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# Mortgage Markets, Collateral Constraints, and Monetary Policy: Do Institutional Factors Matter?*

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**Abstract:**
We study the role of institutional characteristics of mortgage markets in affecting the strength and timing of the effects of monetary policy shocks on house prices and consumption in a sample of OECD countries. We document three facts: (1) there is significant divergence in the structure of mortgage markets across the main industrialised countries; (2) at the business cycle frequency, the correlation between consumption and house prices increases with the degree of flexibility/development of mortgage markets; (3) the transmission of monetary policy shocks on consumption and house prices is stronger in countries with more flexible/developed mortgage markets. We then build a two-sector dynamic general equilibrium model with price stickiness and collateral constraints, where the ability of borrowing is endogenously linked to the nominal value of a durable asset (housing). We study how the response of consumption to monetary policy shocks is affected by alternative values of three key institutional parameters: (i) down-payment rate; (ii) mortgage repayment rate; (iii) interest rate mortgage structure (variable vs. fixed interest rate). In line with our empirical evidence, the sensitivity of consumption to monetary policy shocks increases with lower values of (i) and (ii), and is larger under a variable-rate mortgage structure.

**JEL Classification:** E21, E44, E52

**Keywords:** House Prices, Mortgage Markets, Collateral Constraint, Monetary Policy

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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 industrialised countries over 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. Beyond these policy considerations, there is growing interest for the effects of changes in property prices on consumption decisions, given the predominance of housing in total household wealth (Campbell and Cocco (2003)).

This paper studies the role of *institutional characteristics of mortgage markets* across the main industrialised countries, with particular focus on EU countries, in determining the channels of monetary policy transmission. We begin by establishing two facts on the relationship between mortgage markets, consumption, and house prices. First, there is significant *heterogeneity* in the institutional characteristics of national mortgage markets across the main industrialised countries, and especially within the EU. Examples of such institutional characteristics include the typical duration of mortgage contracts, the required levels of down-payment, the existence (or lack thereof) of equity release products, and the interest-rate structure of mortgage contracts (e.g., variable vs. fixed rate). We interpret these indicators as measures of the degree of development/flexibility of mortgage markets. Second, the correlation between private consumption and house prices at the business cycle frequency is significantly related to mortgage markets characteristics, with that correlation being larger in countries featuring more developed mortgage markets.

We then conduct a VAR-based analysis of the effects of monetary policy shocks on consumption and house prices in a sample of euro area countries, with the addition of Canada, the U.K. and the U.S.. We find significant heterogeneity in both the *timing* and *strength* of those effects across countries. In particular, we find that the size of the peak effect of a monetary policy shock on consumption and real house prices is positively related to indicators of development/flexibility in mortgage markets, such as the mortgage debt to

[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); for a press account see The Economist (2003).

GDP ratio, the loan-to-value (LTV henceforth) ratio, and the existence of equity release products.

In particular, the evidence that private consumption is more responsive to monetary impulses in economies with more developed mortgage markets is *prima facie* puzzling. In fact, a priori, less imperfect financial markets should allow agents to smooth consumption more efficiently. Accounting for this fact requires a theoretical framework in which (at least) a fraction of agents does not act as permanent-income consumers. We thus build a model that extends the baseline New Keynesian framework in three main directions. 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 act as standard permanent-income agents, but exhibit preferences tilted towards current consumption. The borrowers may be thought of as the relatively larger 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 nominal price of housing.

Thus, in a context where credit markets allow more easily to convert asset values into borrowing, and therefore consumption, the latter should be more responsive to underlying shocks. In our framework, the relevant institutional features of the mortgage market are summarized by three main parameters: (i) the down-payment rate, (ii) the repayment rate (or rate of equity release), and (iii) 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 OECD countries. We find that the response of consumption to policy shocks is magnified in more flexible mortgage markets, symbolized by lower down-payment rates and lower rates of repayment. In addition, the prevalence of variable interest rate mortgages, and hence of a stronger pass-through of interest rate shocks to mortgage lending rates, also enhances the response of consumption to monetary policy shocks.

The paper is structured as follows. In Section 2 we document some key institutional differences in mortgage markets across industrialised countries. We then 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. Section 5 discusses the steady state of the model, which is then simulated in Section 6. Section 7

concludes.

# 2 Institutional Features of Mortgage Markets in EU Countries

A distinctive feature of mortgage markets in the EU (and, more generally, of the EU's retail financial services sectors) is their lack of cross-border integration. This implies that 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. EU policy makers have repeatedly indicated that further integration would yield a number of benefits to EU mortgage markets, including the removal of inefficiencies, increased competition and a higher degree of market completeness, while possibly also enhancing the monetary policy transmission mechanism.[2]

## 2.1 Cross-Country Heterogeneity

Mortgage markets differ significantly across EU countries in terms of both size and key institutional characteristics, such as the prevailing contractual arrangements and the available product range. Table 1 summarises 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 18 countries: euro area countries plus Japan and the main Anglo-Saxon countries.

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

Cross-country heterogeneity is pervasive in all indicators considered. Mortgage-to-GDP ratios vary widely across countries: values range between 15% in Italy and 111% in the

[2]EU policy-makers have set out to promote integration in mortgage markets. In particular, the Forum Group on Mortgage Credit, set up by the European Commission in 2003, proposed legislative and non-legislative measures to boost the integration of the EU home loans market. More recently, the European Commission has launched a public consultation and commissioned research on the economic costs and benefits of further integration across the national mortgage markets, with a view to assessing the opportunity of further intervention (European Commission (2005)).

Netherlands. Among the large countries, Italy and France have the lowest ratios, while the ratios in the U.K. and the U.S. are relatively high. Countries also differ in terms of home ownership ratios, with values ranging between 39% in Germany and 85% in Spain. With the exception of Germany, the majority of homes are owner-occupied in all countries. Also LTV ratios vary significantly across countries, ranging between 50% in Italy and over 110% in the Netherlands. Cross-country variations in these ratios partly reflect differences in legal and regulatory frameworks.[3] 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 EU countries. 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 U.K., Spain and Italy mainly have variable or adjustable rate mortgages, although for the latter two countries this reflects a relatively recent development.[4] By contrast, Germany, France, Austria, Belgium, Denmark and the Netherlands are mainly characterised by fixed rate mortgages, similar to the U.S. and Canada.

Finally, an important 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, liquidity-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, following house prices rises, 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

[3]For instance, it has been argued (e.g. MacLennan et al., 1998, and Ahearne et al., 2005) that the reason why the loan to value 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.

[4]Japan also has mainly variable rate mortgages.

or, alternatively, they may want to increase their borrowing to reflect their increased debt servicing capacity.

Overall, the use of home equity release remains limited in most 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. U.S., U.K. 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.[5] 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 U.S. has been historically one of the main exceptions to this pattern, with the exceptional nature of the U.S. mortgage market becoming particularly evident in recent years as U.S. borrowers have taken advantage of low interest rates, high house prices and a dramatic decline in transaction costs to engage in a wave of mortgage refinancing and equity extraction commonly thought to be large enough to influence aggregate spending.

## 2.2 House Prices and Consumption

In Table 3 we report the correlation between house prices and *total* private consumption measured at the business cycle frequency for that subset of countries with reliable house price data.[6] While the correlation is generally positive, it is noticeable how it varies significantly across countries, ranging from 0.79 in the U.K. to almost zero in Italy.

A natural question is whether that correlation shows any significant pattern against the characteristics of mortgage markets. Figure 1 (1a to 1d) describes how the correlation between consumption and house prices varies with four indicators of development and flexibility of mortgage markets: (i) mortgage to GDP ratio, (ii) home-ownership ratio, (iii) the degree of completeness in mortgage markets proposed by Mercer Oliver Wyman (2003) (MOW henceforth, which mainly measures the number of mortgage products available in a

[5] 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.

[6] See Table 2 in the Appendix for the description of the house price data.

given market)[7] and (iv) the typical LTV ratio (LTV henceforth). Notice that the correlation is significant and increasing in all cases.

Table 4 shows how the correlation between house prices and consumption varies (on average across countries) with (i) the possibility of resorting to mortgage refinancing, and (ii) the interest-rate mortgage structure. The correlation is on average twice as large in those countries where *mortgage refinancing* is feasible, and is also higher in those countries with a prevalence of *variable* rate contracts.

## 2.3 Country Clustering

A further issue worth exploring is whether it is possible to identify "clusters" of countries on the basis of the institutional characteristics of their mortgage markets. In general, in countries where LTV ratios are high, the level of mortgage debt relative to GDP tends to be large. High LTV ratios and large mortgage debts also tend to be accompanied by relatively long durations. In addition, countries where home equity release is common and households are able to borrow easily against their housing wealth tend to exhibit relatively high mortgage debt to GDP ratios. By contrast, there is no clear correlation between home ownership ratios and other characteristics, perhaps reflecting the prevailing role of public policies and cultural factors in determining the diffusion of home ownership in a country.[8] Likewise, there is no obvious link between the prevailing type of interest rate adjustment and the relative size of the mortgage market or other institutional factors.

In general, mortgage markets tend to be *larger* and more *flexible* in the Anglo-Saxon economies than in Japan and continental Europe (with the exception of the Netherlands). In particular, mortgage equity release is more extensively used in the U.S., U.K., Australia and the Netherlands than in the other countries. This country split coincides with that between countries with market- and bank-based financial systems, suggesting that the extent to which households can borrow against their housing wealth partly depends on the availability of developed and well-functioning capital markets in which lenders can raise loanable funds

[7] Note that this index is only available for EU countries.

[8] Governments aiming to promote home ownership have historically intervened in a variety of ways, such as the establishment of public housing finance agencies, the provision of deposit insurance to institutions specialised in mortgage lending, regulation and direct provision by public authorities of rental housing, welfare support to mortgage borrowers or fiscal incentives (e.g. the deductability of homeowners' interest payments).

and transfer risks. It should be also noted that countries with market-based financial systems are typically those in which mortgage markets have been longer and more extensively exposed to liberalisation and deregulation.

A more formal clustering exercise is pursued by Tsatsaronis and Zhu (2004), who group various national mortgage markets according to a set of institutional characteristics such as LTV ratios, the use of market or historical prices to value collateral and the extent of home equity release. The authors argue that most continental European countries are characterised by conservative lending practices and limited mortgage equity release, while Anglo-Saxon countries are exposed to more aggressive practices and more extensive mortgage equity release, particularly in countries where variable rate mortgages are predominant. The main exceptions to this classification are the Netherlands, Finland and Ireland among the continental European countries and Canada among the Anglo-Saxon countries.

Overall, within the EU there appears to be at least *two clusters* of countries:

- first, a group with less developed and more regulated mortgage markets (Italy, Germany, Austria, Belgium) where mortgage debt to GDP ratios tend to be low;
- second, a group of countries with deregulated mortgage markets and high mortgage debt to GDP ratios where home equity extraction is common (notably, the Netherlands, the U.K. and Denmark).

Other countries such as France and Spain fall under intermediate categories or may be undergoing structural adjustments that render their categorisation more difficult (e.g. Spain which has been exposed to significant financial innovation in recent years).

# 3 The Transmission of Monetary Policy Shocks in EU Countries, the U.S. and Canada: a VAR Analysis

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. In particular, a higher share of variable rate mortgages is generally expected to be conducive to a stronger "housing channel" and, ultimately, to a more effective monetary transmission mechanism (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 (2004) relates variations in the magnitude of output responses to monetary policy shocks across European countries to differences in financial systems. Likewise, Angeloni et al. (2004) 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 U.S.. 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.

In this section we estimate VAR models for three Anglo-Saxon countries (Canada, the U.S. and the U.K.), seven euro area countries (Germany, Italy, France, Spain, the Netherlands, Belgium and Austria) plus a non-euro area EU member country with a highly developed mortgage market (Denmark).[9] Given the more sophisticated nature of the Anglo-Saxon and Danish housing finance systems, they provide a natural benchmark against which to assess the potential implications of less flexible institutional settings in euro area countries.[10]

We estimate the model on quarterly data over a sample period from 1980:1 to 2004:4 (except from 1986 for Austria due to data availability). Each VAR model includes *five* endogenous variables: (i) real total private consumption, (ii) the consumer price index (CPI); (iii) real house prices (deflated using the CPI); (iv) the 3-month nominal interest rate, and

[9] Note that we include all major industrialised countries in our analysis with the exception of Japan, for which a measure of monetary policy shock may be particularly problematic due to the zero interest rate policy from the mid 1990s to the end of the sample period.

[10] In particular, the US and the UK are characterised by relatively more developed and flexible mortgage markets, with the main contractual difference perhaps being the different type of mortgage lending rate adjustment (fixed in the US versus variable in the UK).

(v) the real effective exchange rate. We include the real effective exchange rate to cater for open economy influences that, while arguably secondary for the U.S. economy, are likely to matter considerably for the European countries and Canada. For the U.S., which is a large closed economy, we also estimate the model without the real effective exchange rate. Since this specification turns out to be better than the one including the exchange rate according to standard information criteria and the significance of the impulse responses, we select this one in the baseline exercise.

The VARs are specified in levels (hence long-run relationships are implicitly allowed for) and, with the exception of the interest rates, all variables are in logs. A constant and a linear trend are also added as exogenous variables. Based on the Schwartz information criterion, a lag order of two (in levels) is optimal for this model across all countries.

The VAR models include house prices since they are of direct relevance to the household sector and the housing market.[11] However, the lack of harmonised data on house prices has to be emphasised. Table 2 reports a detailed description of the data used in this study, which indicates a certain degree of heterogeneity in the available house price data available. Even within the euro area house price data are not fully comparable. For this reason, the results have to be interpreted with some caution.

The identification of the monetary policy shocks is achieved through a standard recursive procedure based on a Cholesky factorisation of the estimated variance-covariance matrix. The policy-related variable - the 3-month nominal interest rate - is ordered after all other variables, except the exchange rate (changes in the ordering of the latter, however, do not affect the main results shown below).

Figure 2 reports the impulse responses of private consumption and of the real house price to a 100 basis points *rise* in the policy interest rate, for all considered countries. Qualitatively, the impact of a policy shock is in line with previous studies for U.S., Canada and EA countries (Angeloni et al., 2004, Aoki et al., 2004, and Mojon and Peersman, 2003): both consumption and the real house price tend to *fall*. However, a noticeable result of the VAR analysis is the significant *heterogeneity* in the impact of a monetary policy shock across different countries. For example, there is a striking difference between the impact of a policy

[11] Giuliodori (2004) conducts a similar analysis for several EU countries, finding similar results to this study. Note that, due to data limitations, we have not included another highly relevant variable in the VARs, i.e., mortgage debt.

shock in France, where the effects are very small and almost statistically insignificant, and the impact in the Netherlands and the United Kingdom, where the effects are very large (indeed larger than in the U.S.). In Germany, the effects are even of the "wrong" sign, although this may be partly due to the impact of the German reunification (see also Mojon and Peersman (2003)).

The finding that monetary policy transmission seems to be stronger in countries like the U.K., the Netherlands and the U.S., and weaker in France and Germany, may indeed suggest a link with the degree of development in mortgage markets. To further explore this issue, in Figures 3 and 4 we plot the estimated peak response of private consumption and the real house price to a standardised monetary policy shock in the cross-section of countries respectively against four indicators:

(i) mortgage debt to GDP ratio;

(ii) degree of home ownership;

(iii) MOW index of completeness in mortgage markets;

(iv) typical LTV ratio.

In all cases, we find a clearly positive relationship. In particular, in the case of the MOW index the link appears to be quite strong, especially as regards the effects of monetary policy on real house prices.

In Table 5 we also relate the (cross-country) average estimated peak effects of a contractionary monetary policy shock on private consumption and real house price to two dummy indicators: (i) the use of mortgage refinancing and (ii) the interest rate structure (predominantly fixed or variable interest rate). In line with the previous results, we find a comparatively stronger reaction of both consumption and the real house price to a policy shock in countries with a variable rate structure and, even more markedly, where mortgage refinancing is used. For example, the peak response of the real house price is 1.82 per cent where mortgage refinancing is allowed, and only 0.38 per cent where refinancing is not allowed or not practiced.

