate mortgages.

We have also investigated whether cross country differences in monetary policy transmission can be equally detected, in particular for the variables related to the housing market, by looking at alternative indicators of financial and economic structure. For financial structure, we look at (i) stock market capitalisation over GDP; (ii) ratio of total liquid liabilities over GDP; (iii) ratio of total private credit over GDP; for economic structure, we look at economic size, trade openness and share of industry over total value added. We repeat the same procedure as reported for the mortgage market development measures, dividing the total list of countries in two sub-groups of 'highs' and 'lows' (results are not reported for brevity but are available from the authors upon request). The only variable which we find to be consistently correlated with the size of the response of

residential investment and the real house price to a monetary policy shock is stock market capitalisation over GDP, which is an indicator of overall financial development.[16]

Two observations are relevant at this stage. First, a more structural investigation of the link between mortgage markets characteristics and the transmission of monetary policy shocks requires a theoretical framework. Second, the fact that private spending is more responsive to monetary impulses in economies with more developed credit/mortgage markets, at least according to some indicators, may be perceived as a puzzle. In principle, in a standard representative-agent model of the monetary transmission with free borrowing and lending, the structure of credit/mortgage markets should be immaterial for the effects of policy. In addition, a priori, one may believe that more developed financial markets would allow households to smooth consumption more efficiently, whereas our results point to a larger variability of consumption, at least conditional on monetary policy shocks.

In the following, we present a model in which a fraction of agents, in equilibrium, do not choose to behave as permanent-income consumers. Rather, for these agents, it is optimal to increase their borrowing in light of any given rise in income. Their access to credit is constrained by an endogenously determined limit. Thus, in a context where credit markets allow to convert asset values (e.g., housing) into borrowing and therefore consumption more easily, consumption itself should be in principle more responsive to underlying shocks. We describe our model in the next section.

4 The model

The economy is composed of a continuum of households in the interval $(0, 1)$. As in Iacoviello (2005) and Campbell and Hercowitz (2004), there are two groups of households, named *borrowers* and *savers*, that we assume of measure ω and $1 - \omega$ respectively. Each group of households is endowed with one unit of time, so that an individual borrower and an individual saver are endowed with a fraction $1/\omega$ and $1/1 - \omega$ respectively. There are also *two sectors*, producing (non-durable) consumption goods and new *housing* respectively. In each sector there are competitive producers of a final good and monopolistic competitive producers of intermediate goods, with the latter hiring labour from both the borrowers and the savers. The two types of households feature heterogeneous preferences,

[16] citation needed

with the borrowers being *more impatient* than the savers, implying that their marginal utility of consumption exceeds the marginal utility of saving.[17] Both borrowers and savers derive utility from consumption of the non-durable final good and from housing services. Notice that debt accumulation reflects intertemporal equilibrium trading between the two agents. Borrowers are subject to a *collateral constraint*, with the borrowing limit tied to the value of the existing stock of housing.

4.1 Final good producers

In each sector ($j = c, h$) a perfectly competitive final good producer purchases $Y_{j,t}(i)$ units of intermediate good i. The final good producer in sector j operates the production function:

$$Y_{j,t} \equiv \left(\int_0^1 Y_{j,t}(i)^{\frac{\varepsilon_j - 1}{\varepsilon_j}} di \right)^{\frac{\varepsilon_j}{\varepsilon_j - 1}} \tag{4}$$

where $Y_{j,t}(i)$ is the quantity demanded of the intermediate good i by final good producer j, and ε_j is the elasticity of substitution between differentiated varieties in sector j. Notice, in particular, that in the housing sector $Y_{h,t}(i)$ refers to expenditure in the *new* residential good i (rather than services). Maximization of profits yields demand functions for the typical intermediate good i in sector j:

$$Y_{j,t}(i) = \left(\frac{P_{j,t}(i)}{P_{j,t}} \right)^{-\varepsilon_j} Y_{j,t} \qquad j = c, h \tag{5}$$

for all i. In particular, $P_{j,t} \equiv \left(\int_0^1 P_{j,t}(i)^{1-\varepsilon_j} di \right)^{\frac{1}{1-\varepsilon_j}}$ is the price index consistent with the final good producer in sector j earning zero profits.[18]

4.2 Borrowers

A typical borrower consumes an index of consumption *services* of housing and *non-durable* final goods, defined as:

[17] For previous examples of saver-borrower models, see Becker (1980), Becker and Foias (1987), Krusell and Smith (1998), Kiyotaki and Moore (1997).

[18] Hence the problem of the final good producer j is: $max\ P_{j,t}Y_{j,t} - \int_0^1 P_{j,t}(i)Y_{j,t}(i)di$ subject to (4).

$$X_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} C_t^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} H_t^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{6}$$

where C_t denotes (non-durable) consumption services, H_t denotes the stock of housing at the end of period t, $\alpha > 0$ is the share of housing in the composite consumption index, and $\eta > 0$ is the elasticity of substitution between consumption and housing.[19]

The borrower maximizes the following utility program:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(X_t, N_{c,t}, N_{h,t}) \right\} \tag{7}$$

subject to the sequence of budget constraints (in *nominal* terms):

$$P_{c,t}\ C_t + P_{h,t} I_{h,t} + R^m_{t-1} B_{t-1} = B_t + W_{c,t} N_{c,t} + W_{h,t} N_{h,t} + T_t \tag{8}$$

where $I_{h,t} \equiv H_t - (1-\delta) H_{t-1}$ is residential investment, B_t is end-of-period t net nominal debt, and R^m_{t-1} is the nominal lending rate on debt contracts stipulated at time $t-1$ with maturity m. Furthermore, $W_{j,t}$ is the nominal wage earned by the borrower in sector j (with $j = c, h$), and $N_{j,t}$ is total hours supplied in sector j. Finally T_t are net nominal government transfers.

In real terms (units of non-durable consumption), (8) reads

$$C_t + q_t (H_t - (1-\delta) H_{t-1}) + \frac{R^m_{t-1} b_{t-1}}{\pi_{c,t}} = b_t + \frac{W_t}{P_{c,t}} N_t + \frac{T_t}{P_{c,t}} \tag{9}$$

where $q_t \equiv P_{h,t}/P_{c,t}$ is the relative price of housing, and $b_t \equiv B_t/P_{c,t}$ is real debt. Notice that, as a consequence of debt being predetermined in nominal terms, variations in inflation affect the real ex-post cost of debt service, and therefore borrower's net worth.

Later we will work with the utility specification:

$$U(X_t, N_t) = \log(X_t) - \frac{v_c}{1+\varphi} N_{c,t}^{1+\varphi} - \frac{v_h}{1+\varphi} N_{h,t}^{1+\varphi} \tag{10}$$

[19] To define a utility-based aggregate price index one needs to assume the existence of an additional final good producer, whose task consists in assembling housing and consumption services via the production function (6). The price index consistent with maximization of profits by this producer would read:

$$P_t \equiv \left[(1-\alpha)\ (P_{c,t})^{1-\eta} + \alpha\ (P_{h,t})^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

where φ is the inverse of the wage elasticity of labor supply and v_j is a scale parameter.[20]

Variable vs. Fixed-Rate Contracts The interest rate R_t^m on a mortgage contract of maturity m is related to the policy rates R_{t+k} $(k = 0, 1, 2...)$ via the term-structure equation:

$$R_t^m = \left(\sum_{k=0}^{m-1} \tau^k\right)^{-1} \sum_{k=0}^{m-1} \tau^k E_t \left\{R_{t+k}\right\} \tag{11}$$

with $\tau \in [0, 1]$.

