Home Equity, Mobility, and Macroeconomic Fluctuations

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Abstract

How does a fall in house prices affect real activity? This paper presents a business cycle model in which a decline in house prices reduces geographical mobility, creating distortions in the labor market. This happens because homeowners face declines in their home equity levels, after which it becomes more difficult to provide the down-payment required for a new mortgage loan. Unemployed homeowners therefore turn down job offers that would require them to move. The model explains joint cyclical patterns in housing and labor market aggregates, as well as the puzzling breakdown of the U.S. Beveridge curve that occurred during 2009.

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1 Introduction

The recent "Great Recession" is characterized by unusual disruptions in both housing and labor markets. In housing markets, there was a sharp fall in both prices and the number of transactions. In labor markets, there was an increase in the unemployment rate that was not only exceptional in terms of its magnitude, but also surprising given that the number of vacancies did not fall as much (Elsby, Hobijn and Sahin (2010)). Figure 1 plots vacancies versus the unemployment rate. The figure shows that the historically strong and negative correlation between the unemployment rate and vacancies, known as the Beveridge Curve, broke down during 2009. An interpretation of this finding is that frictions in the labor market had become more severe, causing unemployed workers and firms to be matched less efficiently.

This paper develops a Dynamic and Stochastic General Equilibrium (DSGE) model in which house prices affect real activity through a *geographical mobility channel*. When house prices decline, homeowners face difficulties in moving to a new house, reducing their incentives to accept job offers that are not within commutable distances from their current homes. As a consequence, a decline in house prices causes unemployment to rise and output to fall, which in turn feeds back into house prices. The calibrated model can explain joint cyclical fluctuations in housing and labor market variables. Moreover, based on *only* house price and output data, the model generates for 2009 a flattening of the Beveridge Curve that is remarkably similar to the one observed in reality.

Joint movements in house prices and mobility arise due to the presence of a *refinancing constraint* that is new to DSGE models.[1] Standard constraints tie the amount of debt to the value of the underlying housing collateral and in each period mortgagees have to refinance their loans (see e.g. Iacoviello (2005)). The unrealistic implication is that fluctuations in house prices affect the borrowing limits of *all* homeowners during *each* period. In contrast, my constraint *only* requires those who move to a new house to refinance their loans. In this environment, households can shield their borrowing capacity

[1] Stein (1995) considers a somewhat similar constraint and shows that it can generate positive comovement between house prices and transaction volumes in a determistic partial equilibrium model with only three periods. The advantage of my constraint is that is easily embedded in a DSGE framework that can be solved using standard techniques.

from a fall in house prices by staying at their current locations, avoiding the need to take out a new mortgage loan. After a fall in housing wealth, it becomes harder to provide the downpayment for a new loan, reducing incentives to move.

Fluctuations in mobility affect real activity through their effects on the process that matches unemployed workers and firms. This process is modeled following a standard version of the Diamond-Mortensen-Pissarides model, but with the addition that *some* job offers can only be accepted if the worker moves to a new location. When there are barriers to mobility due to a fall in house prices, more job offers are turned down. Thus, the economy enters a period during which, for a given level of vacancies, the unemployment rate is higher than during normal times. An interesting prediction of the model is that the mobility effects persist beyond the fall in house prices. Moreover, as the amount of leverage among households increases due to structural changes in mortgage markets, real activity becomes more sensitive to shocks, especially to those that arise in housing markets.

The model developed in this paper is the first that allows one to study the dynamic effects of house prices on mobility, as well as the spillovers to the labor market and real activity. Because outcomes in all markets are endogenous, one can also analyze feedback effects on house prices. Head and Lloyd-Ellis (2008) and Rupert and Wasmer (2009) have developed models with mobility effects to study the role of housing markets in determining long-run unemployment rates. However, their models are much less suited to study *fluctuations* in housing and labor markets, because solving stochastic versions of their models would be very challenging. In contrast, my model can be easily solved using standard methods.[2]

The proposed geographical mobility channel is consistent with joint cyclical properties of aggregate housing and labor market data. This is shown in Section 2. Section 3 describes the theoretical model. The predictions of the calibrated model are presented, compared to the data, and explained in Section 4. Section 5 concludes.