**Summary of Empirical Evidence: Why is Consumption More Responsive in More Flexible Mortgage Markets?** Overall, the empirical analysis seems to convey a sufficiently robust general message: both the business-cycle link between private consumption and house prices, as well as the transmission of monetary policy shocks on consumption and

house prices, seem to be significantly related to the characteristics of mortgage markets in different countries. In particular, house prices and private consumption co-move more strongly, and monetary policy seems more powerful (on consumer spending and house prices) in countries with more developed/flexible mortgage markets.

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 modelling framework. Second, the fact that private spending is more responsive to monetary impulses in economies with more developed credit/mortgage markets may be perceived as a puzzle. In fact, a priori, one may believe that more developed financial markets allow households to smooth consumption more efficiently. 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* consumption in light of any given rise in income. They can do this by increasing borrowing, although up to some 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 types of households, named *borrowers* and *savers*, of measure $\omega$ and $1 - \omega$ respectively. Each household's time endowment is normalized to one. There are also *two sectors*, producing a durable good (identified as new *housing*) and non-durable goods 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 the borrowers. The two types of households feature heterogeneous preferences, with the borrowers being *more impatient* than the savers, so that their marginal utility of consumption exceeds the marginal utility of saving.[12] Both borrowers and savers derive utility from consumption of the non-durable final good and from housing services.

[12]For previous examples of saver-borrower models, see Becker (1980), Becker and Foias (1987), Krusell and Smith (1993), Kiyotaki and Moore (1997).

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

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

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

$$Y_{j,t}(i) = \left( \frac{P_{j,t}(i)}{P_{j,t}} \right)^{-\varepsilon_j} Y_{j,t} \qquad j = c, d \tag{2}$$

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.[13]

## 4.2 Borrowers

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

$$X_t \equiv \left[ (1-\alpha)^{\frac{1}{\eta}} \, (C_t)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} \, (D_t)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{3}$$

where $C_t$ denotes (non-durable) consumption services, $D_t$ denotes housing services at the end of period t, $\alpha > 0$ is the share of housing services in the composite consumption index,

[13] 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 (1).

and $\eta > 0$ is the elasticity of substitution between consumption and housing services.[14]

The borrower maximizes the following utility program

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(X_t, N_t) \right\} \tag{4}$$

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

$$P_{c,t}\ C_t + P_{d,t}(D_t - (1-\delta)D_{t-1}) + R^m_{t-1} B_{t-1} = B_t + W_t N_t + T_t \tag{5}$$

where $B_t$ 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, $W_t$ is the nominal wage, $N_t$ is labor supply, and $T_t$ are net government transfers. Labor is assumed to be perfectly mobile across sectors, implying that the nominal wage rate is common across sectors.

In real terms (units of non-durable consumption), (5) reads

$$C_t + q_t(D_t - (1-\delta)D_{t-1}) + \frac{R^m_{t-1} b_{t-1}}{\pi_{c,t}} = b_t + \frac{W_t}{P_{c,t}} N_t + \frac{T_t}{P_{c,t}} \tag{6}$$

where $q_t \equiv \frac{P_{d,t}}{P_{c,t}}$ is the relative price of housing, and $b_t \equiv \frac{B_t}{P_{c,t}}$ 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 following specification of the utility function

$$U(X_t, N_t) = \log(X_t) - \frac{v}{1+\varphi} N_t^{1+\varphi}$$

where $\varphi$ is the inverse elasticity of labor supply and $v$ is a scale parameter.

**Variable vs. Fixed-Rate Contracts** The interest rate $R^m_t$ 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:

[14] 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 (3). The price index consistent with maximization of profits by this producer would read:

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

$$R_t^m = \left( \sum_{k=0}^{m-1} \tau^k \right)^{-1} \sum_{k=0}^{m-1} \tau^k E_t \left\{ R_{t+k} \right\} \tag{7}$$

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

In the case $m = 1$ the mortgage and policy rates 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 $\tau$. 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.[15]

**Collateral Constraint** Private borrowing is subject to a collateral constraint. We assume that the whole stock of debt is collateralized by the value of the *accumulated stock* of housing. By definition, if the collateral value depreciates at the same rate of physical depreciation $\delta$, we would write the accumulated equity value at time t as:

$$P_{d,t} D_t = \left[ \sum_{s=0}^{\infty} (1-\delta)^s (D_{t-s} - (1-\delta) D_{t-1-s}) \right] P_{d,t}$$

More generally, and as in Campbell and Hercowitz (2004), we allow for the collateral value to depreciate economically at a rate $\xi$ higher than physical depreciation, and therefore write the collateral constraint as:

$$\begin{aligned} B_t &\leq (1-\chi) \left[ \sum_{s=0}^{\infty} (1-\xi)^s (D_{t-s} - (1-\delta) D_{t-1-s}) \right] P_{d,t} \\ &= (1-\chi) P_{d,t} (D_t - (1-\delta) D_{t-1}) + (1-\xi) B_{t-1} \frac{P_{d,t}}{P_{d,t-1}} \end{aligned} \tag{8}$$

where $\chi$ is the fraction of the housing value that *cannot* be used as a collateral, and where $\xi \geq \delta$. A constraint of this kind can be justified on the basis of limited enforcement.[16] Since the borrower can run away with the assets in case of default, requiring a collateral ex-ante

[15] For a normative analysis see Campbell and Cocco (2003).

[16] Kiyotaki and Moore (1997).

acts against that temptation. One can think of parameters $\chi$ and $\xi$ as being determined by institutional factors prevailing in the credit market. For one, $\chi$ can be defined as the *down-payment* rate (or inverse $LTV$ ratio), and therefore represents a direct measure of the flexibility of the mortgage market (Jappelli and Pagano (1989)). As already discussed above, the value of $\chi$ may reflect legal and regulatory constraints changing across countries (see Table 1).

Parameter $\xi$ can be defined as the rate at which a good loses its value as collateral to the creditor. In the mortgage markets, $\xi$ may capture the effect of all those supply-side factors that influence the ability of households to refinance their existing mortgages or to use their housing wealth to release liquidity.[17] For instance, *lower* values of $\xi$ closer to $\delta$ – and hence a *better* performance of the housing stock as a collateral in a lending relationship – may reflect technological, industrial and structural developments in the banking sector that render *mortgage refinancing* easier and less costly, thereby lengthening debt repayment. Bennett et al. (2001) argue that the increase in the propensity to mortgage refinancing observed in the U.S. in the 1990s was due to a combination of technological, structural and regulatory changes that rendered mortgage markets more competitive and efficient, thereby lowering the transaction costs associated with refinancing. An example may be developments in the information and banking technology available to lending institutions in order to process information on the creditworthiness of borrowers or to manage the risks associated with their mortgage portfolios (e.g., through the securitisation of mortgage loans or the use of credit derivatives). In addition, the liberalisation and deregulation of mortgage markets, with the ensuing product innovation and increase in competitive pressures, may also lower the value of $\xi$. Muellbauer and Murphy (1997) analyse the house price boom of the late 1980s in the U.K. and note that financial liberalisation rendered illiquid assets more spendable and allowed households to increase their leverage ratios. Girouard and Blöndal (2001) and Debelle (2004) also describe the impact of financial liberalisation and deregulation on the easing of borrowing constraints in more recent episodes in various OECD countries.

We will distinguish *two* alternative scenarios for the calibration of $\xi$:

[17] 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, and Krainer and Masquis (2003) for a model of optimal refinancing of a fixed-rate mortgage depending on house prices and interest rates. We leave for future research the task of embedding an explicit refinancing choice into the model.

- $\xi = \delta$ (baseline). In this case, the rate of repayment coincides with the rate of economic depreciation of housing. This scenario is akin to one of *full* mortgage refinancing.

- $\xi > \delta$. In this scenario $\xi$ will assume alternative values depending on the typical average duration of the mortgage contract (see Table 1 and below for the parameterization).

Finally, notice that movements in real house prices affect the ability of borrowing. This assumption is consistent with the evidence that equity valuation effects have been important for the recent business cycle evolution in some OECD countries, in which the link between house price fluctuations and ability of borrowing has played a major role in supporting household consumption.[18]

Assuming that, in a neighborhood of the deterministic steady state, equation (5) is always satisfied with the *equality*, we can rewrite the collateral constraint in *real* terms (i.e., in units of consumption) as follows

$$b_t = (1-\chi)\ q_t(D_t - (1-\delta)D_{t-1})\ +\ (1-\xi)b_{t-1}\frac{q_t}{q_{t-1}} \tag{9}$$

Notice that, in this specification, both the *level* and the *rate of change* of $q_t$ affect the ability of borrowing.

Given $\{b_0,\ D_{-1}\}$ the borrower chooses $\{N_t,\ b_t,\ D_t,\ C_t\}$ to maximize (4) subject to (6) and (9). By defining $\lambda_t$ and $\lambda_t\psi_t$ as the multipliers on constraints (6) and (9) respectively, and $U_{i,t}$ as the marginal utility of variable $i$, efficiency conditions read:

$$\frac{-U_{n,t}}{U_{c,t}} = \frac{W_t}{P_{c,t}} \tag{10}$$

$$U_{c,t} = \lambda_t \tag{11}$$

$$U_{c,t}Z_t = U_{d,t}\ +\ \beta(1-\delta)E_t\left\{U_{c,t+1}Z_{t+1}\right\} \tag{12}$$

[18] On the other hand, we are not explicitly allowing for the presence of *home equity loans* (otherwise defined as home mortgage loans). These are typically secondary loans for which accumulated equity (defined as the difference between the value of the outstanding housing stock and the debt principal still due) is used as a collateral. Allowing for home equity loans would not qualitatively alter our results.

$$\psi_t = 1 - \beta E_t \left\{ \frac{U_{c,t+1}}{U_{c,t}} \frac{R_t^m}{\pi_{c,t+1}} \right\} + (1-\xi)\, \beta E_t \left\{ \frac{U_{c,t+1}}{U_{c,t}} \psi_{t+1} \frac{q_{t+1}}{q_t} \right\} \tag{13}$$

where

$$Z_t \equiv q_t \left[ 1 - (1-\chi)\psi_t \right]$$

can be defined as the "effective" relative price of housing. The latter depends directly on the real price of housing $q_t$, and inversely on the shadow value $\psi_t$ of relaxing the collateral constraint.

### 4.2.1 Interpretation

Equation (10) governs the consumption/leisure margin, while (11) equates the marginal utility of consumption to the shadow value of the flow budget constraint (5). Equation (12) 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 two components: (i) the direct utility gain of an additional unit of housing; and (ii) the expected utility stemming from the possibility of expanding future consumption by means of the realized resale value of a new unit of housing purchased in the previous period.

Equation (13) 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 $t$. The shadow value of relaxing the collateral constraint $\psi_t$ is tied to a payoff which has two components. The first is the *current* deviation from the standard Euler condition. When that component is positive the marginal utility of consumption exceeds the (expected) marginal utility of shifting consumption intertemporally. Hence the borrower has a marginal benefit from acquiring a unit of housing and purchase additional current consumption via a relaxation of the collateral constraint. The second term in (13) indicates that the shadow value of borrowing depends also on the ability of expanding *future* consumption, which is proportional to the rate at which the housing asset depreciates. The lower $\xi$, the larger the rate at which borrowers can expand private borrowing at each time $t$. In general, a unit of housing acquired in time $t$ allows to expand future borrowing (and consumption) at a rate $(1-\xi)^j$ in period $t+j$. In this respect, $\xi$ can be thought of capturing (exogenous) variations in the rate of mortgage refinancing.

**The Euler Gap** Integrating both (12) and (13) forward, and combining, we can express the margin between consumption and housing in more compact form as

$$U_{c,t}q_t = E_t\left\{\sum_{j=0}^{\infty}\left[\beta(1-\delta)\right]^j U_{d,t+j}\right\} + (1-\chi)U_{c,t}q_t\psi_t \quad (14)$$

$$= E_t\left\{\sum_{j=0}^{\infty}\left[\beta(1-\delta)\right]^j U_{d,t+j}\right\} + (1-\chi)E_t\left\{\sum_{j=0}^{\infty}\left[\beta(1-\xi)\right]^j q_{t+j}\Delta_{t+j}\right\} \quad (15)$$

where $\Delta_t \equiv U_{c,t} - \beta U_{c,t+1}\frac{R_t^m}{\pi_{c,t+1}}$ is a term summarizing the *deviation* from the Euler condition in any given time $t$. We label $\Delta_t$ the *Euler gap*. In (14), the marginal utility of consumption is equated to an alternative representation of the marginal utility of housing. The latter has two *dynamic* components. First, the current and expected future flow of utility of housing services. This term is standard in a framework with free borrowing. Second, the current and expected future benefits deriving from the possibility of expanding (current and future) consumption by means of increased borrowing. Indeed those benefits coincide with positive values of the Euler gap, which in turn reflect proportional variations in the tightness of the collateral constraint captured by the multiplier $\psi_t$. Notice that, in this interpretation, $(1-\chi)(1-\xi)^j$ is the *effective* rate at which the household can expand borrowing at any time $t+j$, with $j \geq 0$.

## 4.3 The Channels of Monetary Policy Transmission

In this environment the transmission of monetary policy shocks works primarily via *three* channels: (i) a *nominal-debt* channel, stemming from private debt being non-indexed and predetermined in nominal terms; (ii) a *collateral-constraint* channel, working via fluctuations in the shadow value of borrowing; and (iii) an *asset-price* channel, stemming from real house prices affecting the collateral value. It is important to emphasize that, conditional on monetary policy shocks, channel (i) and (ii) work independently of the presence of nominal price rigidity, although the strength of those channels can be affected by the degree of price stickiness.

**Nominal Debt Channel** With private debt being predetermined in nominal terms, fluctuations in current (non-durable) inflation affect the real ex-post cost of debt service.

This is clear from the borrower's budget constraint (6). This effect is akin to an *income* effect. For instance, a policy tightening, by rising the real cost of debt service, will induce the borrower to decrease spending in both consumption and housing.

**Collateral-Constraint Channel** Equilibrium fluctuations in the shadow value of borrowing $\psi_t$ are key to the transmission of policy shocks on consumption. To clarify this, notice that, because of durability, the term $\sum_{j=0}^{\infty} [\beta(1-\delta)]^j U_{d,t+j}$ in (14) can be thought of as being roughly *constant*. In fact, suppose $\delta$ were equal to 1 (i.e., no durability). In this case, variations in the shadow value of housing would be driven entirely by the *current* marginal utility of housing services. For values of $\delta$ sufficiently below 1, though, variations in the marginal utility of housing services in the distant future matter substantially for the current shadow value.[19] This argument applies a fortiori to our environment, given the extremely low rate of physical depreciation of housing.

The above consideration allows to rewrite (14) as:

$$U_{c,t} q_t \simeq const. + (1-\chi) E_t \left\{ \sum_{j=0}^{\infty} [\beta(1-\xi)]^j q_{t+j} \Delta_{t+j} \right\} \tag{16}$$

Variations in the present discounted value of the Euler gap are the specific feature characterizing the monetary transmission under a collateral constraint. Consider a monetary policy *contraction*, in the form of an interest rate hike. This induces a *tightening* of the collateral constraint via two channels: first, and regardless of price stickiness, via an effect of debt inflation (see above); second, but only in the presence of price stickiness, via a rise in the real interest rate. Formally, as a result, $\psi_t$ must *rise*, for the shadow value of relaxing the constraint is higher in the presence of a heightened service cost of debt. In this respect, $\psi_t$ bears the genuine interpretation of an *asset price.* From (13), in fact, a rise in the shadow value $\psi_t$ signals positive current and expected future variations in the Euler gap. Yet, in equation (16), a rise in the right-hand side implies that, for any given relative price $q_t$, the marginal utility of consumption $U_{c,t}$ must rise. Hence, in turn, consumption must *fall*.