In the case $m = 1$ the mortgage and the policy rate coincide. Mortgage contracts are typically multi-period. Multi-period loan contracts can be defined as at *variable* rate (i.e., contracts tied to the short-term policy rate), or at *fixed* rate (tied to a long-term interest rate) depending on the value of τ. For $\tau = 0$ the mortgage rate is perfectly indexed to the policy rate, while for $\tau = 1$ it is fixed to the m-period interest rate. We assume that the decision on who bears the interest rate risk (either the borrower or the saver) mainly reflects institutional factors which lie outside the scope of our model.[21]

Collateral Constraint Private borrowing is subject to a collateral constraint. At any time t, the amount that the borrower agrees to repay in the following period, $R_t B_t$, is tied to the expected future value of the housing stock (after depreciation):

$$R_t B_t \leq (1 - \chi)(1 - \delta) E_t \left\{H_t P_{h,t+1}\right\} \tag{12}$$

where χ is the fraction of the housing value that *cannot* be used as a collateral. This type of constraint can be justified on the basis of limited enforcement.[22] Since the borrower can run away with the assets in case of default, requiring a collateral ex-ante acts against that temptation. At the margin, the larger the expected realized value of the asset prevailing

[20] Notice that each household is assumed to derive independent disutility from work in each sector. As a result, the nominal wage will not be equalized across sectors. This form of labor market segmentation is useful to dampen the substitution effect across sectors in response to relative price movements, which would otherwise tend to generate a counterfactual negative sectoral co-movement in response to aggregate monetary shocks.

[21] See Campbell and Cocco (2003) for a normative analysis of the optimal choice between a variable-rate and a fixed-rate mortgage contract based on household-level risk management.

[22] Kiyotaki and Moore (1997), Kocherlakota (2000).

at the time of the loan repayment (i.e., $t+1$), the larger is the lender's willingness to extend credit in the current period. The reason is that in the event of default in time $t+1$ the lender will be able to seize an asset whose value has increased over time. In this vein, an expected future housing appreciation contributes to expand the ability to borrow in the current period.

One can think of parameter χ as the *down-payment* rate (or inverse LTV ratio) required at the beginning of the loan contract (time t), therefore representing a direct measure of the flexibility of the mortgage market (Jappelli and Pagano 1989). As already discussed above, the value of χ may reflect legal and regulatory constraints changing across countries (see *Table 1*). Notice, though, that loan contracts extend for one period in our environment. Hence parameter χ can be broadly interpreted as measuring the ability of extracting equity from the value of the house during the life span of the mortgage: in other words, it can be interpreted also as a measure of mortgage equity withdrawal (MEW), or of the willingness by lenders to extend home equity lines of credit.[23]

Given initial values $\{b_{-1},\ H_{-1}\}$, the borrower chooses $\{N_{j,t},\ b_t,\ H_t,\ C_t\}$ to maximize (7) subject to (9) and (12). By defining λ_t and $\lambda_t\psi_t$ as the multipliers on constraints (9) and (12) respectively, and $U_{x,t}$ as the marginal utility of variable $x = C, N_j, H$, efficiency conditions for the above program read:

$$\frac{-U_{n_j,t}}{U_{c,t}} = \frac{W_{j,t}}{P_{c,t}} \qquad j = c, h \tag{13}$$

$$U_{c,t} = \lambda_t \tag{14}$$

$$q_t U_{c,t} = U_{h,t} + \beta(1-\delta)E_t\left\{U_{c,t+1}q_{t+1}\right\} + (1-\chi)\,(1-\delta)U_{c,t}q_t\psi_t E_t\left\{\pi_{h,t+1}\right\} \tag{15}$$

$$R_t\psi_t = 1 - \beta E_t\left\{\frac{U_{c,t+1}}{U_{c,t}}\frac{R_t}{\pi_{c,t+1}}\right\} \tag{16}$$

[23] Technically speaking a measure of MEW should be based on the realized difference between the *current* value of the house and the debt principal still due, rather than be based on the *expected* realized market value of the house. The results, however, would not be qualitatively altered in our setting if we were to adopt the former specification.

4.2.1 Interpretation

Equations (13) governs the consumption/leisure margin in each sector, while (14) equates the marginal utility of consumption to the shadow value of the flow budget constraint (8). Equation (15) is an intertemporal condition driving the choice between housing and consumption. It requires the borrower to equate the marginal utility of current consumption (left-hand side) to the marginal gain of housing services (right-hand side). The latter depends on three components: (i) the direct utility gain of an additional unit of housing; (ii) the expected utility of expanding future consumption by means of the realized resale value of a new unit of housing purchased in the previous period; (iii) the marginal utility stemming from the possibility of using housing in the form of collateral. Notice that the latter component (which is critical in our analysis) is proportional to the shadow value of borrowing ψ_t, with that component disappearing when $\psi_t = 0$, i.e., when the collateral constraint is not binding.

Equation (16) is a modified version of an Euler equation. Indeed it reduces to a standard Euler condition in the case of $\psi_t = 0$ for all t. This condition is basically stating that when the collateral constraint is binding ($\psi_t > 0$), the borrower's marginal utility of consumption exceeds the marginal utility of saving (i.e., of shifting consumption intertemporally).

Integrating both (15) and (16) forward, and combining, we can express the margin between consumption and housing in more compact form as:

$$U_{c,t} q_t = V_t + \Omega_t \tag{17}$$

where

$$V_t \equiv E_t \left\{ \sum_{j=0}^{\infty} \left[\beta(1-\delta)\right]^j U_{h,t+j} \right\}$$

and

$$\Omega_t \equiv (1-\chi)(1-\delta) E_t \left\{ \sum_{j=0}^{\infty} \left[\beta(1-\delta)\right]^j U_{c,t+j} q_{t+j} \psi_{t+j} E_t \left\{ \pi_{h,t+j+1} \right\} \right\}$$

The above equation illustrates the channel linking housing collateral and consumption. The right hand-side of (17) has two components, V_t and Ω_t. The first is the present

discounted value of the current and future marginal utility of housing. Given that the stock-flow ratio of housing is extremely high, V_t behaves very smoothly in response to shocks, and especially if those shocks are temporary in nature as monetary policy ones. Intuitively, the marginal increment in utility of a new unit of housing is small relatively to the stock. Notice that under perfect capital markets V_t would be the only component of the marginal utility of housing. The second term on the right hand side of (17), Ω_t, depends on current and future values of the shadow value of borrowing ψ_t. Monetary policy has a direct effect on Ω_t by altering the cost of servicing the debt, and therefore the shadow value of borrowing.

Next consider equation (17): if V_t is quasi constant, and even in the case of purely flexible prices in *both* sectors (so that the relative price q_t is constant in response to aggregate shocks), any effect on the shadow value of borrowing will affect the marginal utility of consumption. Suppose monetary policy tightens: this will generate a rise in the current and future values of ψ_t, and therefore a rise in Ω_t. In turn, via (17), this will raise the marginal utility consumption and, in equilibrium, generate a fall in consumption. In addition, movements in the relative price of housing help to strengthen this channel: for instance, if the current and future real price of housing falls, the value of collateral shrinks proportionally, thereby affecting current borrowing and consumption.