[2] Business cycle models that are related to my model include those of Iacoviello and Pavan (2010), who model borrowing constraints and infrequent housing adjustments, but not matching frictions in the labor market, and of Andrés, Boscá and Ferri (2010), who analyze a model with frictions in labor and credit markets, but without mobility effects.

2 Fluctuations in housing and labor markets: empirical evidence

The idea that house price declines deter geographical mobility is strongly supported by micro-econometric studies, including Henley (1998), Chan (2001), Engelhardt (2003), and Ferreira, Gyourko and Tracy (2010). The latter find that for U.S. homeowners, having negative equity reduces the probability of moving by about thirty five percent.[3]

At the *aggregate* level there is evidence that falls in house prices are associated with falls in housing transaction volumes. Stein (1995) finds that housing transaction volumes are positively correlated with past house price growth. Ngai and Tenreyro (2009) document that there is a common seasonal factor in house prices and transaction volumes. Given that a housing transaction is typically associated with a homeowner moving out, these findings are consistent with the idea that a fall in house prices reduces geographical mobility at the aggregate level.

The focus of this paper is on the joint behavior of housing and labor market variables at business cycle frequencies. I consider measures of volatility and comovement that are standard in the business cycle literature, permitting a relatively straightforward confrontation of my business cycle model with the data. At the center of the analysis are house prices, the number of home sales, and the rate at which workers flow out of unemployment. A link between these three variables is crucial for the proposed mobility channel to be at play at the aggregate level. But of course, unconditional business cycle statistics provide only limited information. I therefore also estimate a structural Vector AutoRegressive model (VAR), which allows me to condition on shocks that arise in housing markets.

2.1 Data and methodology

The data analysis focuses on quarterly observations of two housing market variables and three labor market variables. The sample runs from the first quarter of 1970 until the last quarter of 2009. The housing market variables are the real house price and home sales. These data were provided by the National Association of Realtors. The house price

[3] This is especially a strong finding given that in many states homeowners have the option to default strategically on their mortgages.

is the median sales price on existing single-family homes, deflated by the consumer price index.[4] Home sales are measured by the number of existing single-family homes sold in a particular month.[5] The reason for analyzing home sales is that this series can be expected to be a good proxy for overall mobility among homeowners.[6]

The labor market variables are unemployment, vacancies, and the unemployment outflow hazard. Unemployment is measured by the civilian unemployment rate as released by the U.S. Department of Labor. Vacancies are measured by the Help Wanted Index, released by the Conference Board. To account for the rise in internet vacancies, I use the corrected series as constructed by Barnichon (2009) for the post 1995 period. Following Shimer (2007), the quarterly unemployment outflow hazard, F_t, is constructed as

$$F_t = 1 - \frac{n_{u,t+1} - \widehat{n}_{u,t+1}}{n_{u,t}},$$

where $n_{u,t}$ is the size of the pool of the unemployed, and $\widehat{n}_{u,t}$ denotes the pool of those who have been unemployed for zero to four weeks.[7]

The first part of the empirical analysis consists of a detailed graphical investigation of the data. I consider raw data and construct their cyclical components using the Hodrick-Prescott (HP) filter. Finally, I estimate a structural VAR using nine variables. The VAR has the following form:

$$A(L)Z_t = u_t, \quad A(0) = I, \quad E\left(u_t u_t'\right) = \Sigma,$$

where $A(L)$ is a lag polynomial, u_t is a vector of residuals of length 9, and Σ is the variance-

[4] The conclusions are not affected by using the OFHEO house price index (all transactions) instead. A disadvantage of this series is that data are only available from 1975 onwards.

[5] Monthly series on house prices and the number of home sales were converted into quarterly series by taking simple averages.

[6] The main alternative to the home sales index would be the mobility measures constructed from the Current Population Survey (CPS), that distinguish between owners and renters, but are released on a yearly frequency only. This severely limits the information content of these data, especially when constructing business cycle statistics. However, according to CPS data the mobility rate among homeowners fell thirty percent during the period 2005-2009, which is very similar to drop in the home sales during the same period.