This interpretation clarifies the role of the institutional parameters $\chi$ and $\xi$. For the borrower, the policy contraction amounts to a negative shock to real income. A rise in the shadow value $\psi_t$ signals exactly this effect. Recall that the borrower behaves in exactly

[19] See also Barsky et al. (2006).

the opposite way to a standard permanent-income consumer. In fact, the borrower would like to decrease (increase) borrowing in light of a negative (positive) income shock (whereas the permanent-income consumer would instead obey to consumption-smoothing). A lower (higher) down-payment rate $\chi$ and/or a lower repayment rate $\xi$, both representative of a "more (less) flexible" mortgage market, entail that a larger (smaller) variation in consumption is needed to satisfy (16) for any given variation in $\psi_t$ (i.e., for any given impact on the tightness of the collateral constraint). Intuitively, in times of negative (positive) shocks to real income, a more flexible mortgage market allows to decrease (increase) borrowing more rapidly, with this effect translating proportionally into a variation in consumption.

**Asset-Price Channel** Finally, movements in real house prices $q_t$ also affect the transmission of monetary policy shocks, by affecting the 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 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 real house prices, 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, the asset-price channel works by strengthening the impact of the collateral-constraint channel. In equation (16), 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 of the tightness of the collateral constraint represented by the right-hand side of (16).

## 4.4 Savers

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

$$E_0 \left\{ \sum_{t=0}^{\infty} \gamma^t U(\widetilde{C}_t, \widetilde{D}_t) \right\} \tag{17}$$

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

$$P_{c,t}\ \widetilde{C}_t + P_{d,t}(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1}) + R^m_{t-1}\widetilde{B}_{t-1} = \widetilde{B}_t + \widetilde{T}_t + \widetilde{\Gamma}_{j,t} \tag{18}$$

where $\widetilde{C}_t$ is saver's consumption, $\widetilde{D}_t$ is saver's housing services at the end of period t, $\widetilde{B}_t$ is nominal debt (credit) at the end-of-period t , $\widetilde{T}_t$ are net government transfers, and $\widetilde{\Gamma}_{j,t}$ are nominal profits from the holding of monopolistic competitive firms in sector $j$. We assume that the savers' labor supply is rigid. Given any initial distribution of wealth, in fact, the savers will end-up owning all financial assets in the steady state. This would insure a flow of financial income that would induce them, in equilibrium, to work only a small fraction of their time endowment. Quantitatively, then, their labor supply choice would impact very little on aggregate fluctuations.

Efficiency conditions for the saver's program read:

$$\widetilde{U}_{c,t} = \gamma E_t \left\{ \frac{\widetilde{U}_{c,t+1}}{\pi_{c,t+1}} R^m_t \right\} \tag{19}$$

$$q_t = \frac{\widetilde{U}_{d,t}}{\widetilde{U}_{c,t}} + \gamma(1-\delta) E_t \left\{ \frac{\widetilde{U}_{c,t+1}}{\widetilde{U}_{c,t}} q_{t+1} \right\} \tag{20}$$

## 4.5 Production and Pricing of Intermediate Goods

Intermediate-good firm $i$ in sector $j$ hires labor (supplied by the borrowers) to operate a linear production function:

$$Y_{j,t}(i) = \omega N_{j,t}(i) \tag{21}$$

where, for simplicity, labor productivity is assumed to be constant and normalized to 1 in both sectors. 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

$$\frac{\vartheta_j}{2} \left( \frac{P_{j,t}(i)}{P_{j,t-1}(i)} - 1 \right)^2 Y_{j,t} \tag{22}$$

where the parameter $\vartheta_j$ measures the degree of sectoral nominal price rigidity. The higher $\vartheta_j$, 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:

$$E_0 \left\{ \sum_{t=0}^{\infty} \Lambda_{j,t} \left( P_{j,t}(i) Y_{j,t}(i) - W_t N_{j,t}(i) - \frac{\vartheta_j}{2} \left( \frac{P_{j,t}(i)}{P_{j,t-1}(i)} - 1 \right)^2 P_{j,t} Y_{j,t} \right) \right\} \tag{23}$$

subject to (21). In (23), $\Lambda_{j,t} \equiv \gamma E_t \left\{ \frac{\widetilde{\lambda}_{t+1}}{\widetilde{\lambda}_t} \right\}$ is the saver's stochastic discount factor, and $\widetilde{\lambda}_t$ is the saver's marginal utility of nominal income. Let's denote by $\frac{P_{j,t}(i)}{P_{j,t}}$ the relative price of variety $i$ in sector $j$. In a *symmetric* equilibrium in which $\frac{P_{j,t}(i)}{P_{j,t}} = 1$ 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:

$$\begin{aligned} ((1-\varepsilon_j) + \varepsilon_j mc_{j,t}) &= \vartheta_j (\pi_{j,t} - 1) \pi_{j,t} \\ &\quad - \vartheta_j E_t \left\{ \frac{\Lambda_{j,t+1}}{\Lambda_{j,t}} \frac{P_{j,t+1}}{P_{j,t}} \frac{Y_{j,t+1}}{Y_{j,t}} (\pi_{j,t+1} - 1) \pi_{j,t+1} \right\} \qquad (j = c, d) \end{aligned} \tag{24}$$

where $\pi_{j,t} \equiv \frac{P_{j,t}}{P_{j,t-1}}$ is the gross inflation rate in sector $j$, and

$$mc_{j,t} \equiv \frac{W_t}{P_{j,t}} \tag{25}$$

is the real marginal cost in sector j.

In the particular case of *flexible prices,* the *sectoral* real marginal cost must be constant and equal to the inverse steady-state markup $\frac{\varepsilon_j - 1}{\varepsilon_j}$. By using (10), the pricing condition (24) reads:

$$\frac{-U_{n,t}}{U_{c,t}} = \frac{\varepsilon_c - 1}{\varepsilon_c} \qquad \text{if } j = c \tag{26}$$

$$\frac{-U_{n,t}}{U_{c,t}} q_t^{-1} = \frac{\varepsilon_d - 1}{\varepsilon_d} \qquad \text{if } j = d \tag{27}$$

## 4.6 Market clearing

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

$$Y_{c,t} = \omega C_t + (1-\omega)\widetilde{C}_t + \frac{\vartheta_c}{2}\left(\pi_{c,t} - 1\right)^2 \omega Y_{c,t} \tag{28}$$

$$Y_{d,t} = \omega\left(D_t - (1-\delta)D_{t-1}\right) + (1-\omega)\left(\widetilde{D}_t - (1-\delta)\widetilde{D}_{t-1}\right) \tag{29}$$

where

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

Equilibrium in the debt and labor market requires respectively

$$\omega B_t + (1-\omega)\widetilde{B}_t = 0 \tag{30}$$

$$\sum_j N_{j,t} = N_t \tag{31}$$

## 4.7 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:

$$\begin{aligned} \ln\left(\frac{R_t}{R}\right) &= (1-\phi_r)\phi_\pi \ln\left(\frac{\pi_{j,t}}{\overline{\pi}}\right) \\ &\quad +\phi_r \ln\left(\frac{R_{t-1}}{R}\right) + \varepsilon_t \end{aligned} \tag{32}$$

where $R_t$ is the short-term policy rate, and $\varepsilon_t$ is a policy shock evolving

$$\varepsilon_t = \exp(\varepsilon_{t-1})^\rho + u_t$$

with $u_t \tilde{} i.i.d.$.

### 4.8 Equilibrium

An (imperfectly) *competitive allocation,* with sticky prices in the non-durable sector, is a sequence for $N_t$, $N_{c,t}$, $N_{d,t}$, $b_t$, $D_t$, $C_t$, $\widetilde{C}_t$, $\pi_{c,t}$, $\pi_{d,t}$, $R_t$, $R_{m,t}$, $\psi_t$, $q_t$, $mc_t$ satisfying (6), (7), (9), (10)-(13), (19), (24), (28), (29), (31), (32).

## 5 Deterministic Steady State

In the deterministic steady state, as a result of heterogeneity in patience rates, the shadow value of relaxing the collateral constraint is always positive. This prevents the borrower from accumulating debt indefinitely (until labor income resources have been exhausted). The borrower will then always choose to hold a positive amount of debt. To show this we simply combine the steady-state version of (19), which implies $R = \frac{\pi_c}{\beta}$, with (13), obtaining:

$$\psi = \frac{1 - \frac{\beta}{\gamma}}{[1 - (1 - \xi)\beta]} > 0 \tag{33}$$

Notice that, to insure a well-defined steady state, both heterogeneity in patience rates *and* a borrowing limit are required. In fact, if discount rates were equal, the steady-state level of debt would be indeterminate (Becker (1980), Becker and Foias (1987)). In this case, in fact, it would hold $\frac{\beta}{\gamma} = \beta RR = 1$, and the economy would display a well-known problem of dependence of the steady state on the initial conditions.[20] With different discount rates, and yet still free borrowing, the consumption path of the borrower would be tilted downward, and the ratio of consumption to income would asymptotically shrink to zero.[21] Hence a binding collateral constraint allows a constant consumption path to be compatible with heterogeneity in discount rates.

In a flexible-price steady state for both sectors, taking the ratio of (26) and (27) the relative price of housing reads

$$q = \frac{\frac{\varepsilon_d - 1}{\varepsilon_d}}{\frac{\varepsilon_c - 1}{\varepsilon_c}} \equiv \overline{q} \tag{34}$$

[20] In other words, under $\beta = \gamma$, the economy would constantly replicate the initial (arbitrary) distribution of wealth forever.

[21] In this case the assumption $\beta < \gamma$ is equivalent to $\beta RR < 1$. In the absence of exogenous growth, this implies that the (gross) growth rate of consumption ($\beta RR$) is below the (gross) growth rate of income (which is 1). Hence, the ratio of consumption to output must shrink over time.

By evaluating (12) in the steady state we obtain the borrower's ratio between the stock of housing and consumption

$$\frac{D}{C} = \frac{\alpha}{1-\alpha}\left[Z\ \ (1-\beta(1-\delta))\right]^{-\eta} \equiv \overline{\left(\frac{D}{C}\right)} \tag{35}$$

which is decreasing in the effective relative price of housing $Z \equiv \overline{q}\left(1 - \frac{(1-\chi)\left(1-\frac{\beta}{\gamma}\right)}{[1-(1-\xi)\beta]}\right)$.

The borrower's steady-state leverage ratio reads:

$$\frac{b}{D} = \frac{(1-\chi)\,\delta}{1-(1-\xi)} \tag{36}$$

Notice that both a lower down-payment rate $\chi$ and a lower repayment rate $\xi$ increase the borrower's leverage ratio.

To pin down the level of debt we proceed as follows. We set parameter $v$ in order to pin down a certain level of hours worked in steady state ($N = \overline{N}$). By combining (6), (9) and (36) we can write:

$$D = \frac{\overline{N}^{\ \frac{\varepsilon_c - 1}{\varepsilon_c}}}{\Omega} \tag{37}$$

where $\Omega \equiv \overline{\left(\frac{C}{D}\right)} + \delta\left(q + \frac{(1-\gamma)(1-\chi)}{\gamma\xi}\right)$.

Once obtained $D$ from (37), using (36), one can solve for the unique steady-state level of borrower's debt

$$b = \frac{(1-\chi)\,\overline{N}}{1-(1-\xi)\mu^c\Omega} \equiv \overline{b} \tag{38}$$

It is easy to show that, under the assumption $\beta < \gamma$, the steady-state level of debt $\overline{b}$ is stable, i.e., the economy will converge to $\overline{b}$ starting from any initial value different from $\overline{b}$.

# 6 Institutional Factors and Sensitivity to Policy Shocks

In this section we evaluate how the transmission of monetary policy shocks is affected by three key institutional features:

- down-payment rate $\chi$

- repayment rate $\xi$
- 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 $\gamma = 0.99 > \beta = 0.96$. This value is in the range between values respectively chosen by Krusell and Smith (1998) and estimated by Iacoviello (2005). 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 7.5, which yields a steady-state mark-up of 15%. We assume throughout that house prices are *flexible*[22] while we set the stickiness parameter for consumer prices equal to a benchmark value of $\vartheta_c = 76$. To pin down this value we proceed as follows. Let $\theta$ be the probability of not resetting prices in the standard Calvo-Yun model. We parameterize $\frac{1}{1-\theta} = 4$, 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 (24) around a zero-inflation steady state (in the consumption sector) yields a slope of the Phillips curve equal to $\frac{\varepsilon_c - 1}{\vartheta_c}$. Setting the elasticity $\varepsilon$ equal to 7.5, which implies a steady-state markup of 15 percent, the resulting stickiness parameter satisfies $\vartheta_c = \frac{\theta(\varepsilon-1)}{(1-\theta)(1-\beta\theta)} = 20$.

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 $\alpha$ 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 U.S., although statistical methodologies differ substantially. We choose to pick an intermediate value of $\alpha = 16\%$.

[22] Our results do not hinge critically on the assumed relative degree of stickiness between house and consumption prices. See Monacelli (2006) for an analysis on this point. At the same time, the assumption that house prices are more flexible than consumption prices seems reasonable. For one, house prices tend to incorporate an asset-price behavior. In addition, as argued in Barsky et al. (2006), house prices, unlike consumption prices, are largely subject to negotiation upon transactions. Even the common perception that house prices are sticky downward is probably misguided.

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. Below, however, we experiment with alternative values of this parameter.

As to the repayment rate $\xi$, in the baseline scenario we set $\xi = \delta$, and interpret this case as the one of full mortgage refinancing. Alternatively we link the quarterly repayment rate to the average duration of the loan. Table 1 shows that, within the European countries, the average duration ranges between 15 and 30 years. In the table below we summarize how the value of $\xi$ changes depending on the specified loan duration[23]:

| *Mortgage duration* | *Quarterly repayment rate* $\xi$ |
|---|---|
| 30 $yrs$ | 0.0083 |
| 20 $yrs$ | 0.0125 |
| 15 $yrs$ | 0.0166 |
| 10 $yrs$ | 0.025 |

Below we describe the effects on the transmission of policy shocks of varying, alternatively, the institutional parameters $\chi$ and $\xi$, and of varying the interest rate mortgage structure. Throughout we assume that (i) durable prices are *flexible; (ii)* the elasticity of substitution $\eta$ 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]

We assume that the monetary policy innovation is a purely *i.i.d.* shock to the policy rule (32). The temporary nature of the shock helps to highlight how the transmission mechanism built in the model contributes to generate an effect of endogenous persistence in response to policy impulses.

## 6.2 Varying the Down-Payment Rate

Figure 5 depicts the effect on selected (per capita) variables of a 25 basis points rise in the nominal (policy) interest rate for alternative values of the *down-payment rate* $\chi$. In order to isolate the role of down-payment we assume full mortgage refinancing, i.e., $\xi = \delta$, and a variable interest-rate mortgage structure.

We consider two variants to the baseline calibration: (i) a *low* down-payment rate $\chi = 0.15$, similar to the level prevailing for example in Spain, and (ii) a *high* down-payment

[23] For instance, the quarterly repayment rate for a 30-year loan is computed as $\frac{100}{120} = 0.83\%$.

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

rate $\chi = 0.5$, close to the situation in Italy (see Table 1). Most of the countries in our sample are comprised within this range for $\chi$.

Notice, first, that the monetary policy tightening induces a rise in the shadow value of borrowing $\psi_t$. This signals a rise in current and expected future values of the Euler gap (see equation (16)), which in turn induce a contractionary effect on borrrower'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 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 falls, it is useful to notice that a policy tightening increases the *user cost* of housing. The relevant user cost for housing can be written, from (12), as:

$$usc_t \equiv Z_t - \beta(1-\delta)E_t\left\{\frac{U_{c,t+1}}{U_{c,t}}Z_{t+1}\right\} \tag{39}$$

Thus the user cost depends positively on the current effective relative price of housing and inversely on the future price. (Intuitively, expected capital gains on the holding of housing decrease the current user cost.) In turn, under a collateral constraint, the effective price of housing $Z_t$ depends on the shadow value of borrowing $\psi_t$. Figure 5 makes clear that fluctuations in the shadow value of borrowing (and therefore in the Euler gap) overwhelmingly drive the user cost. As a result, a policy tightening induces a rise in the user cost and a fall in the relative demand for housing services.