4.3 Savers

We assume that the savers are the owners of the monopolistic firms in each sector. A typical saver maximizes the utility program

$$E_0 \left\{ \sum_{t=0}^{\infty} \gamma^t U(\widetilde{X}_t,\ \widetilde{N}_{c,t},\ \widetilde{N}_{h,t}) \right\} \tag{18}$$

where

$$\widetilde{X}_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}}\ \widetilde{C}_t^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\ \widetilde{H}_t^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{19}$$

Importantly, the discount rate γ is such that $\gamma > \beta$. The saver's sequence of budget constraints reads (in nominal terms):

$$P_{c,t}\ \widetilde{C}_t + P_{h,t}(\widetilde{H}_t - (1-\delta)\widetilde{H}_{t-1}) + R^m_{t-1}\widetilde{B}_{t-1} = \widetilde{W}_{c,t}\widetilde{N}_{c,t} + \widetilde{W}_{h,t}\widetilde{N}_{h,t} + \widetilde{B}_t + \widetilde{T}_t + \sum_j \widetilde{\Gamma}_{j,t} \quad (20)$$

where $\widetilde{W}_{j,t}$ is the nominal wage rate paid to the saver in sector j, and $\widetilde{\Gamma}_{j,t}$ are nominal profits from the holding of monopolistic competitive firms in sector j.

Efficiency conditions for the saver's program read:

$$\frac{-\widetilde{U}_{n_j,t}}{\widetilde{U}_{c,t}} = \frac{\widetilde{W}_{j,t}}{P_{c,t}} \qquad j = c, h \quad (21)$$

$$\widetilde{U}_{c,t} = \gamma E_t \left\{ \frac{\widetilde{U}_{c,t+1}}{\pi_{c,t+1}} R^m_t \right\} \quad (22)$$

$$q_t = \frac{\widetilde{U}_{h,t}}{\widetilde{U}_{c,t}} + \gamma(1-\delta)E_t \left\{ \frac{\widetilde{U}_{c,t+1}}{\widetilde{U}_{c,t}} q_{t+1} \right\} \quad (23)$$

The interpretation of the above efficiency conditions is standard. In fact, those conditions can be derived as a particular case of (13), (14), and (15) when $\psi_t = 0$ for all t, and $\gamma = \beta$.

4.4 Production and pricing of intermediate goods

Intermediate-good firm i in sector j hires labor to operate the following production function:

$$Y_{j,t}(i) = L_{j,t}(i) \quad (24)$$

where $L_{j,t}(i)$ is total labor employed by firm i in sector j.

Each firm i has monopolistic power in the production of its own variety and therefore has leverage in setting the price. In so doing it faces a quadratic cost proportional to output, and equal to:

$$\frac{\vartheta_j}{2}\left(\frac{P_{j,t}(i)}{P_{j,t-1}(i)} - 1\right)^2 Y_{j,t} \quad (25)$$

where the parameter ϑ_j measures the degree of sectoral nominal price rigidity. The higher ϑ_j, the more sluggish the adjustment of nominal prices in sector j. For $\vartheta_j = 0$ prices are flexible.

The problem of each monopolistic firm is to choose the sequence $\{N_{j,t}(i),\, P_{j,t}(i)\}_{t=0}^{\infty}$ to maximize expected discounted nominal profits:

$$E_0 \left\{ \sum_{t=0}^{\infty} \Lambda_{j,t} \left(P_{j,t}(i) Y_{j,t}(i) - W_{j,t} L_{j,t}(i) - \frac{\vartheta_j}{2} \left(\frac{P_{j,t}(i)}{P_{j,t-1}(i)} - 1 \right)^2 P_{j,t} Y_{j,t} \right) \right\} \tag{26}$$

subject to (24). In (26), $\Lambda_{j,t} \equiv \gamma E_t \left\{ \widetilde{\lambda}_{t+1} / \widetilde{\lambda}_t \right\}$ is the saver's stochastic discount factor, and $\widetilde{\lambda}_t$ is the saver's marginal utility of nominal income.

Let's denote by $P_{j,t}(i)/P_{j,t}$ the relative price of variety i in sector j. In a *symmetric* equilibrium in which $P_{j,t}(i)/P_{j,t} = 1$ for all i and j, and all firms employ the same amount of labor in each sector, the first order condition of the above problem reads:

$$\begin{aligned} ((1-\varepsilon_j) + \varepsilon_j mc_{j,t}) \;=\; & \vartheta_j \left(\pi_{j,t} - 1\right) \pi_{j,t} \\ & - \vartheta_j E_t \left\{ \frac{\Lambda_{j,t+1}}{\Lambda_{j,t}} \frac{P_{j,t+1}}{P_{j,t}} \frac{Y_{j,t+1}}{Y_{j,t}} \left(\pi_{j,t+1} - 1\right) \pi_{j,t+1} \right\} \qquad (j = c, h) \end{aligned} \tag{27}$$

where $\pi_{j,t} \equiv P_{j,t}/P_{j,t-1}$ is the gross inflation rate in sector j, and $mc_{j,t}$ is the real marginal cost in sector j.

Optimal choice of the labor input implies that the real marginal cost in sector j reads:

$$mc_{j,t} \;= \frac{W_{j,t}}{P_{j,t}} \tag{28}$$

Finally, sectoral inflation and relative prices are related as follows:

$$\frac{\pi_{h,t}}{\pi_{c,t}} = \frac{q_t}{q_{t-1}} \tag{29}$$

4.5 Market clearing

Equilibrium in the goods market of sector $j = c, h$ requires that the production of the final good be allocated to *total* households' expenditure and to resource costs originating from the adjustment of prices:

$$Y_{c,t} = \omega C_t + (1-\omega)\widetilde{C}_t + \frac{\vartheta_c}{2}\left(\pi_{c,t}-1\right)^2 Y_{c,t} \tag{30}$$

$$Y_{h,t} = \omega\left(H_t - (1-\delta)H_{t-1}\right) + (1-\omega)\left(\widetilde{H}_t - (1-\delta)\widetilde{H}_{t-1}\right) + \frac{\vartheta_d}{2}\left(\pi_{d,t}-1\right)^2 Y_{d,t} \tag{31}$$

where

$$Y_{j,t} \equiv \int_0^1 Y_{j,t}(i)\ di \qquad j = c, h$$

Equilibrium in the debt and labor market requires respectively

$$\omega B_t + (1-\omega)\widetilde{B}_t = 0 \tag{32}$$

$$L_{j,t} = \omega N_{j,t}(i) + (1-\omega)\widetilde{N}_{j,t}(i) \qquad j = c, h \tag{33}$$

4.6 Monetary policy

We assume that monetary policy is conducted by means of an interest rate reaction function, constrained to be linear in the logs of the relevant arguments:

$$\begin{aligned} \ln\left(\frac{R_t}{R}\right) &= (1-\phi_r)\phi_\pi \ln\left(\frac{\pi_{j,t}}{\overline{\pi}}\right) \\ &\quad +\phi_r \ln\left(\frac{R_{t-1}}{R}\right) + \zeta_t \end{aligned} \tag{34}$$

where R_t is the short-term policy rate, and ζ_t is a policy shock evolving as:

$$\zeta_t = \rho_r\ \zeta_{t-1} + u_t$$

with $u_t \tilde{}\, i.i.d.$,with mean zero and variance σ_u^2. Our baseline assumption is to employ a version of (34) in which $\pi_{j,t} = \pi_{c,t}$, although the results will not be sensitive to specifying rules in which the inflation index is the CPI.