[7] The series used to construct F_t is based on data from the CPS. Due to a change in CPS methodology, there is a structural break in January 1994. To account for this, the adjustment of Shimer (2007) is applied. I would like to thank Ayşegül Şahin for sharing the adjusted series.

covariance matrix of the residuals.[8] Z_t is a vector a vector of the variables contained in the VAR, and can be divided into three parts:

$$Z_t = \begin{pmatrix} Z_{1,t} \\ Z_{2t} \\ Z_{3,t} \end{pmatrix}.$$

$Z_{1,t}$ is a (5×1) vector that contains the consumer price index, industrial production, the unemployment rate, vacancies, and the unemployment outflow rate. $Z_{2,t}$ is a (2×1) vector contains the two variables that are directly associated with housing market shocks: the real house price and home sales. $Z_{3,t}$ is a (2×1) vector that contains the S&P 500 index, and the federal funds rate. The VAR has four lags and is estimated in log levels.[9]

My goal is to identify shocks that arise in housing markets. One can assume that the reduced-form shocks in the VAR are related to a vector of uncorrelated structural shocks ε_t by:

$$u_t = \overline{Q}\varepsilon_t.$$

In order to identify structural shocks, restrictions on $\overline{Q}$ need to be imposed. Instead of using the standard Cholesky decomposition, I adopt a weaker assumption, as discussed in Christiano, Eichenbaum and Evans (1999), by imposing a block-diagonal structure on $\overline{Q}$:

$$\overline{Q} = \begin{pmatrix} \underset{(5\times5)}{\overline{q}_{11}} & \underset{(5\times2)}{0} & \underset{(5\times2)}{0} \\ \underset{(2\times5)}{\overline{q}_{21}} & \underset{(2\times2)}{\overline{q}_{22}} & \underset{(2\times2)}{0} \\ \underset{(2\times5)}{\overline{q}_{31}} & \underset{(2\times2)}{\overline{q}_{32}} & \underset{(2\times2)}{\overline{q}_{33}} \end{pmatrix}.$$

This identifying assumption implies that the variables contained in $Z_{1,t}$ can only respond with a lag to housing market shocks. The motivation is that I am interested in shocks that arise in housing markets and subsequently spill over to real activity. My identifying assumptions also imply that the variables in $Z_{3,t}$ can respond to housing market shocks contemporaneously. The reason for allowing stock prices and the monetary policy rate

[8] The VAR also contains a constant, a linear time trend, and quarterly dummies. For notational convenience, I do not display the corresponding terms.

[9] Although imposing unit roots or cointegration relationships on the variables contained in the VAR could improve the efficiency of the estimation, it would introduce a greater risk of misspecification.

to respond to housing market shocks within the quarter is that these two variables can be argued to be relatively forward looking.[10] Given that both the real house price and home sales are contained in $Z_{2,t}$, one can identify two orthogonal housing market shocks by imposing restrictions on $\overline{q}_{22}$. My identification assumes $\overline{q}_{22}$ to be lower-diagonal, and orders the real house price above home sales. The idea behind this assumption is that house prices are more sluggish in nature than transaction volumes.

The VAR is used for two purposes. First, the VAR allows me to construct an alternative measure of comovement, namely the correlations between forecast errors of the variables in the VAR, as described by Den Haan (2000). Second, I use the VAR to condition on housing shocks and recalculate the correlations between the forecast errors. I also study the underlying Impulse Response Functions (IRFs).

2.2 Is the geographical mobility channel present in aggregate data?

This subsection discusses the extent to which there is support in the aggregate data for the proposed geographical mobility channel. I analyze raw data and transformed data, using the methods that were discussed in the previous subsection.

If the geographical mobility channel is relevant, what cyclical patterns would one expect to see? First, one would expect that during periods when house prices are low, fewer homes are sold. At the same time, one would expect to see a fall in unemployment outflow rates during those periods. Moreover, the geographical mobility channel relies crucially on variations in the *efficiency* of labor market matching. Thus, one would expect measures of labor market efficiency to decline when house prices fall. Finally, one could expect comovements between housing and labor market variables to be particularly strong when conditioning on shocks that arise in housing markets.