A *smaller* down-payment rate $\chi$ leads to a *more pronounced* impact effect of the monetary policy shock on consumption, real debt and the relative price of durables $q$. As suggested above, the monetary tightening amounts to a negative shock to real income. In light of that, the borrower would like to *decrease* borrowing and therefore consumption. A lower down-payment $\chi$ increases the effective rate at which the impatient agent can contract borrowing between any two periods in time. A more rapid contraction of borrowing leads to a more rapid contraction of both housing services and consumption. In addition, a lower down-payment rate increases, all else equal, the sensitivity of borrowing to changes in the value of the collateral, leading to a magnification of both the nominal debt channel and the

collateral-constraint channel.

**Aggregate Responses** Figure 6 illustrates the effects of the same policy shock on *aggregate* consumption for alternative values of the down-payment rate. We define aggregate consumption as[25]:

$$\mathcal{C}_t \equiv \omega C_t + (1-\omega)\widetilde{C}_t \tag{40}$$

Aggregation requires first an understanding of the *savers'* consumption responses to the policy shock. 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 observed to move only slightly (and to fall in particular, not shown). At the same time, since the relative price of durables falls, the savers increase their demand for housing services. For these agents, in 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 relative price $q_t$ (and not on $\psi_t$). Overall, we observe that the model exhibits aggregation properties in line with our empirical evidence. Aggregate consumption falls in response to the shock, with the impact response of consumption being magnified for lower values of the down-payment rate $\chi$.

**Persistence** Notice that the effect on consumption extends beyond the duration of the policy shock (which is i.i.d.). This effect of persistence depends on the form of the collateral

[25]The choice of the share of borrowers $\omega$ is irrelevant for the computation of *aggregate* (consumption) responses. In fact, it is easy to show that the set of equilibrium conditions expressed in terms of *aggregate* variables differs from the one expressed in *per-capita* terms only up to a constant (and featured in the condition equating the marginal rate of substitution between consumption and leisure to the real wage). In practice, when log-linearizing equation (40), the steady-state share of consumption of the two groups will adjust with $\omega$ accordingly to keep the aggregate response unchanged. Alternatively, one can have $\omega$ to matter by normalizing consumption of borrowers and savers to be the same across categories of groups (as in Galí et al. (2006)). This strategy may be justified when the exercise (indeed as here) focuses on the short-run dynamic responses to shocks in the neighborhood of the steady state. An equalization of the consumption levels across groups can be achieved by an appropriate calibration of lump-sum transfers in the steady state. Quantitatively, however, the results for aggregate consumption are only little affected by the choice of the aggregation strategy.

constraint, namely on the ability of borrowing being linked to an asset with high durability. In turn, the persistence depends on the value of $\delta$, and obviously tends to vanish for values of $\delta \rightarrow 1$. Intuitively, when real income falls (rises) because of an increase (decrease) in real interest rates, the borrower optimally wishes to decrease (increase) real debt. But this requires depleting (increasing) the stock of housing. Since housing durability implies that the flow-stock ratio is low, it takes time to change the stock of housing, and therefore the demand for debt changes only gradually over time. In turn, this is reflected in a gradual effect on consumption.

**Shutting Down Stickiness: Decomposing the Channels** Next we evaluate the role of price stickiness. We compare the response of aggregate consumption under three scenarios: (i) *flexible* consumer prices; (ii) *low* stickiness and (iii) *baseline* stickiness. The first scenario, coupled with our maintained assumption that house prices are flexible, entails that prices are fully flexible in both sectors. In the second scenario, the frequency of price adjustment is less than one quarter, in line with the empirical micro-based evidence of Bils and Klenow (2004) for the U.S.. In the third scenario, the frequency of price adjustment is at our baseline value of four quarters (considered realistic for the EA countries based on the micro-based evidence discussed in Angeloni et al. (2006)). Notice that the flexible-price scenario corresponds to a shutting-down of the asset price channel, since the relative price of housing will remain constant in response to a monetary policy variation, and hence will not affect the value of the collateral. As already argued above, though, abstracting from price stickiness in consumption prices alters also the strength of both the nominal-debt channel and of the collateral constraint channel.

Figure 7 depicts the effects on *aggregate* consumption of a 25 basis points increase in the nominal interest rate under alternative degrees of consumer price stickiness. Moving from the baseline case of four-quarter stickiness to the one of fully flexible prices substantially reduces the effect on consumption. On the other hand, though, the experiment shows that price stickiness is not a strictly necessary ingredient to the transmission mechanism of monetary policy shocks. Overall, under flexible prices, and conditional on our parameterization, we find that a 1% rise in the policy rate reduces aggregate consumption on impact by 0.8%. The residual impact on consumption under flexible prices is still sizeable and is due to the combination of the nominal-debt effect and of the collateral-constraint effect.

## 6.3 Varying the Repayment Rate

Figure 8 depicts the response of aggregate consumption to a temporary (i.i.d.) 25 basis-point rise in the nominal policy rate under alternative values of the repayment rate $\xi$. We do not report per-capita responses of selected variables because the picture is qualitatively similar to the one obtained above under alternative values for $\chi$.

The values chosen for $\xi$ are the ones reported earlier, which correspond to alternative durations of the underlying mortgage contract. The baseline case, labelled *full refinancing,* corresponds to $\xi = \delta$. We think of this as a limit case in which continuous mortgage refinancing allows to make the rate of housing "economic" depreciation coincide with the physical rate of depreciation. Hence, implicitly, values of $\xi$ higher than $\delta$ can be thought of as capturing a reduced ability to refinance the mortgage. Notice that the effect of varying the repayment rate is qualitatively similar to the one of changing the down-payment rate, i.e., the peak response of consumption is magnified by lowering $\xi$. In fact, a lower $\xi$ rises the effective rate $(1-\chi)(1-\xi)^j$ at which the impatient agent can expand borrowing in any future period $t+j$. The latter point explains also why varying the repayment rate $\xi$ affects not only the impact response of consumption, but also its persistence, with a lower $\xi$ generating a more persistent decline of consumption below baseline.

## 6.4 Varying the Interest-Rate Mortgage Structure

Figure 9 displays the effect of varying the interest-rate mortgage structure (which, in practice, corresponds to the degree of interest rate pass-through). We analyze three 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 (7)). The second case considers an intermediate possibility in which the mortgage interest rate is linked to a return on a ten-year bond ($m = 40$, see equation (7)). The third case is a limit case of *fixed-rate* mortgage structure. This is obtained by considering the variant of the term structure equation (7) for $\tau \to 1$, with maturity $m$ extending to a 30-year period.

A fixed-rate mortgage structure significantly dampens the dynamic effect on consumption relative to a case of flexible-rate structure. Notice, however, that 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 durables, 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 institutional characteristics of mortgage markets for the transmission of monetary policy on house prices and consumption in a sample of OECD countries. We have provided evidence in support of three facts: first, there is significant divergence in the structure of mortgage markets across the main industrialised countries; second, at the business cycle frequency, the correlation between consumption and house prices increases with the degree of flexibility/development of mortgage markets; third, the transmission of monetary policy shocks on consumption and house prices is stronger in countries with more flexible/developed mortgage markets.

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 analysed how the response of consumption to monetary policy shocks is affected by alternative values of three important institutional parameters of mortgage markets: (i) the down-payment rate; (ii) the mortgage-repayment rate (a proxy for the possibility of mortgage refinancing); (iii) interest-rate mortgage structure (variable vs. fixed interest rate). Consistent with our empirical evidence, the sensitivity of consumption to monetary policy shocks increases with lower values of the down-payment rate and of the mortgage repayment rate, and is larger under a variable-rate mortgage structure. Thus the model can rationalize the evidence that private consumption is more responsive to monetary impulses in economies with more developed/flexible mortgage markets, somewhat in contrast with the presumption that developed mortgage 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 work. First, providing a full estimation of the model.[26] Second, introducing an endogenous choice by the households between variable and

[26] Iacoviello and Neri (2006) is an interesting step in this direction.

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.

# References


[1] **Ahearne, A. G., Ammer, J., Doyle, B. M., Kole, L. S. and F. M. Martin** (2005) "House prices and monetary policy: A cross-country study", Board of Governors of the Federal Reserve System International Financial Discussion Papers n. 841.

[2] **Alvarez, L. J., Dhyne, E., Hoeberichts, M. M., Kwapil, C., Le Bihan, H., Lünnemann, P., Martins, F., Sabbatini, R., Stahl, H., Vermeulen, P. and J. Vilmunen** (2005): "Sticky prices in the euro area: a summary of new micro evidence", ECB Working Paper 563, forthcoming in Journal of the European Economic Association.

[3] **Angeloni, I., Kashyap, A. K., Mojon, B. and D. Terlizzese** (2004): "The output composition puzzle: a difference in the monetary transmission mechanism in the euro area and the U.S.", *J*ournal of Money, Credit and Banking, 35(6, Part 2), 1265-1306.

[4] **Angeloni I., L. Aucremanne, M. Ehrmann, J. Galí, A. Levin, F. Smets** (2006), "New Evidence on Inflation Persistence and Price Stickiness in the Euro Area: Implications for Macro Modelling", Journal of the European Economic Association, 4 (2-3), 562-574.

[5] **Aoki, K., Proudman, J. and G. Vlieghe** (2004): "House prices, consumption and monetary policy: a financial accelerator approach", Journal of Financial Intermediation, 13(4), 414-435.

[6] **Barsky, R., House, C. and M. Kimball** (2006): "Sticky-price models and durable goods", NBER Working Paper # 9832.

[7] **Becker, R. A**. (1980): "On the long-run steady state in a simple dynamic model of equilibrium with heterogeneous households", Quarterly Journal of Economics, 95(2), 375-82.

[8] **Becker, R. A. and C. Foias** (1987): "A characterization of Ramsey equilibrium", Journal of Economic Theory, 41(1), 173-184.

[9] **Bennett, P., Peach, R. and S. Peristiani** (2001): "Structural change in the mortgage market and the propensity to refinance", Journal of Money, Credit and Banking, 33(4), 955-975.

[10] **Bils, P and M. Klenow** (2004): "Some evidence on the importance of sticky prices", Journal of Political Economy, 112(5), 947-985.

[11] **BIS** (1995): "Financial Structure and the Monetary Policy Transmission Mechanism", C.B. 394.

[12] **BIS** (2004): "International banking and financial market developments", BIS Quarterly Review, March 2004.

[13] **Borio, C**. (1996): "Credit characteristics and the monetary policy transmission in fourteen industrial countries: Facts, conjectures and some econometric evidence", in Alders, K. et al. (Eds.) *Monetary Policy in a Converging Europe*, Dordrecht/Boston/London: Kluwer Academic Publishers, 77-115.

[14] **Campbell, J. R. and Z. Hercowitz** (2004): "The role of households' collateralized debts in macroeconomic stabilization", Federal Reserve Bank of Chicago, working paper n. 2004-24.

[15] **Campbell, J. Y. and J. F. Cocco** (2003): "Household risk management and optimal mortgage choice", Quarterly Journal of Economics, 118 (May), 1149-1194.

[16] **Catte, P., Girouard, N., Price, R. and C. Andre** (2004): "Housing markets, wealth and the business cycle", OECD Economics department Working Paper n. 394.

[17] **Davies, M. A. and J. Heathcote** (2005): "Housing and the business cycle", International Economic Review, 46(3), 751-784.

[18] **Debelle, G**. (2004): "Macroeconomic implications of rising household debt", BIS working paper n. 153.

[19] **ECB** (2003): *Structural factors in the EU housing markets*, Frankfurt: ECB, March.

[20] **European Commission** (2005): "Green paper on mortgage credit in the EU", COM(2005) 327.

[21] **Galí, J., López-Salido, J. D. and J. Vallés** (2006): "Understanding the effects of government spending on consumption", forthcoming in Journal of the European Economic Association.

[22] **Girouard, N. and S. Blöndal** (2001): "House prices and economic activity", OECD Economics department Working Paper n. 279.

[23] **Giuliodori, M**. (2004): "Monetary policy shocks and the role of house prices across European countries", DNB working paper n. 15/04.

[24] **Iacoviello, M**. (2004): "Consumption, house prices and collateral constraints: a structural econometric analysis", Journal of Housing Economics, 13(4), 305-321.

[25] **Iacoviello, M.** (2005): "House prices, collateral constraints and monetary policy in the business cycle", American Economic Review, 95(3), 739–764.

[26] **Iacoviello M. and S. Neri** (2006), "The Role of Housing Collateral in an Estimated Two-Sector Model of the U.S. Economy", Mimeo.

[27] **IMF** (2005): "Household balance sheets", Global Financial Stability Report, Chapter III, April 2005.

[28] **Jappelli, T and M. Pagano** (1989): "Consumption and capital market imperfections: An international comparison", American Economic Review, 79(5), 1088–1105.

[29] **Kiyotaki, N. and J. Moore** (1997): "Credit cycles", Journal of Political Economy, 105(2), 211-248.

[30] **Krainer, J. and M. Marquis** (2003): "Mortgages as Recursive Contracts", Federal Reserve Bank of San Francisco 2003-03.

[31] **Krusell, P. and A. Smith** (1998): "Income and Wealth Heterogeneity in the Macroeconomy", Journal of Political Economy, 106(5), 867-96.

[32] **Leung, C**. (2004): "Macroeconomics and housing: a review of the literature", Journal of Housing Economics, 13, 249-267.

[33] **MacLennan, D., Muellbauer, J. and M. Stephens** (1998): "Asymmetries in housing and financial market institutions and EMU", Oxford Review of Economic Policy 14(3), 54-80.

[34] **Mercer Oliver Wyman** (2003): *Study on the Integration of European Mortgage Markets*, European Mortgage Federation: Bruxelles.

[35] **Mojon, B. and G. Peersman** (2003): "A VAR description of the effects of monetary policy in the individual countries of the euro area", in Angeloni, I. Kashyap, A. and B Mojon (Eds.), *Monetary Policy Transmission in the Euro Area*, Cambridge: Cambridge University Press, Chap.3, 56-74.

[36] **Monacelli T.**, (2006), "New Keynesian Models, Durable Goods, and Collateral Constraints", unpublished, Igier-Bocconi.

[37] **Muellbauer, J. and A. Murphy** (1997): "Booms and busts in the U.K. housing market", Economic Journal 107(November), 1701-1727.

[38] **Terrones, M. and C. Otrok** (2004): "The global house price boom", IMF World Economic Outlook September 2004.

[39] **The Economist** (2003): "Survey: Property", 29 May 2003.

[40] **Tsatsaronis, K. and H. Zhu** (2004): "What drives housing price dynamics: cross-country evidence", BIS Quarterly Review, March.