5 The channels of monetary policy transmission

Relative to a standard monetary NK framework with perfect financial markets, monetary policy works via three novel channels in this framework. Although these channels are interrelated, it is helpful, for expositional purposes, to consider them distinctively.

Consider a monetary policy *contraction*, in the form of an interest rate hike: first, this produces a fall in inflation and therefore a rise in the *real* service cost of debt, which is predetermined in nominal terms at time t. This effect is akin to a negative income effect via the borrower's budget constraint. We feature this as an independent channel because it would be at work also in the absence of a collateral constraint.

Second, the policy tightening works via the collateral constraint. The rise in the nominal interest rate induces a rise in the shadow value of borrowing both directly (via a mechanical fall in debt B_t in equation 12) and indirectly, via a heightened future service cost of debt. The rise in the shadow value of borrowing, in turn, induces a fall in consumption via the channel described in equation (17).

Finally, movements in the real price of housing q_t also affect the transmission of monetary policy shocks, by affecting the (expected) value of the housing stock that can be used as a collateral. Fluctuations in that value affect the tightness of the collateral constraint. In our two-sector model, however, this effect is operative only in the case of *asymmetric* price stickiness. With prices flexible or equally sticky in both sectors, in fact, real house prices would remain unchanged in response to a monetary policy shock. Under our baseline assumption that house prices are flexible and non-durable prices sticky, however, a policy tightening will induce a fall in the real house price, thereby inducing (all else equal) a depreciation of the collateral value and a further tightening of the collateral constraint. In turn, this will induce a fall in the demand for borrowing, and therefore a fall in the demand for housing, which will further depress its relative price, all in a self-reinforcing fashion. In this respect, this asset price channel works by strengthening the collateral channel. In equation (17), in fact, a fall in q_t requires an even larger increase in the marginal utility of consumption in order to match any given variation in the tightness of the collateral constraint represented by the right-hand side of (17).

This interpretation of the channels at work clarifies the role of the institutional features of mortgage markets. First, a lower value of χ, representing a more flexible/developed

mortgage market, implies that a larger variation in consumption is needed to satisfy (17) for any given variation in ψ_t (i.e., for any given impact on the tightness of the collateral constraint). Intuitively, in light of a policy tightening, a more flexible mortgage market entails that credit to households will be reduced more rapidly, with this effect translating proportionally into a variation in consumption. Second, any given variation of the short-term interest rate will be passed-through to mortgage rates more rapidly if the structure of mortgage contracts is at variable rate. This pass-through effect, in turn, will be larger in those economies with low χ mortgage contracts.

6 Dynamic simulations

In this section we evaluate the transmission of monetary policy shocks. We begin by illustrating how the role of borrowers and of a collateral constraint alter the equilibrium dynamics relative to a baseline NK model. We then analyze how the transmission of monetary policy shocks is affected by two key institutional features: (i) the down-payment rate χ; (ii) the interest-rate mortgage structure (fixed vs. variable debt contract)

6.1 Calibration

We resort to the following calibration. Time is in quarters. We set the quarterly discount factor $\gamma = 0.99 > \beta = 0.98$. The annual real interest rate is pinned down by the saver's patience rate and is equal to 4%. The annual physical depreciation rate for housing is generally low, and around 1% per year. Therefore we set $\delta = 0.01/4$ as a baseline value. The elasticity of substitution between varieties is set to 7.5 in both sectors, which yields a steady-state mark-up of 20%.

We assume throughout that house prices are *flexible*. This assumption is not without controversy. For one, as argued in Barsky et al. (2007), house prices, unlike consumption prices, are largely subject to negotiation upon transactions, so it could be plausible that they are relatively more flexible. At the same time, there is evidence that house prices are subject to a large degree of predictability (see Glaeser and Gyourko 2007), both upward and downward. Our results, however, do not hinge critically on this assumption.

We set the stickiness parameter for consumer prices equal to a benchmark value of $\vartheta_c = 75$. To pin down this value we proceed as follows. Let θ be the probability of

not resetting prices in the standard Calvo-Yun model. We parameterize $1/1-\theta = 4$, which implies $\theta = 0.75$, and therefore an average frequency of price adjustment of one year. This value is roughly in line with the micro-based evidence for European countries summarized in Alvarez et al. (2006) and Angeloni et al. (2006). Log-linearization of (27) around a zero-inflation steady state (in the consumption sector) yields a slope of the Phillips curve equal to $(\varepsilon_c - 1)/\vartheta_c$, whereas the slope of the Phillips curve in the Calvo-Yun model reads $(1-\theta)(1-\beta\theta)/\theta$. Setting the elasticity ε_c equal to 7.5, which implies a steady-state markup of 15 percent, the resulting stickiness parameter satisfies $\vartheta_c = \theta(\varepsilon_c - 1)/(1-\theta)(1-\beta\theta) \simeq 75$.

The current share of housing and housing-related expenditure is about 10% on average in the euro area. However, by adding owner-occupied housing that number would increase to 17.5%. Since we do not have rents in the model, we calibrate the share α in order to match the expenditure for owner-occupied housing. The latter value is estimated as being 7.5% in the euro area and 24% in the US, although statistical methodologies differ substantially. We choose to pick an intermediate value of $\alpha = 16\%$. The down-payment rate is set at $\chi = 0.3$ in the baseline calibration, a value which is close to the euro area average, corresponding to a LTV ratio of about 0.7 (see *Table 1*). Below, however, we experiment with alternative values of this parameter. As to monetary policy, we set the Taylor rule parameters $\phi_\pi = 1.5$ and $\phi_r = 0$, and the persistence of the monetary policy innovation $\rho_r = 0.7$. Throughout we assume that (i) durable prices are *flexible;* (ii) the elasticity of substitution η equals 1 (which implies Cobb-Douglas preferences in consumption and housing services); (iii) the monetary policy rule features a reaction to consumption price inflation.[24]

6.2 The role of the collateral constraint

We begin by describing the general features of the monetary transmission in our setup. *Figure 5* depicts the effect on selected *per capita* variables of a 25 basis point rise in the nominal (policy) interest rate. Solid lines and dashed lines denote respectively the borrower's and the saver's choice variables.

In this exercise, we set the share of borrowers to a baseline value of $\omega = 0.5$. Notice, first, that the monetary policy tightening induces a rise in the shadow value of borrowing

[24] All our results do not hinge on these assumptions in any significant way.

ψ_t. This in turn induces a contractionary effect on borrower's consumption (*collateral-constraint* effect). Since house prices are flexible (and consumption prices sticky), the policy tightening induces also a fall in the real house price q_t, which in turn reduces directly the collateral value, further contributing to a tightening of the borrowing conditions (*asset-price* effect). As a result, real household debt falls, the demand for housing services drops on impact and then starts to gradually revert back towards the steady state.