Raw data. Panels A and B of Figure 2 display the real house price and the number of home sales, respectively, for the period since 1970. Both variables are upward trending

[10] I use end-of-quarter values of stock prices and the federal funds rate. The federal funds rate is included as it is a potentially important driver of house price fluctuations. The main reason for including stock prices in the VAR is to avoid that housing market variables are the most forward-looking ones in the system. Then, housing market shocks might primarily capture news about future economic conditions. However, results are not qualitatively affected by leaving out stock prices.

and display cyclical fluctuations. Two major boom-bust episodes in home sales stand out. The first boom began around 1975 and was associated with a run-up in house prices. The subsequent bust in the number of home sales started around the time Paul Volcker initiated his disinflationary monetary policy, and was accompanied by a moderate decline in house prices. The second boom seems to have started around the year 2000, and resulted in a bust that started around 2005.

At the very end of the sample, there is a brief spike in home sales, which seems related to the Home Buyer Tax Credit program, that applied to homes purchased between January 1, 2009 and May 1, 2010.

The unemployment outflow hazard, the unemployment rate and the vacancy index are plotted in panels C, D, and E of Figure 2. The cyclical fluctuations in these variables seem much related to those in home sales during several episodes. An exception is the period from 2001 until 2004, when home sales increased but the outflow hazard fell. The unemployment rate reached its highest level during the two housing busts discussed above, and the increase in the unemployment rate during recent years was particularly sharp. Note that during the run-up in unemployment in the last year of the sample, vacancies no longer declined. The unemployment outflow hazard, however, declined to a level that is by far the lowest in the sample.

Cyclical components. The cyclical components of the real house price and the number of home sales are plotted in Panel A of Figure 3. Home sales are more volatile than the real house price and there is a positive comovement between the two variables. During the most recent boom-bust episode, the comovement between house prices and home sales seems to have been particularly strong, except for the final spike in home sales. Panel B of Figure 3 displays the cyclical components of home sales and the unemployment outflow hazard and shows that the two variables are positively correlated.

The cyclical properties of the series are characterized more systematically in Table 1, which reports the volatilities of GDP, home sales, the unemployment rate, vacancies, and the unemployment outflow hazard, relative to the volatility of the real house price. Home sales are more volatile than the real house price. The real house price, in turn, is more volatile than GDP. The unemployment rate, vacancies and the unemployment outflow hazard are somewhat more volatile than home sales.

Table 1 also displays the correlations between the above mentioned variables. Home sales are positively correlated with the real house price. Moreover, both house prices and home sales are positively correlated with output, vacancies and the outflow hazard, and negatively with the unemployment rate. These patterns are consistent with the geographical mobility channel.

The estimated reduced-form VAR allows one to construct alternative comovement measures that do not rely on the HP filter. Table 2 displays the correlations of the forecast errors for the real house price, home sales and the outflow hazard, as implied by the VAR and at different forecast horizons. This comovement measure does not depend on the identification of the shocks.[11] There is a positive correlation between all three variables, as for the cyclical components constructed using the HP filter.

Conditioning on housing market shocks. An advantage of the VAR-based comovement measures is that they can be recalculated conditional on housing market shocks.[12] The conditional correlations are displayed in the bottom half of Table 2. The positive correlation between house prices and home sales is slightly weaker than unconditionally, but the correlations between home sales and the outflow hazard, and between the real house price and the outflow hazard, are substantially higher. For example, the correlation between home sales and the outflow hazard is 0.72 at a one year forecast horizon, while unconditionally it is only 0.40.

Figure 4 shows the dynamic responses to a joint shock in house prices and home sales of one standard deviation.[13] A negative shock leads to significant declines in house prices, home sales and the unemployment outflow hazard. Consumer prices, stock prices, industrial production and the federal funds rate also fall, while the unemployment rate increases.

More insight in the effects of housing market disturbances on the labor market matching process can be obtained by imposing a minimal degree of additional structure. Suppose

[11] As described by Den Haan (2000), the comovement measure is constructed as the cumulative product of Impulse Response Functions, summed over all shocks.

[12] It can be shown that given the identification strategy outlined above, these measures does not depend on the whether home sales or the real house price is ordered first.