## TABLE 1. Institutional Characteristics of National Mortgage Systems

| Country | Mortgage debt to GDP ratio (2004) | Home ownership ratio [a] | Loan to value ratio [b] | Interest rate adjustment [c] | Typical duration (years) | Equity release products |
|---|---|---|---|---|---|---|
| BE | 31% | 72% | 80-85% | F(75%)<br>M(19%)<br>V(6%) | 20 | No |
| DE | 52% | 39% | ≈70% | Mainly F and M | ≤30 | Not used |
| DK | 67 | 59 | 80 | F (75%)<br>M (10%)<br>V (15%) | 30 | Used |
| GR | 21% | 80% | 70-80% | F(5%)<br>M(15%)<br>V(80%) | 15-20 | Very limited use |
| ES | 46% | 85% | ≈80% | V(≥75%)<br>Rest mainly M | 15-25 | Very limited use |
| FR | 26% | 58% | 80% | F/M/Other(86%)<br>V(14%) | 15 | Not used |
| IE | 53% | 78% | 60-70% | V(70%)<br>Rest mostly M | 20 | Limited use |
| IT | 15% | 69% | 50% | F(28%)<br>Rest mainly M | 10-25 | Not used |
| LU | 34% | 67% | ≤80% | V(90%) | 20-25 | Not used |
| NL | 111% | 53% | 112% | F(74%)<br>M(19%)<br>V(7%) | 10 | Used |
| AT | 20% | 56% | 60% | F(75%)<br>V(25%) | 20-30 | N.A. |
| PT | 53% | 64% | 70-80% | Mainly V | 25-30 | Not used |
| FI | 38% | 64% | 75-80% | F(2%)<br>V(97%)<br>Other(1%) | 15-20 | Used |
| AU | 74% | 70% | 90-100% | Mainly V | 25 | Used |
| CA | 43% | 66% | 70-80% | F and M(92%)<br>V(8%) | 25 | Limited use |
| UK | 73% | 70% | 70% | M(28%)<br>V(72%) | 25 | Used |
| US | 69% | 69% | 80% | F(85%)<br>M(15%) | 30 | Used |
| JP | 36% | 61% | 80% | F(36%)<br>M and V(64%) | 25-30 | Limited use |

*Notes: a Share of owner-occupied dwelling.*
*b Estimated average loan-to-value ratio on new mortgage loans.*
*c 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.*
*Sources: Ahearne et al. (2005), Borio (1996), Catte et al. (2004), Debelle (2004), ECB (2003), European Mortgage Federation, Girouard and Blöndal (2001), IMF (2004), Tsatsaronis and Zhu (2004).*

**TABLE 2. House Price Data**

| *Country* | *Source and definition* | *Availability* |
|---|---|---|
| Germany | Deutsche Bundesbank: Residential property prices, new and existing dwellings; good & poor condition; West Germany (until 1994), whole country (from 1995) | West Germany: annual data from 1980 to 1994.<br>Germany: annual data from 1995 |
| Spain | Banco de España and Bank of England: Residential property price per square meter, whole country | Annual data from 1980 to 1986<br>Quarterly data from 1987 Q1 |
| France | Ministry of Equipment/ECLN and Bank of England: Residential property prices, new flats; good & poor condition; whole country | Annual data from 1980 to 1984<br>Quarterly data from 1985 Q1 |
| Italy | Banca d'Italia: Residential property prices, new dwellings; good & poor condition; whole country | Semiannual data from 1965 H1 |
| The Netherlands | DNB: Residential property prices, existing dwellings; good & poor condition; whole country | Monthly data from January 1976 |
| Austria | ECB: Residential property prices, new and existing dwellings; good & poor condition; whole country | Quarterly data from 1986 Q3 |
| Belgium | STADIM: Residential property prices, existing dwellings; good & poor condition; whole country | Quarterly data from 1981 Q1 |
| Denmark | NSI: New and existing one-family houses; whole country | Quarterly data from 1971 Q1 |
| Canada | BIS: residential property prices, existing dwellings, national average | Monthly data from January 1980 |
| United Kingdom | ONS: Residential property prices, new and existing dwellings; good & poor condition; whole country | Quarterly data from 1968 Q2 |
| United States | BIS: residential property prices, existing single-family homes, per dwelling | Quarterly data from 1975 Q1 |

Note: Lower-frequency data have been converted to quarterly frequency by linear interpolation.

**TABLE 3. Correlation between the Real House Price and Consumption**

| Country | Correlation coefficient |
|---|---|
| United Kingdom | 0.79 |
| Spain | 0.66 |
| Denmark | 0.57 |
| Canada | 0.52 |
| United States | 0.52 |
| France | 0.45 |
| Netherlands | 0.4 |
| Austria | 0.23 |
| Belgium | 0.15 |
| Germany | 0.12 |
| Italy | 0.05 |

**TABLE 4. Correlation between Real House Price and Consumption**

| Institutional feature | Correlation coefficient |
|---|---|
| *Mortgage refinancing* | |
| No | 0.31 |
| Yes | 0.57 |
| *Interest rate structure* | |
| *Fixed* interest rate | 0.37 |
| *Variable* interest rate | 0.5 |

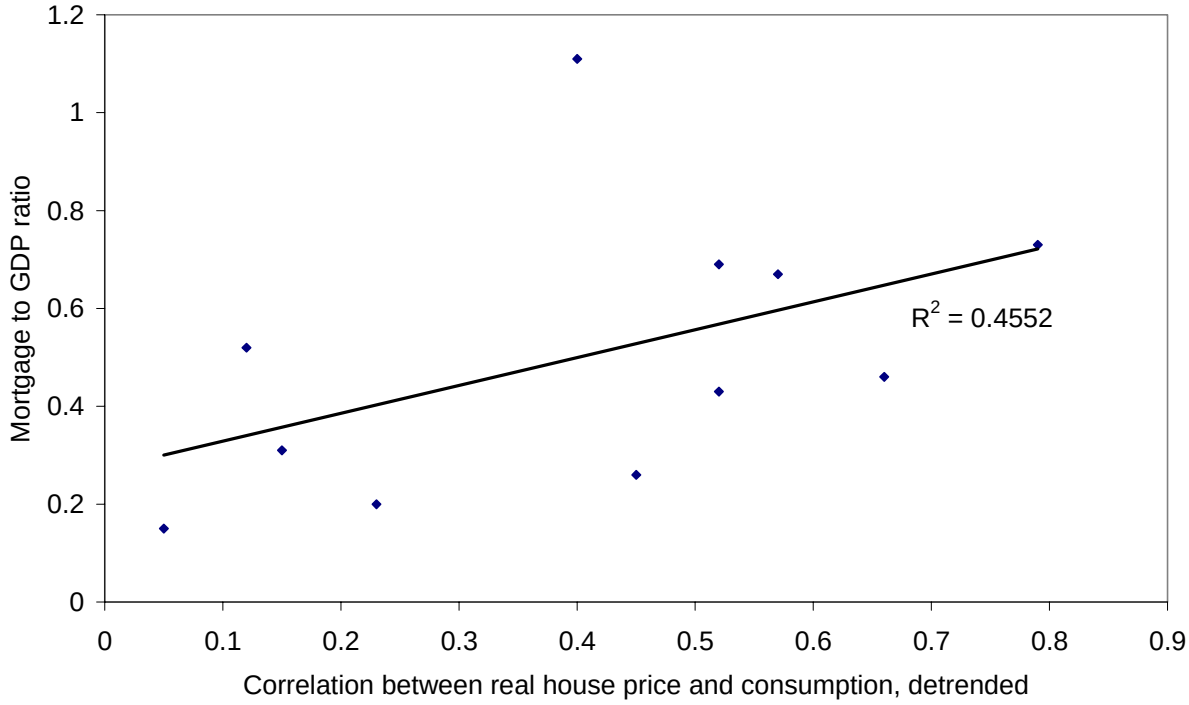
Notes: Quarterly data from 1980:1 to 2004:4. The real house price is deflated using the CPI. Consumption corresponds to total private consumption. Data are de-trended using the HP1600 filter. Countries where mortgage refinancing is practiced are the US, UK, the Netherlands and Denmark; it is not practiced in Canada, France, Germany, Spain, Italy, Austria and Belgium. Countries with predominantly variable rate mortgages are the UK, Spain and Italy; fixed rate mortgages are more common in the remaining countries.

**TABLE 5. Cross-country Average Absolute Response of Consumption to a Contractionary Monetary Policy Shock of 100 basis points**

| *Average response of* ***consumption*** | | *Average response of the* ***real house price*** | |
|---|---|---|---|
| Fixed interest rate | 0.19 | Fixed interest rate | 0.64 |
| Variable interest rate | 0.42 | Variable interest rate | 1.61 |
| Mortgage refinancing | 0.56 | Mortgage refinancing | 1.82 |
| No mortgage refinancing | 0.08 | No mortgage refinancing | 0.38 |

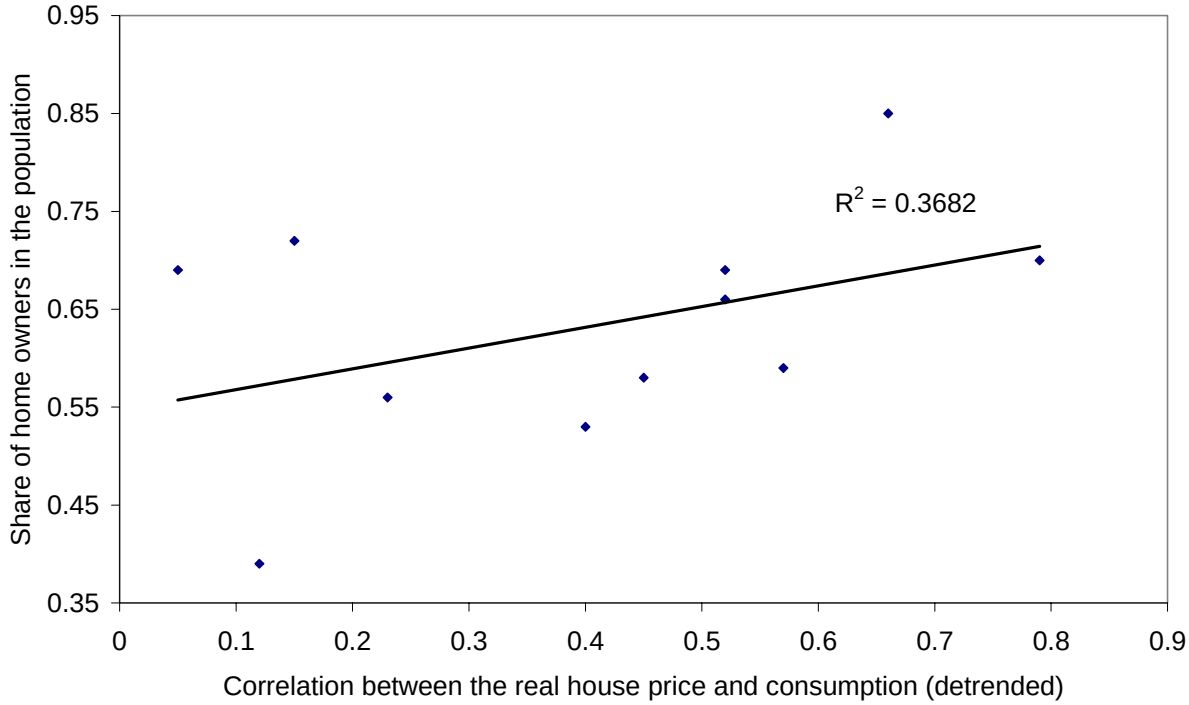
Note: Results are based on the VAR model estimated on quarterly data over the sample period 1980:1 to 2004:4. See text for further explanations. Countries where mortgage refinancing is practiced are the US, UK, the Netherlands and Denmark; it is not practiced in Canada, France, Germany, Spain, Italy, Austria and Belgium. Countries with predominantly variable rate mortgages are the UK, Spain and Italy; fixed rate mortgages are more common in the remaining countries.

**FIGURE 1a. Correlation between Private Consumption and Real House Price and Mortgage-to-GDP Ratio**



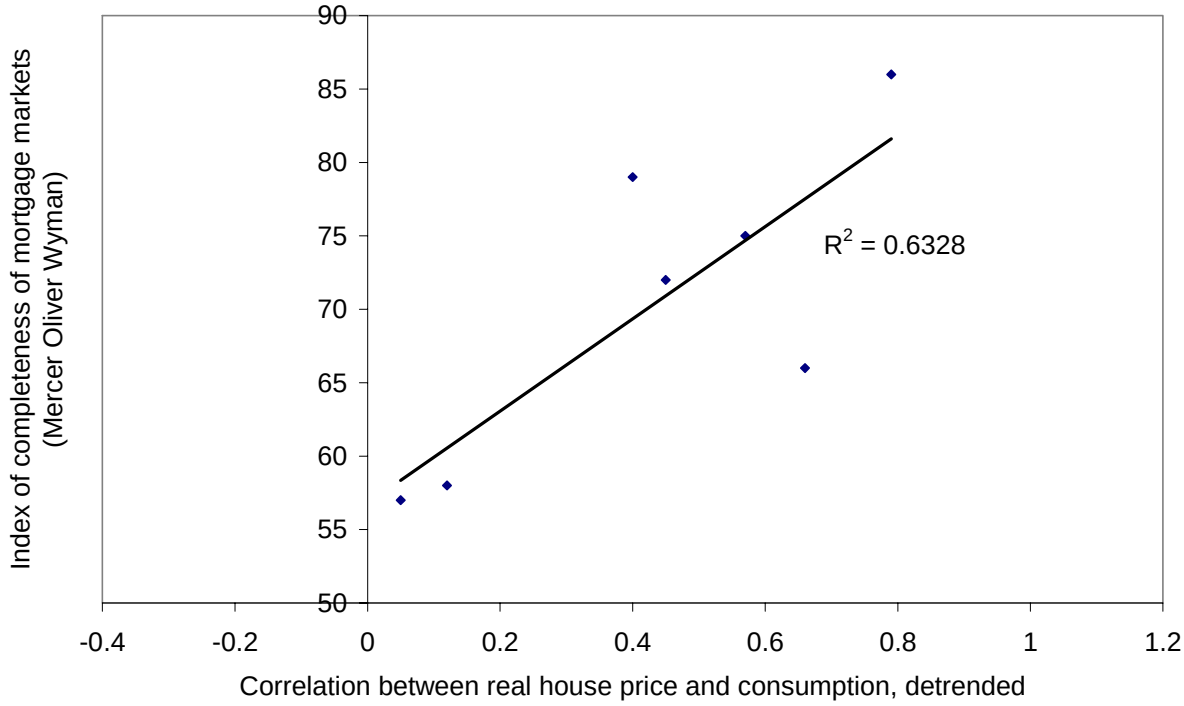

Sample period: Quarterly data from 1980:1 to 2004:4. The real house price is deflated using the CPI. Data are de-trended using the HP1600 filter.

**FIGURE 1b. Correlation between Private Consumption and Real House Price and Home Ownership Ratio**



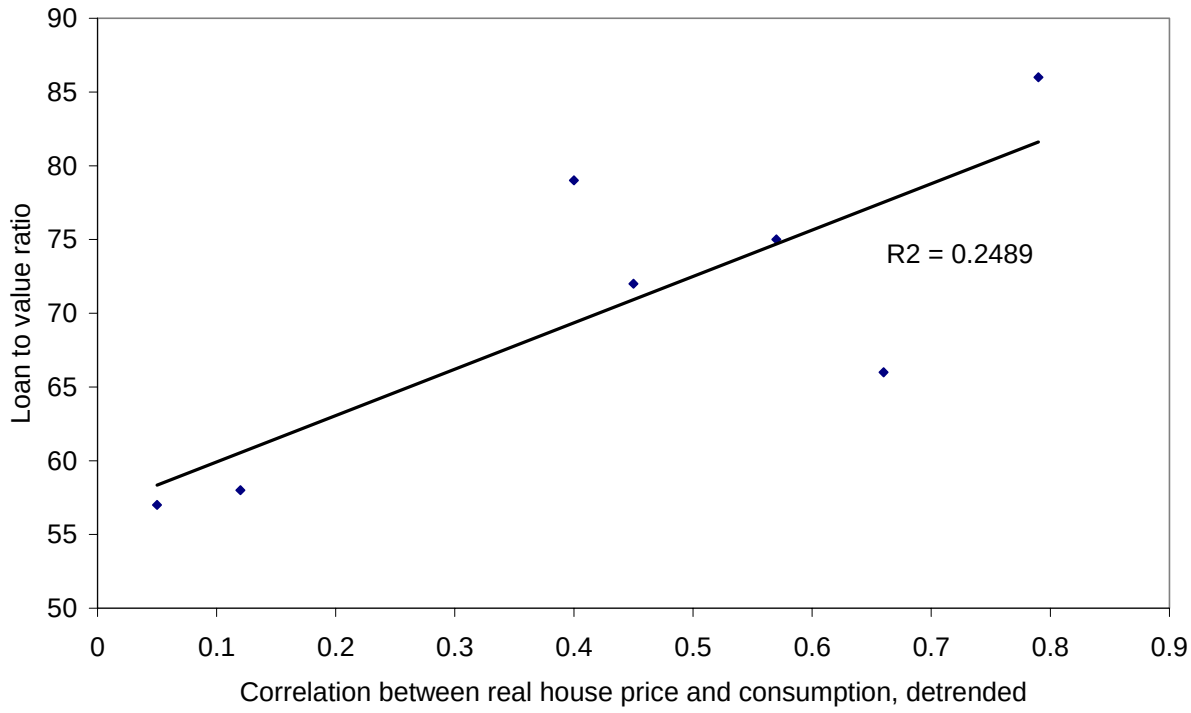

Sample period: Quarterly data from 1980:1 to 2004:4. The real house price is deflated using the CPI. Data are de-trended using the HP1600 filter.