To better understand why, despite prices being flexible in that sector, the demand for housing services and therefore residential investment both fall, it is useful to notice that a policy tightening increases the *user cost* of housing. The user cost is the key intertemporal price that drives the relative demand of housing vs. consumption. Condition (15) requires the marginal rate of substitution between housing and consumption, $U_{h,t}/U_{c,t}$, to be equated to the user cost (Z_t), which in this case reads:

$$Z_t \equiv q_t \left[1 - (1-\chi)(1-\delta)\psi_t E_t \left\{\pi_{d,t+1}\right\}\right] - \beta(1-\delta)E_t \left\{\frac{U_{c,t+1}}{U_{c,t}} q_{t+1}\right\} \tag{35}$$

The user cost depends positively on the current relative price of housing but inversely on the future price. Intuitively, expected capital gains on the holding of housing decrease the current user cost. A typical feature of the model with a collateral constraint is that the user cost depends not only on the dynamic of q_t but also on the shadow value of borrowing ψ_t. In particular, one can show that a rise in the shadow value of borrowing generally induces a rise in the user cost.[25] The figure makes clear that, under a collateral constraint, fluctuations in the shadow value of borrowing overwhelmingly drive the user cost. As a result, a policy tightening induces a rise in the user cost, a fall in the relative demand for housing services, and a fall in residential investment.

The figure shows also the response of consumption by a typical *saver* (dashed lines). Recall that the savers are standard permanent-income agents. Two competing effects drive their demand. For one, a *positive* income shock, which is the counterpart of the negative income shock for the borrowers. This effect leads the savers to increase both consumption and housing services. However, the rise in the real interest rate makes them substitute consumption intertemporally, so that, on balance, savers' consumption is less responsive than borrowers' consumption. At the same time, since the relative price of housing falls, the savers increase their demand for housing services. For these agents, in

[25] See Monacelli (2008) for an analysis on this point referred to durable goods consumption.

fact, the relevant user cost of housing is the one prevailing in the absence of any collateral constraint, and therefore it depends heavily on the behavior of the (intratemporal) relative price of housing q_t (and not on ψ_t).

6.2.1 Varying the down-payment rate and the interest rate structure

Figure 6 depicts the effect on aggregate consumption and residential investment of varying the *down-payment rate* χ. We continue to assume a variable interest-rate mortgage structure. We consider three cases for χ: 0.05, 0.1, 0.3. This range of values approximately spans the gap between LTV ratios that have been common in the US in the last few years (arguably before the onset of the financial crisis) and average European ones.

Two results stand out. First, as in the data, the response of residential investment is significantly larger than the one of consumption. Intuitively, each household tries, in response to the policy shock, to smooth the response of both consumption and the housing stock. Given that the stock-flow ratio of housing is particularly high, the elasticity of residential investment (i.e., of the housing expenditure flow) to interest rate changes is particularly high. Second, the response of both variables is amplified by a smaller down-payment rate. As suggested above, a lower down-payment rate increases, all else equal, the sensitivity of borrowing to changes in the value of the collateral. A more rapid contraction of borrowing leads to a more rapid contraction of both consumption and housing services, and in turn of residential investment.

Figure 7 displays the effect of varying the interest-rate mortgage structure (which, in practice, corresponds to the degree of interest rate pass-through). We analyze two cases. The first case considers a debt structure in which the mortgage rate is freely linked to the short-term policy rate (*variable rate,* $R_t^m = R_t$ for all t, or alternatively $\tau = 0$ in equation (11)). The second case is a limit case of a *fixed-rate* mortgage structure. This is approximated by considering the variant of the term structure equation (11) for $\tau \to 1$, with maturity m extending to a limit case of an infinite number of periods. In each case, we compare the effect of varying the interest rate structure under alternative values of parameter χ. We wish to highlight, in fact, that also the *interaction* of different institutional characteristics of the mortgage market is potentially relevant.

When the down-payment rate χ is low ($\chi = 0.05$, upper panel), a variable rate contract structure significantly amplifies the responses of both consumption and residential invest-

ment relative to the fixed rate case. When the down-payment is high, though, ($\chi = 0.3$, upper panel) the effect of moving from a fixed to a variable rate structure is significantly dampened. Intuitively, even if the pass-through from policy rates to mortgage rates is high (as under variable rate contracts) when the ability to borrow remains limited because of low LTV ratios, the interest rate structure of the mortgage matters relatively less.[26]

Notice, however, that in all cases a fixed-rate structure does *not* necessarily imply that consumption is unresponsive on impact. In this case, a policy tightening is still generating both a nominal-debt and a collateral-constraint effect (via a fall in the relative price of housing, which in turn depresses borrowing capability). With real house prices returning back to baseline, then, the effect on consumption is quickly reversed in the case of a fixed-rate mortgage structure, whereas it continues to persist under a variable rate structure.

7 Conclusions

We have studied the role of housing finance for the transmission of monetary policy on consumption, residential investment and house prices in a sample of industrialized countries. We have provided evidence that, according to a wide set of indicators, such structure varies significantly across industrialized countries. We have then shown that residential investment and house prices are usually more responsive to policy shocks in those countries with more developed/flexible mortgage markets. As for consumption, it is really two indicators that matter: the possibility (or lack thereof) of mortgage equity release and the prevailing interest rate structure of mortgage contracts. We have then built a DSGE model of the monetary transmission with three non-standard features: (i) two sectors; (ii) heterogeneity in patience rates; (iii) a collateral constraint on borrowing. We have shown that the response of consumption and residential investment to monetary policy shocks is affected by alternative values of two institutional parameters of mortgage markets: the down-payment rate, and the interest-rate mortgage structure (variable vs. fixed interest rate). In particular, the model can rationalize the evidence that private consumption is

[26] This result may vary, though, in a context in which multi-period contracts are specified. Namely, if the ability to extract borrowing is influenced by the LTV ratio only at the beginning of the contract, during the maturity of the loan the interest rate structure may continue to affect disposable income significantly. In our context this is not feasible, for debt contracts are renewed in every period.

more responsive to monetary impulses in economies with more developed/flexible mortgage markets, somewhat in contrast with the presumption that more developed mortgage (credit) markets should be conducive to more efficient consumption-smoothing.

There are several issues that have remained unexplored in this work and that it would be interesting to pursue in future research. First, providing a full estimation of the model.[27] Second, introducing an endogenous choice by the households between variable and fixed-rate mortgage contracts. Third, studying how the optimal conduct of monetary policy varies according to the characteristics of mortgage markets, and in particular in the context of a currency area (such as the euro area) in which the heterogeneity of mortgage market institutions remains widespread.

[27] Iacoviello and Neri (2008) is an interesting step in this direction.

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TABLE 1. Institutional characteristics of national mortgage systems.