[13] I consider a joint shock for the sake of a parsimonious presentation. In Appendix A it is documented that the individual responses to a house price and a home sales shock are very similar.

that unemployed workers and firms are matched according to a function that has a (standard) Cobb-Douglas form:

$$f(n_{u,t}, v_t) = \mu n_{u,t}^{\eta} v_t^{1-\eta},$$

where $f(n_{u,t}, v_t)$ is the number of matches, $n_{u,t}$ is the unemployment rate, v_t is the number of vacancies, η is the elasticity of matches with respect to the unemployment rate and μ is a scale parameter. For any given value of η, one can evaluate the response of $f(n_{u,t}, v_t)$ to a housing market shock, given the responses for the unemployment rate and vacancies. Petrolongo and Pissarides (2001) conclude that plausible values for η are between 0.5 and 0.7.[14]

Figure 5 plots the response of the job finding probability implied by the matching function, $f(n_{u,t}, v_t)/n_{u,t}$, for the two extremes of the range for η, and also plots the actual unemployment outflow hazard. For $\eta = 0.7$, the overall decline outflow hazard predicted by the matching function is much smaller than the decline in the actual unemployment outflow hazard. For $\eta = 0.5$, the initial declines in the two variables are similar, but the outflow rate declines more persistently than the decline predicted by the responses of unemployment and vacancies. These results provide evidence for a reduction in matching efficiency after negative housing shocks, although the evidence is particularly convincing for high values of η.

3 The geographical mobility channel in general equilibrium

In this section, I describe the theoretical business cycle model.

3.1 Main features of the model

Three main ingredients allow the model to capture the geographical mobility channel. First, agents are geographically mobile. Mobility decisions are integrated into their intertemporal optimization problems and are affected by both aggregate and individual conditions.

[14] Running a simple OLS regression of the log outflow hazard on a constant and the log of the vacancy-unemployment ration results in an estimate for η of 0.57. The value of the scale parameter μ is irrelevant for this exercise.

The second ingredient is a financial friction on the side of households, in the spirit of Kiyotaki and Moore (1997) and Iacoviello (2005). In their models, borrowing is limited by the value of the underlying collateral and debt contracts are renewed in each period. A consequence of this modeling choice is that a decline in the price of collateral affects the debt limits of all borrowers in the economy. But in reality, borrowers who do not refinance their loans are typically not affected when house prices fall.

A key innovation of my model is that collateral requirements apply only to *new* mortgages, which are taken out at the moment that an agent moves. For existing mortgages, debt is simply limited not to exceed the amount of the previous period.[15] Precisely this feature generates a decline in mobility when house prices fall. Consider for example a fall in house prices that is so large that borrowers' home equity levels shrink to zero. Without any wealth left, it becomes nearly impossible for agents to provide the downpayment required for a new mortgage loan, even a small one. However, when the agent decides not to move there is no renewed downpayment requirement, so the agent can sustain her current level of debt without problems. Consequently, moving is very unattractive in this situation.[16]

The final main ingredient of the model is a friction in the labor market. As in Pissarides (2000), unemployed agents search for vacancies and occasionally receive a job offer. But a fraction of those job offers can *only* be accepted if the agent moves, as commuting would be infeasible. When moving is sufficiently unattractive, e.g. because of difficulties in obtaining a new mortgage loan, the job offer is rejected and the agent continues searching for job offers.

3.2 Model description

The model economy is populated by a continuum of households of unit mass. There are two types of households: impatient and patient households. In equilibrium, the impatient

[15] As a consequence, my constraint does not allow non-movers to increase debt after house prices increase. Allowing for home equity loans would introduce a nonlinearity that creates severe difficulties when solving the model. Note, however, that the key aspect of the proposed geographical mobility channel is that agents can protect their debt limits from *declines* in house prices by not moving.

[16] My model abstracts from mortgage default. But note that homeowners who default are likely to have difficulties in getting a new mortgage for an even longer period of time.

households borrow from the patient ones, but borrowing is restricted by a refinancing constraint. Each of the two representative households consists of a continuum of members, who are either employed or unemployed.[17] In each period, a certain fraction of the members moves and the household pays a fixed moving cost for each of those members. The desire to move depends on the degrees of satisfaction of members with their current locations, which are idiosyncratic and stochastic. So moving costs are only worth paying for those members who are sufficiently dissatisfied with their current locations.

Employment relationships are destroyed at an exogenous rate, after production has taken place during the period. A member whose job gets destroyed in period t, can search for a job in the same period and may have a new job in period $t+1$ without becoming unproductive. If not, the member becomes unemployed in period $t+1$ and continues searching. The total number of meetings between workers and firms is determined by a standard matching function, depending on the aggregate number of job searchers and the number of vacancies. However, a fixed fraction of all meetings can *only* result in a productive relationship if the member moves. This captures the job offers from regions other than in which the worker resides.[18] When moving is sufficiently unattractive, the job offer is turned down and the member remains unemployed.