**FIGURE 1c. Correlation between Private Consumption and Real House Price and MOW Completeness Index**




Sample period: Quarterly data from 1980:1 to 2004:4. The real house price is deflated using the CPI. Data are de-trended using the HP1600 filter. Note: the Mercer Oliver Wyman index is only available for EU countries.

**FIGURE 1d. Correlation between Private Consumption and Real House Price and LTV Ratio**




Sample period: Quarterly data from 1980:1 to 2004:4. The real house price is deflated using the CPI. Data are de-trended using the HP1600 filter.

**FIGURE 2. VAR Impulse Responses to a 100 b.p. Shock to the Nominal Interest Rate** (with 90% confidence bands)

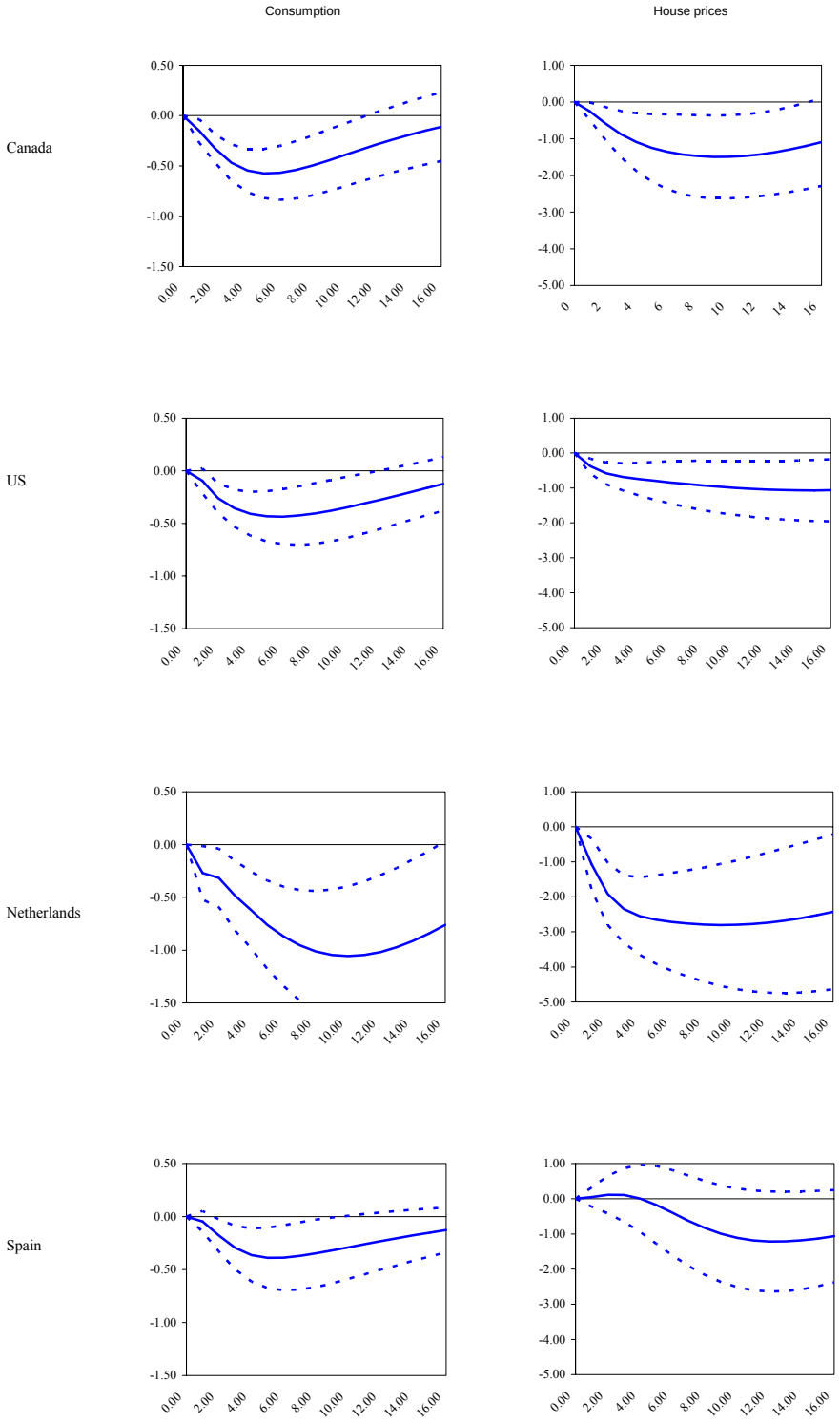
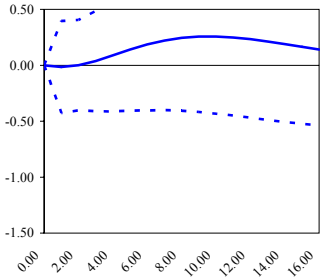
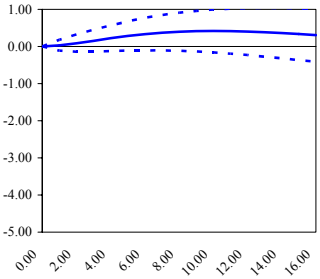


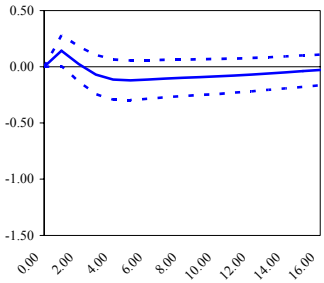
**FIGURE 2 (continued).**

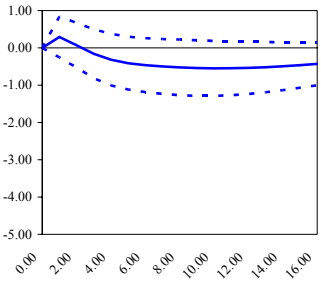
Germany



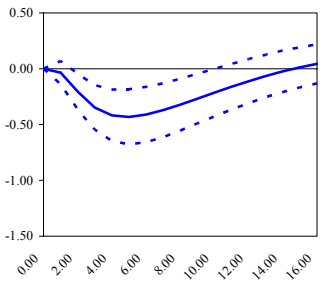



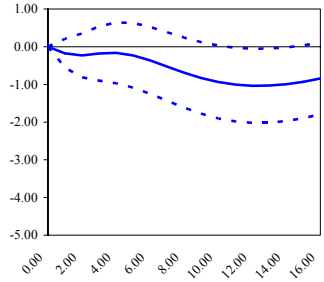

France



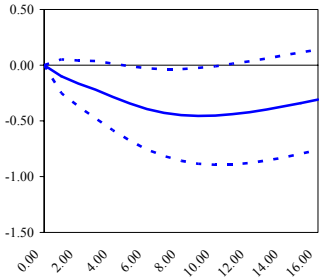




Italy




United Kingdom



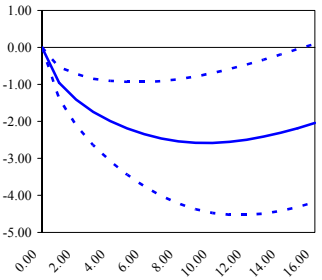
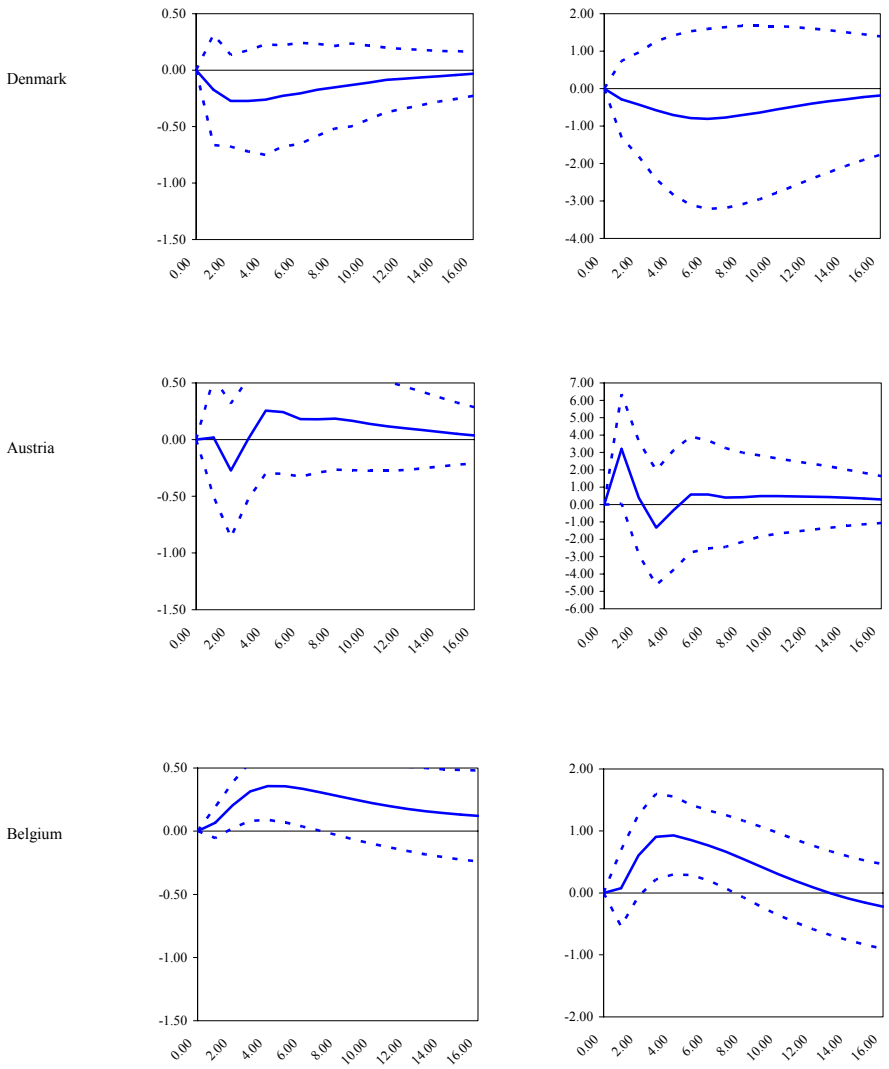
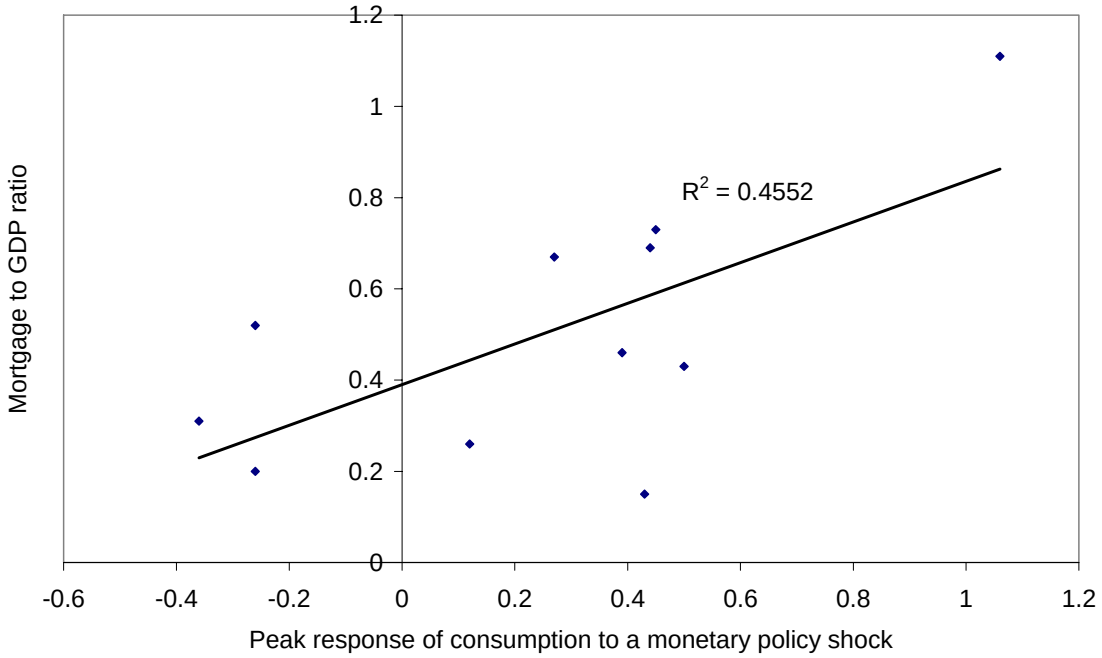



**FIGURE 2. (continued)**




Note: Results are based on the VAR model estimated on quarterly data over the sample period 1980:1 to 2004:4. See text for further explanations.

**FIGURE 3. VAR Peak Responses of Total Private Consumption to a Contractionary Monetary Policy Shock and Indicators of Development and Flexibility of Mortgage Markets**