Country	Mortgage debt to GDP ratio (2004)	Typical loan to value ratio	Interest rate adjustment [a]	Typical duration (years)	Equity release products	IMF mortgage market index [b]
Australia	74%	80%	Mainly V	25	Used	0.69
Austria	20%	60%	F(75%) V(25%)	25	Not used	0.31
Belgium	28%	83%	F(75%) M(19%) V(6%)	20	Not used	0.34
Canada	43%	75%	F and M(92%) V(8%)	25	Used	0.57
Denmark	85%	80%	F (75%) M (10%) V (15%)	30	Used	0.82
Finland	27%	75%	F(2%) V(97%) Other(1%)	17	Used	0.49
France	26%	75%	F/M/Other(86%) V(14%)	15	Not used	0.23
Germany	43%	70%	Mainly F and M	25	Not used	0.28
Ireland	50%	70%	V(70%) Rest mostly M	20	Limited use	0.39
Italy	13%	50%	F(28%) Rest mainly M	15	Not used	0.26
Japan	36%	70-80%	F(36%) M and V(64%)	25	Not used	0.39
Netherlands	68%	90%	F(74%) M(19%) V(7%)	30	Used	0.71
New Zealand	80%	60%	Mainly F	25	Used	NA
Norway	54%	70%	Mainly V	17	Used	0.59
Spain	40%	70%	V(≥75%) Rest mainly M	20	Limited use	0.40
Sweden	35%	80%	F(38%) M(24%) V(38%)	25	Used	0.66
Switzerland	116%	66%	Mainly V	NA	Not used	NA
United Kingdom	74%	80-90%	M(28%) V(72%)	25	Used	0.58
United States	69%	80%	F(85%) M(15%)	30	Used	0.98

Notes: a) Breakdown of new loans by type. Fixed (F): Interest rate fixed for more than five years or until expiry; Mixed (M): Interest rate fixed between one and five years; Variable (V): Interest rate renegotiable after one year or tied to market rates or adjustable at the discretion of the lender. b) The IMF index is a composite indicator (between 0 and 1) of the degree of development and completeness of a national mortgage market; a higher value indicates a higher degree of market development and completeness.
Sources: The main data sources are Council of Mortgage Lenders (http://www.cml.org.uk/cml/home), ECB (2003), IMF (2008), OECD, and Miles and Pillonca (2008). Additional information is drawn from , *Ahearne et al. (2005), Catte et al. (2004), Debelle (2004), Girouard and Blöndal (2001), Muellbauer and Murphy (2008), Seko (1994) and Tsatsaronis and Zhu (2004).*

TABLE 2. Classification of countries according to mortgage market development indicators

Country	*Mortgage to GDP ratio*	*IMF mortgage index*	*Loan to value ratio*	*MEW*	*Fixed (F) or variable (V) rate*
Australia	high	high	high	yes	V
Austria	low	low	low	no	F
Belgium	low	low	high	no	F
Canada	low	low	high	no	F
Denmark	high	high	high	yes	F
Finland	low	low	high	yes	V
France	low	low	low	no	F
Germany	high	low	low	no	F
Ireland	high	low	low	no	V
Italy	low	low	low	no	V
Japan	low	high	low	no	V
Netherlands	high	high	high	yes	F
New Zealand	high	high	high	yes	F
Norway	high	high	low	yes	V
Spain	low	low	low	no	V
Sweden	low	high	high	yes	F
Switzerland	high	high	high	no	V
United Kingdom	high	high	high	yes	V
United States	high	high	high	yes	F

Note: See Table 1 for further reference.

TABLE 3a. Test of the difference in means between simple impulses responses to a standardised contractionary monetary policy shock in country sub-groups, highly developed vs. lowly developed mortgage markets and interest rate adjustment

	Quarters after shock	Loan to value ratio	Mortgage to GDP ratio	MEW	Interest rate adjustment
Consumption	4	0.03	0.05	-0.04	-0.06
	8	0.01	-0.03	-0.1*	-0.1*
	12	-0.01	-0.08*	-0.03	-0.12*
	24	0.01	0	0.04	-0.05
Residential investment	4	-0.43*	-0.52*	-1.16*	-0.59*
	8	-0.17	-0.06	-0.44*	-0.46*
	12	-0.08	-0.02	0.06	-0.38*
	24	-0.06	-0.06	0.06	-0.17
Real house price	4	-0.71*	-0.18	-0.57*	-0.67*
	8	-0.37*	-0.28	-0.47*	-1.07*
	12	-0.08	-0.25	-0.22	-0.94*
	24	0.03	-0.03	0.03	-0.22

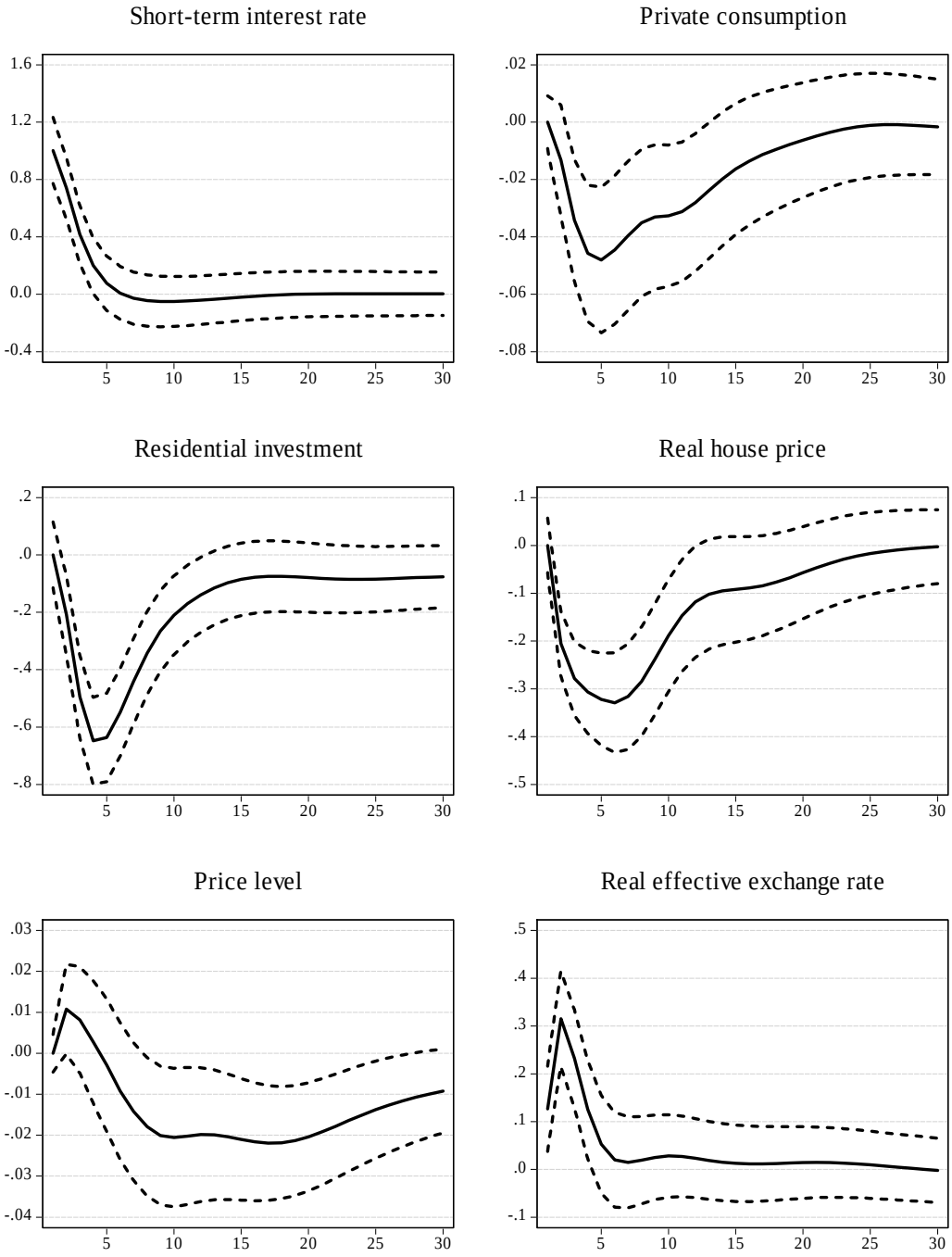
Note: * denotes statistical significance at the 68% confidence level. The null hypothesis is no difference in the average impulse response between the two groups. The table reports the differences, at each selected horizon, in the impulse responses to a standardised contractionary monetary policy shock between countries with respectively high and low loan to value ratio and mortgage to GDP ratio; and between countries where respectively mortgage equity withdrawal (MEW) is allowed or not, and where the interest rate adjustment is variable rate or fixed rate. The groups include a similar number of countries for all the four criteria.