To impatient households, there is one additional factor affecting mobility decisions, namely the effect of mobility on the borrowing capacity of the household. The fraction of debt that the household has to refinance is equal to the fraction of its members moving to a new location. After a fall in house prices, refinancing is hard to accomplish, which creates a barrier to geographical mobility.

[17] This construct was introduced by Merz (1995) and was followed by others, including Gertler and Trigari (2009). According to this setup, agents are fully insured against fluctuations in consumption that arise from idiosyncratic shocks. What follows is a framework with a representative saver and a representative borrower.

[18] For reasons of simplicity, geographic locations are not explicitly modeled, although one could think of the model as one with a continuum of locations that are a priori identical to agents. But note that the proposed framework is consistent with two essential aspects of the geographical mobility channel, namely that (i) moving necessitates refinancing a mortgage and (ii) in some cases moving is required to accept a job offer.

3.2.1 Impatient households

The impatient households maximize the following objective function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_t + \alpha z_{h,t} \ln h_t + \kappa n_{u,t} + u_{lo,t} \right\}, \tag{1}$$

where β is their discount factor, c_t is non-durable consumption, h_t is the stock of housing, α is a housing preference parameter, $z_{h,t}$ is a housing preference shock, $n_{u,t}$ is the fraction of unemployed members, each generating a utility flow κ arising from time spent at home. Finally, $u_{lo,t}$ is a utility flow term that stems from the degree of satisfaction of the household members with their locations of residence, which will be specified below.

Consumption and borrowing decisions. Each period, households decide on the amount of non-durable consumption, housing and borrowing. In doing so, they are restricted by the following budget constraint:

$$c_t + p_{h,t} (h_t - h_{t-1}) + \zeta n_{m,t} + R_{t-1} d_{t-1} = (1 - n_{u,t}) y_t + d_t, \tag{2}$$

where $p_{h,t}$ is the house prices in units of non-durables, ζ is the fixed cost of moving a member, $n_{m,t}$ is the fraction of members that moves, R_t is the gross interest rate on debt to be repaid in period $t+1$, y_t is wage income per employed member, and d_t is the amount of debt.[19] So income consists of wage income, new debt and the sales value of the housing stock of the previous period, and income is spent on non-durable consumption, housing, moving costs, and servicing of old debt.

Debt is limited by the following *refinancing constraint*:

$$d_t \leqslant n_{m,t} \chi p_{h,t} h_t + (1 - n_{m,t}) d_{t-1}. \tag{3}$$

The important feature of this constraint is that the fraction of debt that is refinanced depends on the mobility rate, $n_{m,t}$. If all members move, that is when $n_{m,t} = 1$, all debt is refinanced and the constraint reduces to a standard collateral constraint. In that case, the household can borrow up to $\chi p_{h,t} h_t$, that is, up to a fraction χ of the value of the housing stock. If none of the members moves, that is when $n_{m,t} = 0$, the household can

[19] I limit the attention to loans with variable interest rates, so refinancing only involves the enforcement of a renewed collateral constraint.

borrow up the amount of the previous period, that is up to d_{t-1}.[20] For a given housing stock, h_t, a decline in the house price $p_{h,t}$ lowers $\chi p_{h,t} h_t$ relative to d_{t-1}. This makes moving less attractive. Note that in the steady state, the borrowing constraint reduces to a standard collateral constraint. Given the presence of patient households with a higher discount factor, this constraint binds in the steady state. In order to be able to solve the model using a perturbation method, I following the literature by limiting the attention to shocks that are small enough for the constraint not to become unbinding.[21]

The first-order conditions for the amount of housing and debt are given by:[22]

$$\frac{p_{h,t}}{c_t} = \frac{\alpha z_{h,t}}{h_t} + \beta E_t \frac{p_{h,t+1}}{c_{t+1}} + \lambda_{cc,t} n_{m,t} \chi p_{h,t}, \tag{4}$$

$$\frac{1}{c_t} = \beta E_t \left(\frac{R_t}{c_{t+1}} - \lambda_{cc,t+1} \left(1 - n_{m,t+1}\right) \right) + \lambda_{cc,t}. \tag{5}$$