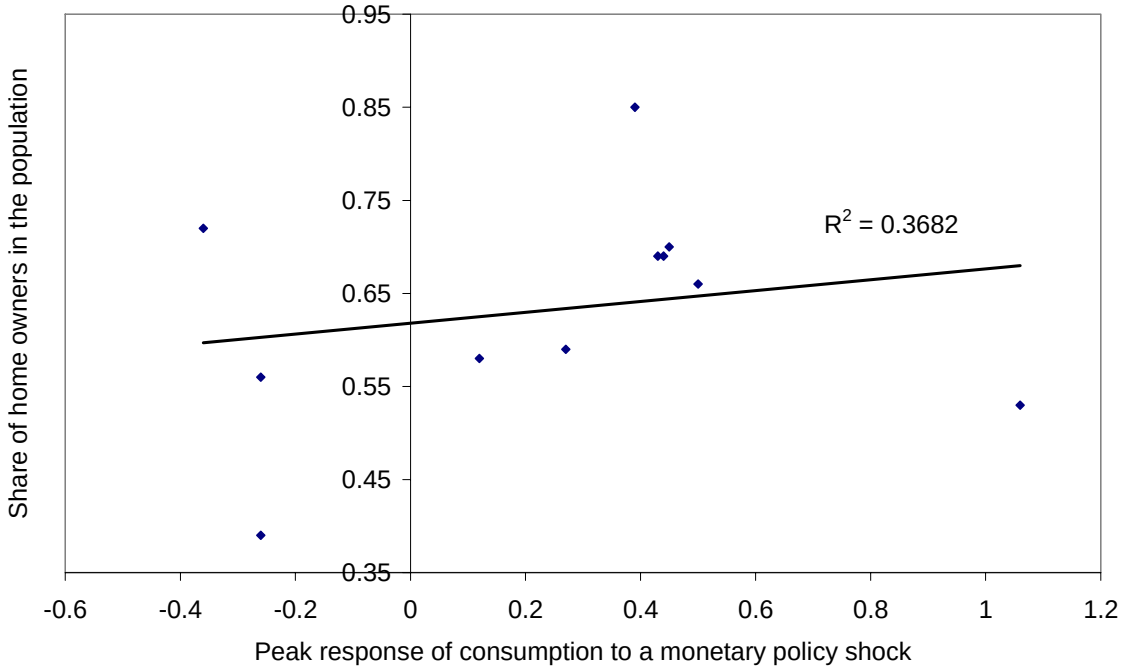
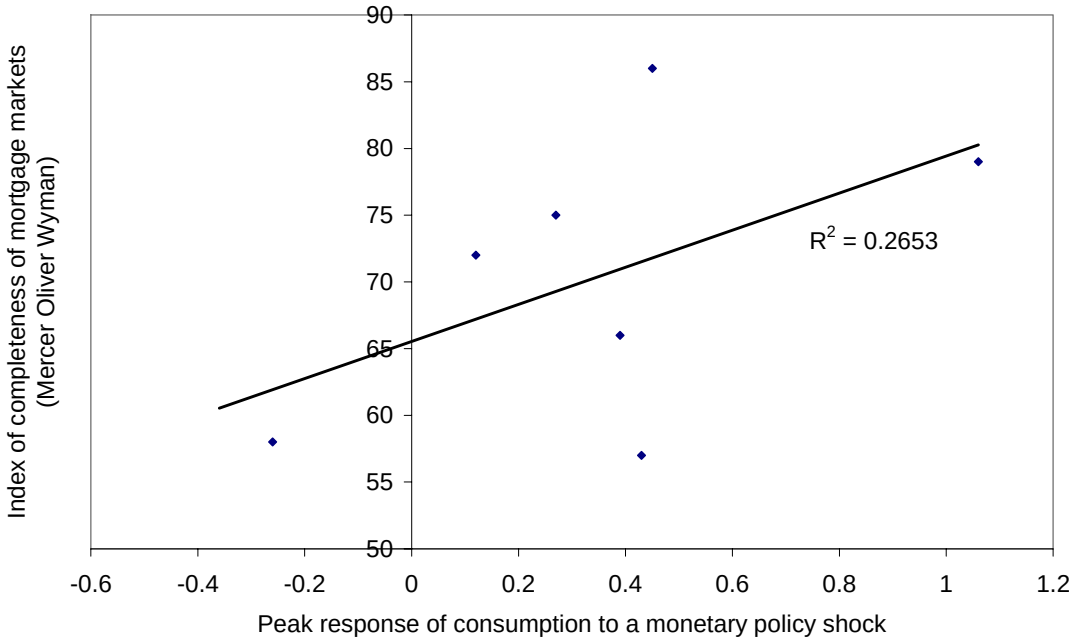
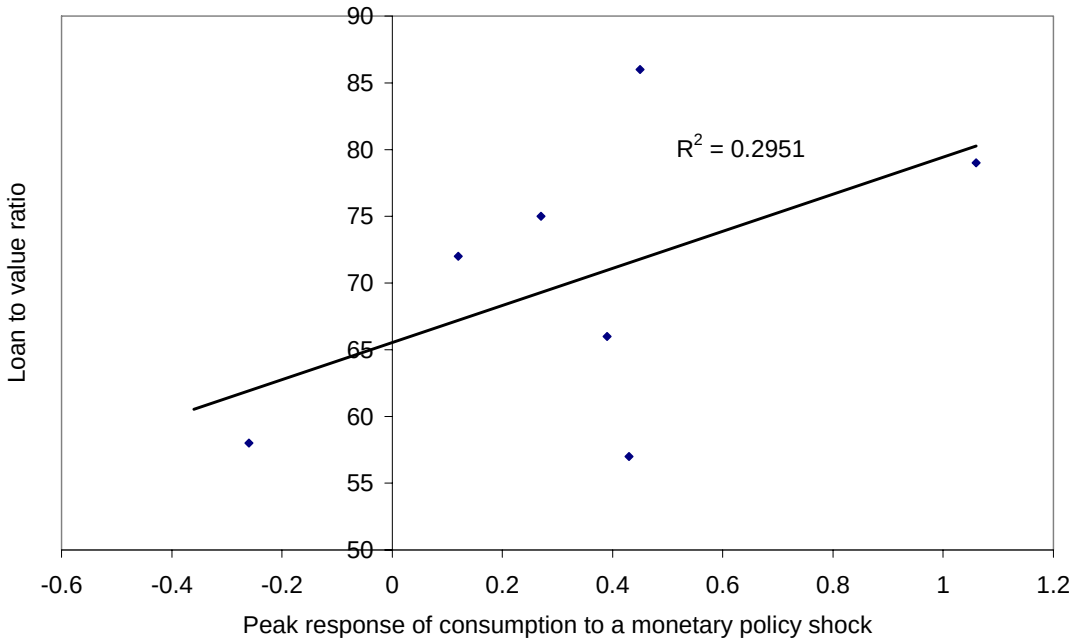



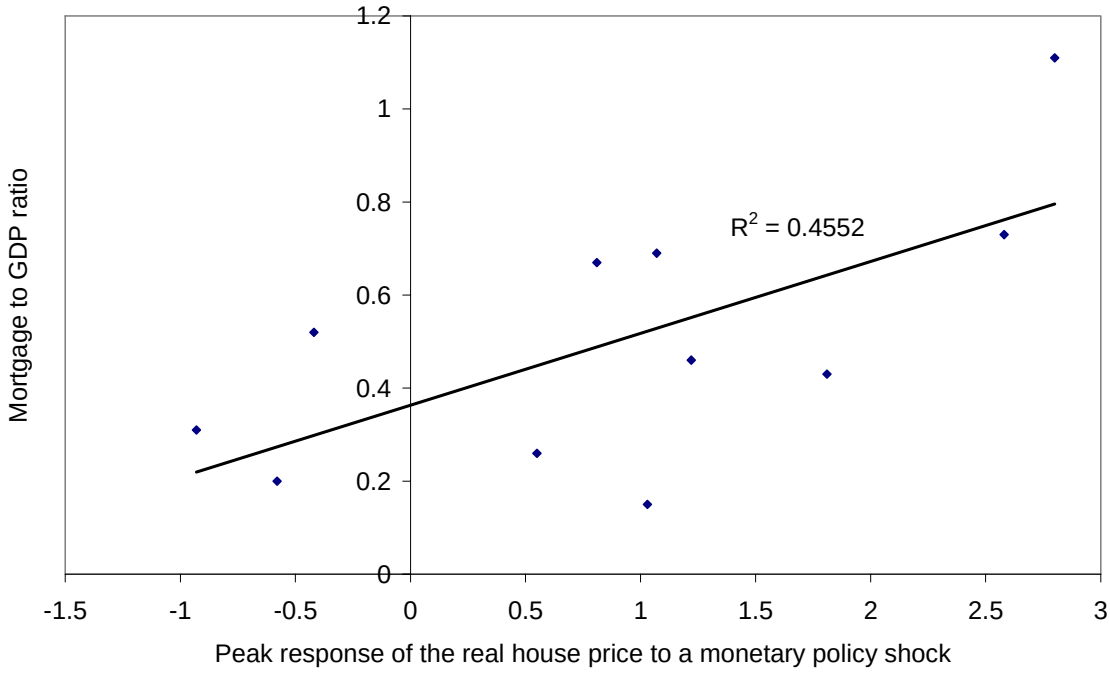
**FIGURE 3. (continued)**




Note: Results are based on the VAR model estimated on quarterly data over the sample period 1980:1 to 2004:4. See text for further explanations. The Mercer Oliver Wyman index is only available for EU countries.

**FIGURE 4. VAR Peak Responses of the Real House Price to a Contractionary Monetary Policy Shock and Indicators of Development and Flexibility of Mortgage Markets**



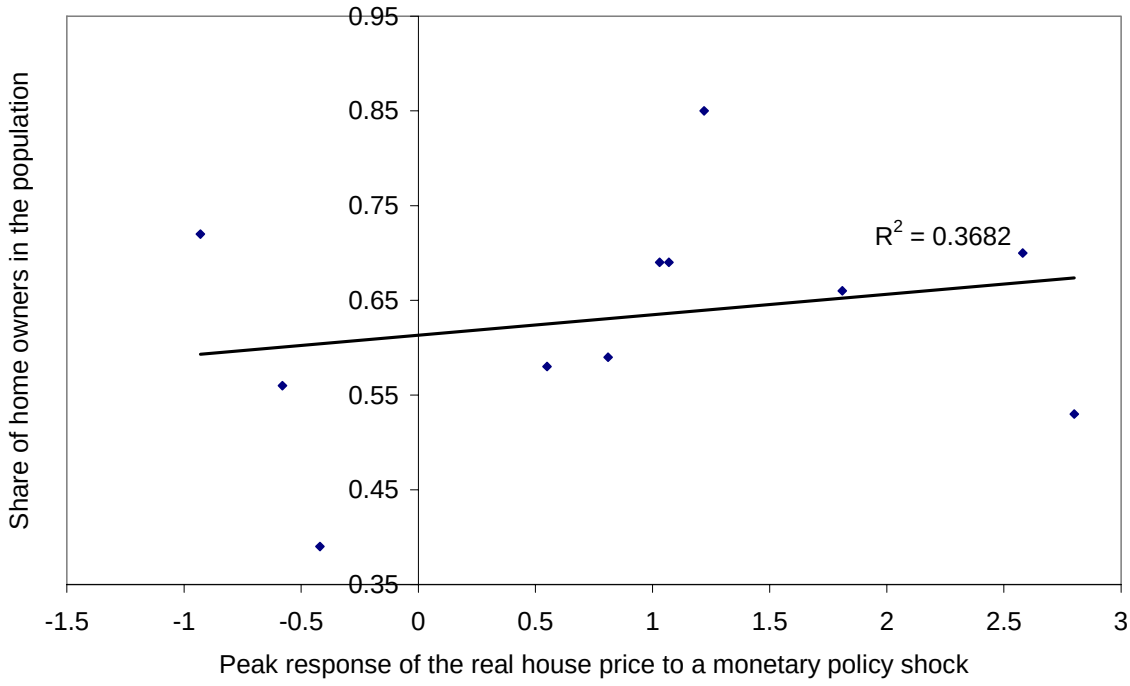
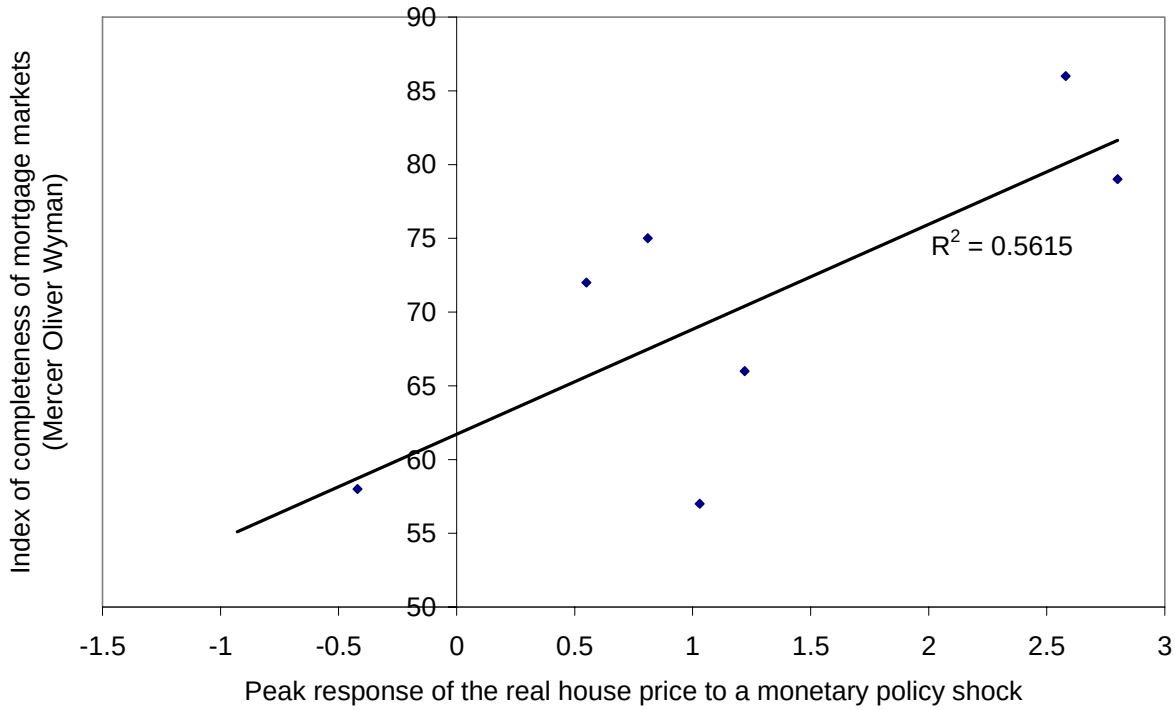



**FIGURE 4. (continued)**



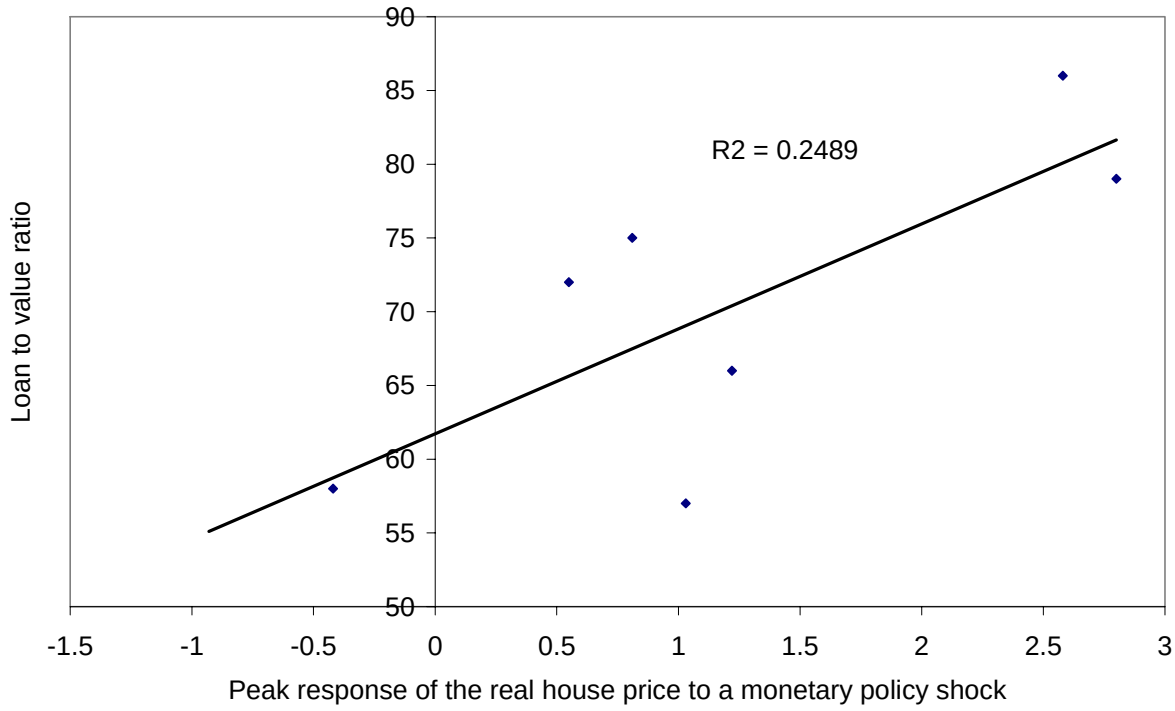



**FIGURE 5. Model Impulse Responses to a Monetary Policy Tightening (i.i.d. shock): Effect of Varying Down-Payment Rate χ (solid line χ = 15%, dashed line χ = 50%)**