TABLE 3b. Test of the difference in means between accumulated impulses responses to a standardised contractionary monetary policy shock in country sub-groups, highly developed vs. lowly developed mortgage markets and interest rate adjustment

	Quarters after shock	Loan to value ratio	Mortgage to GDP ratio	MEW	Interest rate adjustment
Consumption	4	0.04*	0.04	-0.15	-0.17
	8	0.07*	0.12	-0.47	-0.46*
	12	0.06*	-0.13	-0.64	-0.9*
	24	-0.03	-0.92	0.04*	-2.02*
Residential investment	4	-0.73	-2.17*	-4.14*	-1.15*
	8	-2.17*	-2.3*	-7.98*	-3.37*
	12	-3.18*	-2.54*	-7.84*	-5.16*
	24	-5.19*	-4.36*	-4.28*	-9.08*
Real house price	4	-2.05*	-0.5	-1.81*	-1.61*
	8	-3.92*	-1.42	-3.99*	-5.74*
	12	-3.87*	-2.58	-5.26*	-10.28*
	24	-1.88	-3.87	-4.82	-17.29*

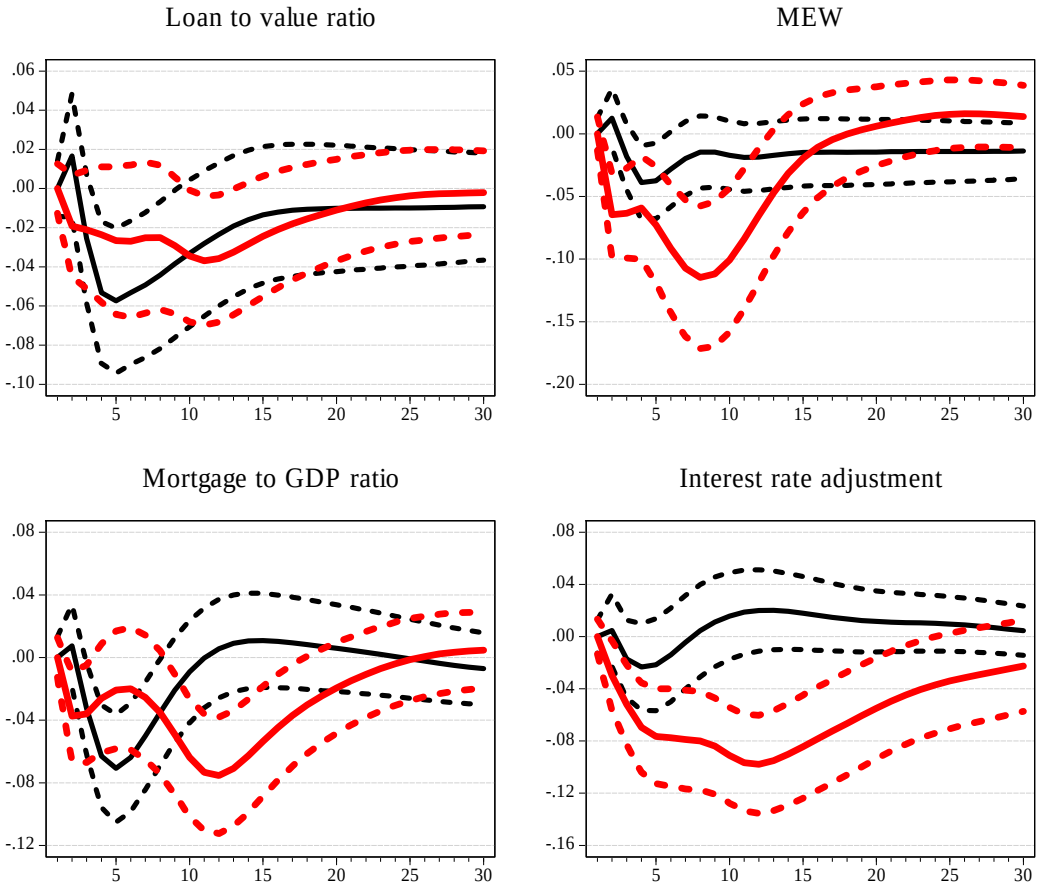
Note: * denotes statistical significance at the 68% confidence level. The null hypothesis is no difference in the average impulse response between the two groups. The table reports the differences, at each selected horizon, in the impulse responses to a standardised contractionary monetary policy shock between countries with respectively high and low loan to value ratio and mortgage to GDP ratio; and between countries where respectively mortgage equity withdrawal (MEW) is allowed or not, and where the interest rate adjustment is variable rate or fixed rate. The groups include a similar number of countries for all the four criteria.

FIGURE 1. Mean posterior impulse responses to a contractionary monetary policy shock over 19 countries



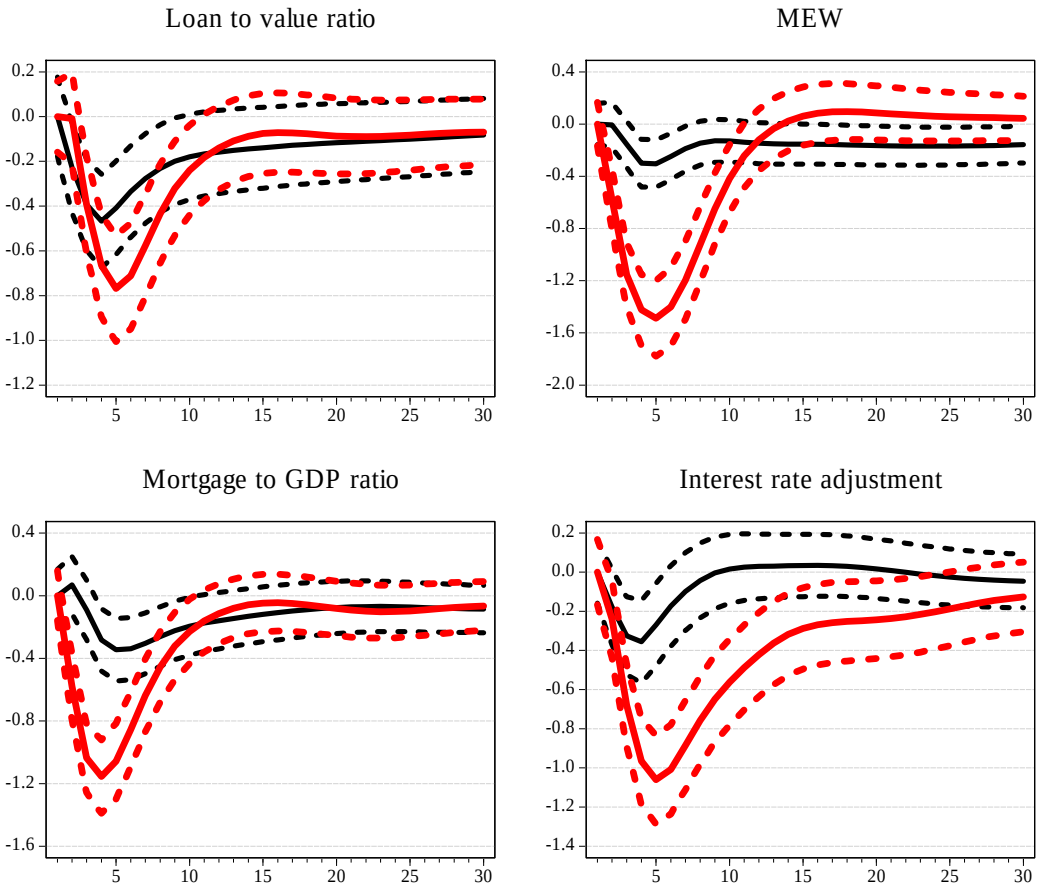
Note: See text for further explanations. The same VAR model is estimated country-by-country over the sample period 1980:Q1 to 2008:Q4. The figures report the cross sectional average impulse responses over 19 countries using the stochastic poolimg approach. See text for further explanations.