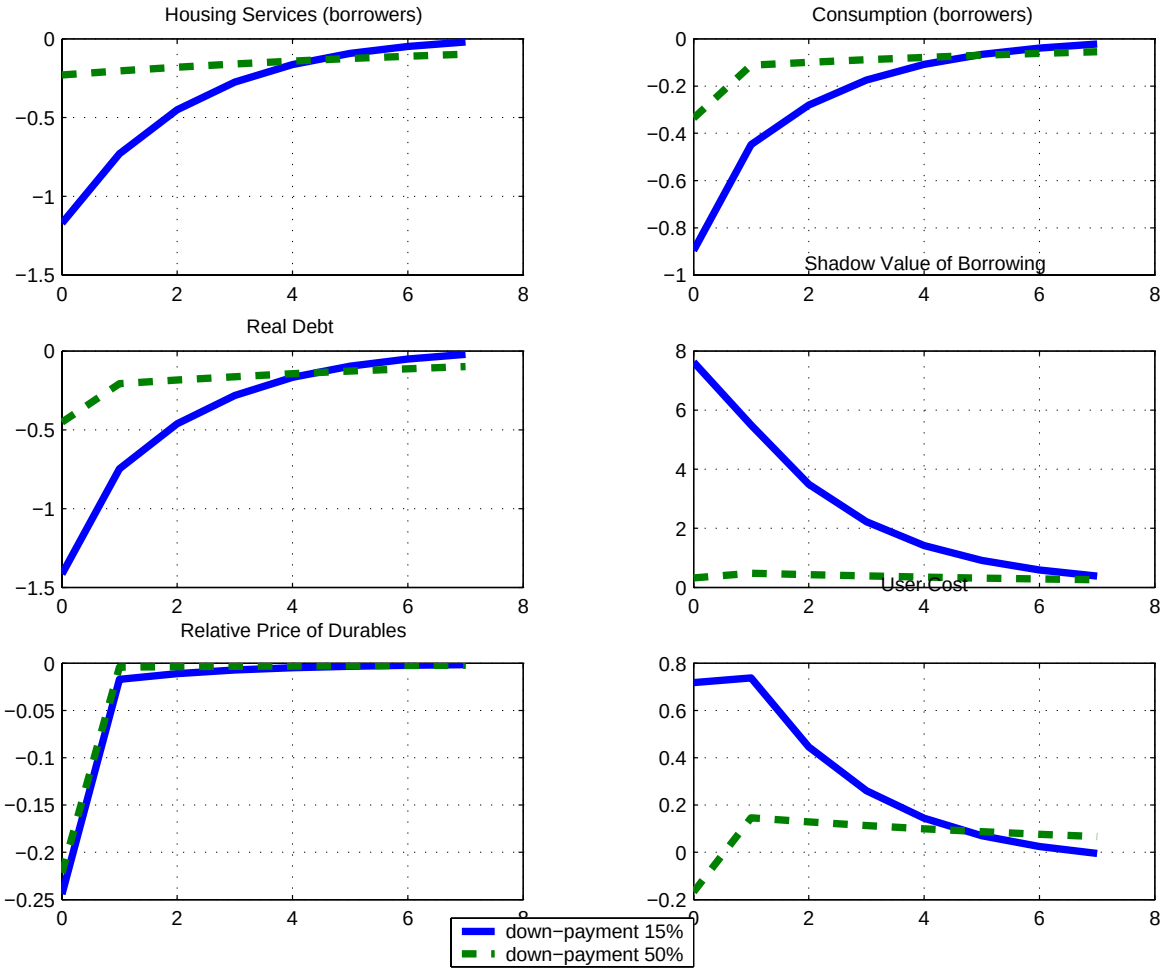


**FIGURE 6. Model Impulse Response of *Aggregate* Consumption to a Monetary Policy Tightening (i.i.d. shock): Effect of Varying Down-Payment Rate $\chi$**

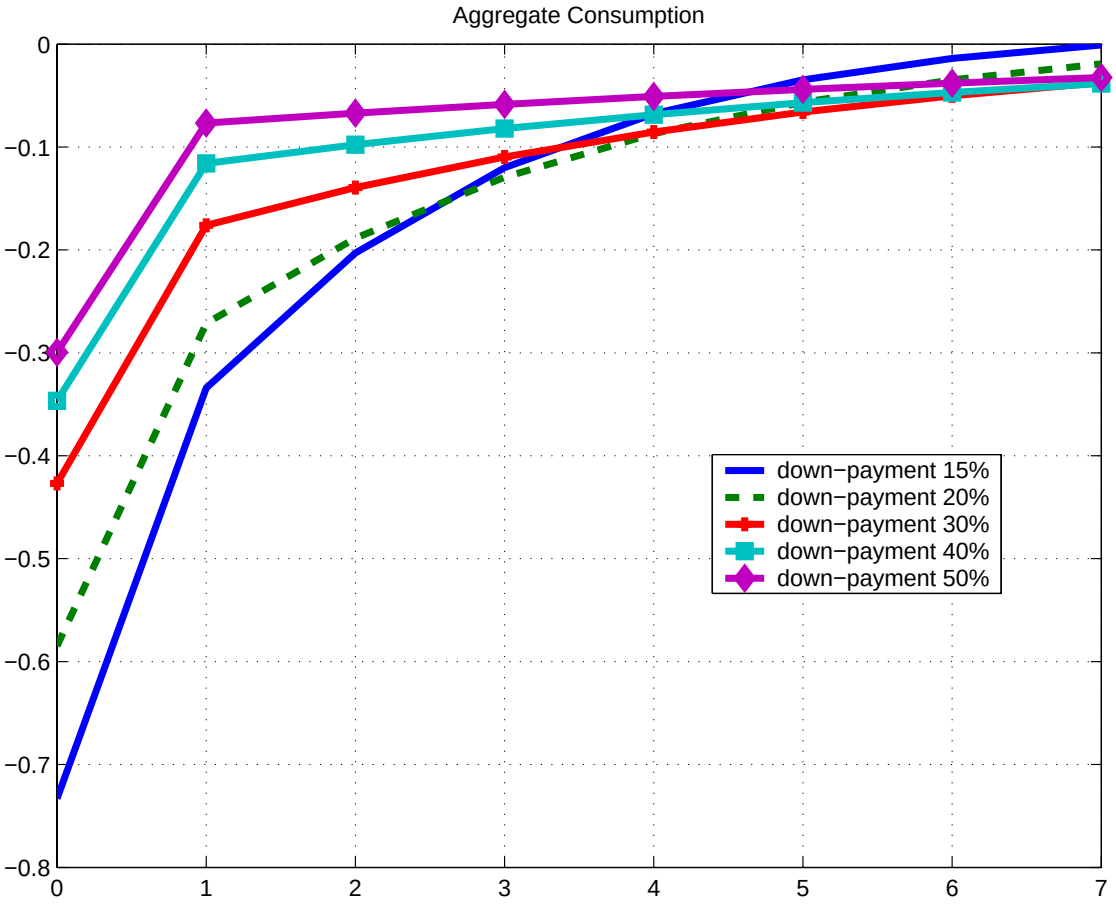
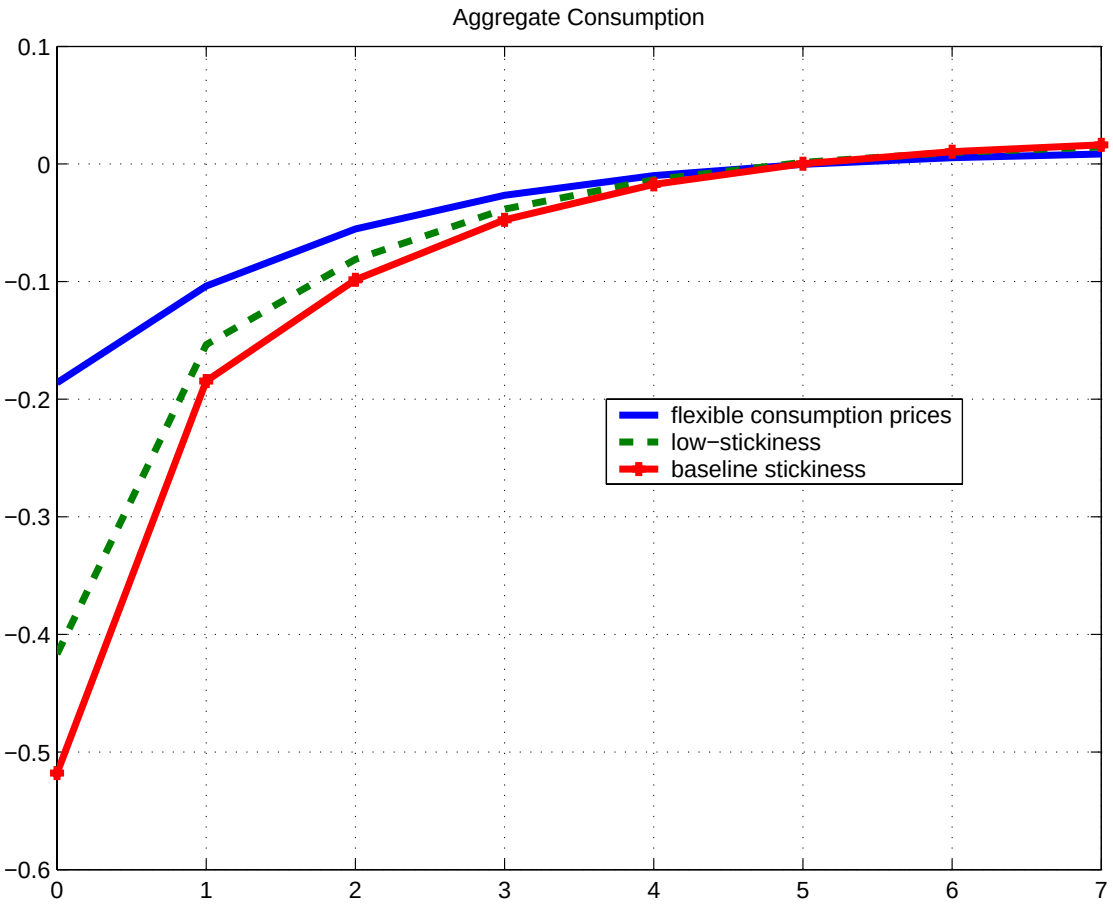


**FIGURE 7. Model Impulse Response of *Aggregate* Consumption to a Monetary Policy Tightening (i.i.d. shock): Effect of Varying Consumption Price Stickiness**




Note: low-stickiness and baseline stickiness correspond respectively to 2-quarter and 4-quarter frequency of price adjustment in consumer prices.

**FIGURE 8. Model Impulse Response of Aggregate Consumption to a Monetary Policy Tightening (i.i.d. shock): Effect of Varying Repayment Rate ξ**

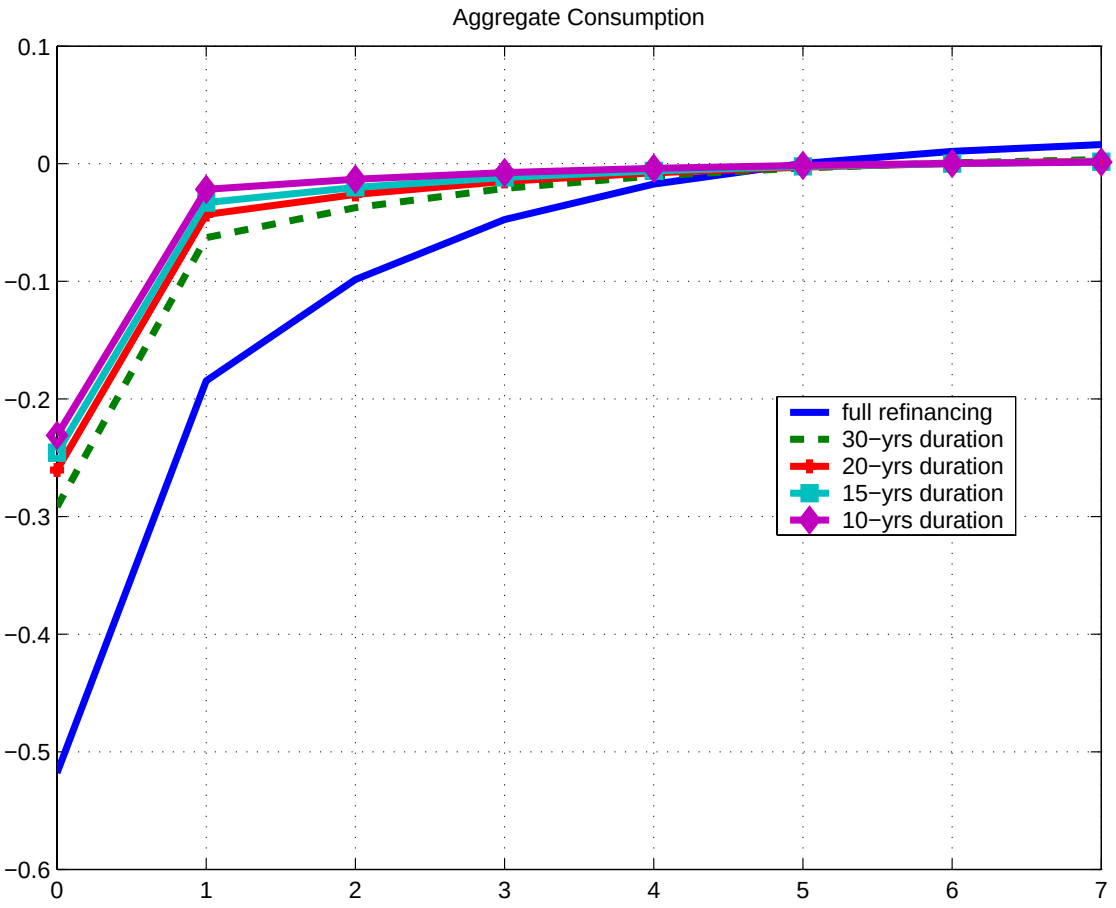
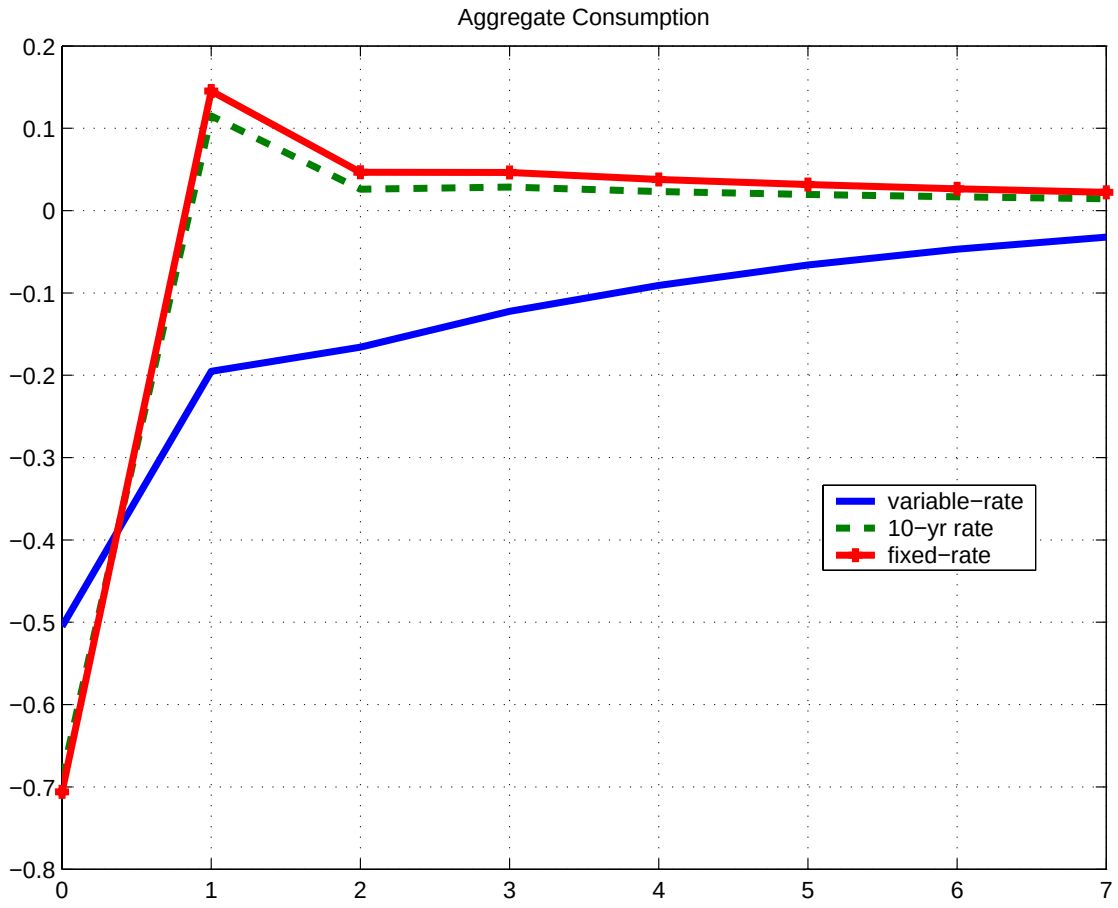


**FIGURE 9. Model Impulse Response of *Aggregate* Consumption to a Monetary Policy Tightening (i.i.d. shock): Effect of Varying the Interest Rate Mortgage Structure**



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