FIGURE 2. Mean posterior impulse responses of private consumption to a contractionary monetary policy shock: mortgage market development indicators



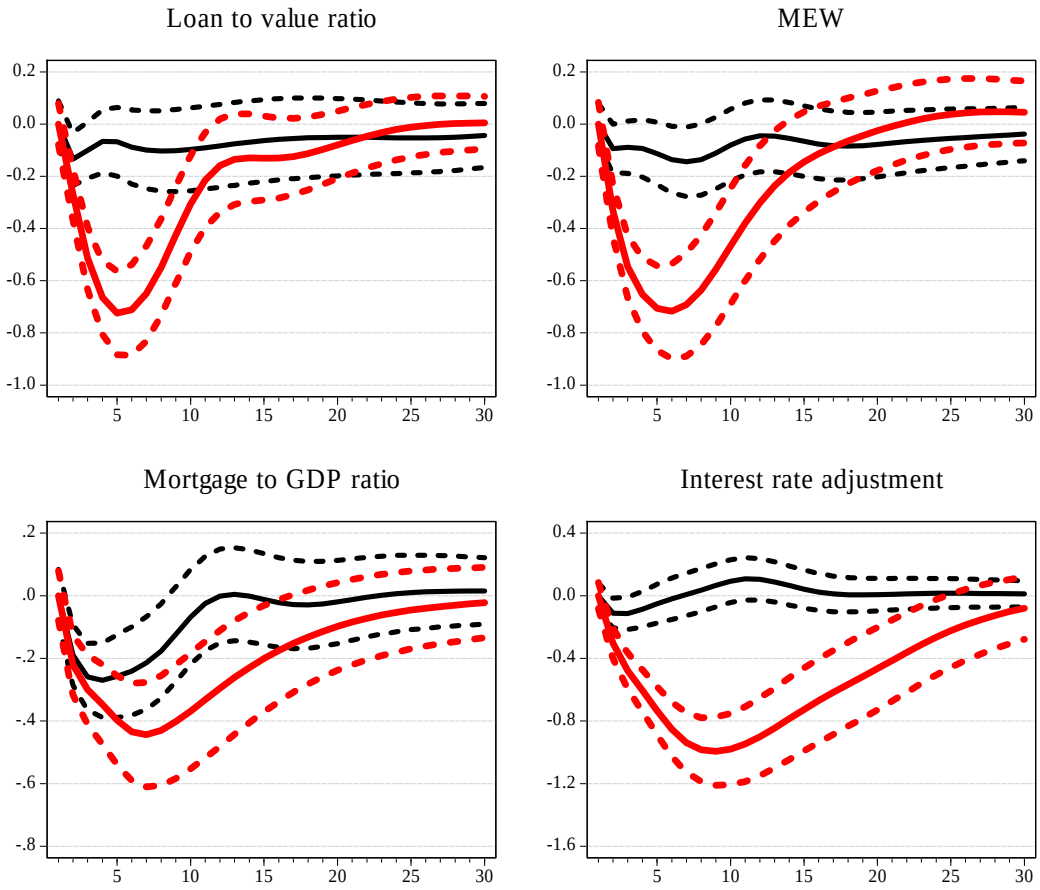
Note: See text for further explanations. The same VAR model is estimated country-by-country over the sample period 1980:Q1 to 2008:Q4 (or closest depending on data availability in each country). The full group of 19 countries is split approximately in half where each country is classified as having a "high developed" or "low developed" mortgage market according to the ranking in the four considered indicators. In particular, countries with (i) relatively higher (lower) loan to value ratio, (ii) where mortgage equity withdrawal is (is not) allowed, (iii) with relatively higher (lower) mortgage to GDP ratio and (iv) where the interest rate adjustment is predominantly variable rate (fixed rate) are classified as high (low) mortgage market developed countries. The thin black line refers to low development countries, the thick red line to high development countries. In each subgroup the same stochastic pooling approach is applied to obtain group-mean posterior distributions.

FIGURE 3. Mean posterior impulse responses of residential investment to a contractionary monetary policy shock: mortgage market development indicators



Note: See text for further explanations. The same VAR model is estimated country-by-country over the sample period 1980:Q1 to 2008:Q4 (or closest depending on data availability in each country). The full group of 19 countries is split approximately in half where each country is classified as having a "high developed" or "low developed" mortgage market according to the ranking in the four considered indicators. In particular, countries with (i) relatively higher (lower) loan to value ratio, (ii) where mortgage equity withdrawal is (is not) allowed, (iii) with relatively higher (lower) mortgage to GDP ratio and (iv) where the interest rate adjustment is predominantly variable rate (fixed rate) are classified as high (low) mortgage market developed countries. The thin black line refers to low development countries, the thick red line to high development countries. In each subgroup the same stochastic pooling approach is applied to obtain group-mean posterior distributions.

FIGURE 4. Mean posterior impulse responses of the real house price to a contractionary monetary policy shock: mortgage market development indicators



Note: See text for further explanations. The same VAR model is estimated country-by-country over the sample period 1980:Q1 to 2008:Q4 (or closest depending on data availability in each country). The full group of 19 countries is split approximately in half where each country is classified as having a "high developed" or "low developed" mortgage market according to the ranking in the four considered indicators. In particular, countries with (i) relatively higher (lower) loan to value ratio, (ii) where mortgage equity withdrawal is (is not) allowed, (iii) with relatively higher (lower) mortgage to GDP ratio and (iv) where the interest rate adjustment is predominantly variable rate (fixed rate) are classified as high (low) mortgage market developed countries. The thin black line refers to low development countries, the thick red line to high development countries. In each subgroup the same stochastic pooling approach is applied to obtain group-mean posterior distributions.