Equation (4) is the first-order condition for the amount of housing consumed by the household. The right hand side is the *shadow value of housing*, which consists of three terms. The first term captures the direct utility gain derived from a marginal unit of housing. The second term is the utility derived from the discounted resale value of the house in the next period. The third term is proportional to the Lagrange multiplier of the borrowing constraint, $\lambda_{cc,t}$, the real house price $p_{h,t}$, and the mobility rate $n_{m,t}$. It captures the additional borrowing capacity that an extra unit of housing generates. If the borrowing constraint is not binding or if no member moves, this term reduces to zero. Equation (4) states that at the optimum, the shadow value of housing must be equal to the utility derived from $p_{h,t}$ marginal units of non-durables. Equation (5) is the Euler equation for debt. A binding borrowing constraint introduces a wedge in this equation. The second term within the conditional expectation represents the fact that of the new debt taken on in period t, only a fraction $n_{m,t+1}$ will be refinanced in period $t+1$. The remaining debt is rolled over to period $t+2$.

[20] Cambell and Hercowitz (2009) consider a model in which debt also evolves in a recursive way. In their model, however, the weight of old debt in the constraint depends on a fixed amortization rate. In my model, it depends on the *mobility* rate, which is a choice variable.

[21] For a discussion on this issue, see Iacoviello (2005).

[22] The optimality conditions for the impatient households are derived in Appendix B.

Location preferences. Geographical mobility is an essential feature of the model. Naturally, mobility decisions are affected by a number of factors. The focus of this paper is on considerations regarding employment and borrowing. However, mobility decisions also depend on more private factors, such as changes in family composition or changes in the degree satisfaction with the neighborhood. In order for the model to generate realistic overall mobility rates, these considerations need to be taken into account as well.

The setup is as follows. For each individual member j, an idiosyncratic location satisfaction shock $\varepsilon_{j,t}$ is observed during period t.[23] This shock represents the private factors that affect how willing somebody is to move.[24] For members that do not move, the realization of $\varepsilon_{j,t}$ is received as a utility flow, while each mover generates a fixed utility flow ψ instead.[25] So for members with a low realization of $\varepsilon_{j,t}$, moving is relatively attractive. For those members that receive a "long-distance job offer", moving has an additional benefit, namely that it enables them to get out of unemployment.

The optimal mobility decision implies a cutoff level for the location satisfaction shock. If the realization of this idiosyncratic shock is below the cutoff level, the member moves, while the member does not move if the realization is above the cutoff level. So the cutoff level represents the location satisfaction of the marginal mover, being exactly indifferent between moving and not moving. Although there may in principle be different cutoff levels for different agents, depending on individual characteristics such as wealth and labor income, the advantage of the complete markets framework adopted here is that there will be only two such values: one for members with a long-distance job offer, denoted by $\overline{\varepsilon}_{do,t}$, and one for those without such an offer, denoted by $\overline{\varepsilon}_t$. Let $F(\cdot)$ be the cumulative distribution function of the shock. Thus, $F(\overline{\varepsilon}_{do,t})$ is the mobility rate among members with a long-distance job offer and $F(\overline{\varepsilon}_t)$ is mobility rate among the members without such a job offer. It follows from this setup that the total location satisfaction utility term in

[23] For simplicity, I assume that this location satisfaction shock is i.i.d. accross time and members.

[24] Stein (1995) and Ngai and Tenreyro (2009) consider similar shocks.

[25] Alternatively, one could consider a model in which ψ is stochastic and ε is fixed, or a model in which both variables are stochastic. However, this would result in an observationally equivalent models under the distributional assumptions made in this paper. The reason is that what truly matters is the distribution of the *difference* between ε_j and ψ.

equation (1) is given by

$$u_{lo,t} = n_{do,t}\left[\psi F\left(\overline{\varepsilon}_{do,t}\right) + \int_{\overline{\varepsilon}_{do,t}}^{\infty} \varepsilon dF(\varepsilon)\right] + (1 - n_{do,t})\left[\psi F\left(\overline{\varepsilon}_{t}\right) + \int_{\overline{\varepsilon}_{t}}^{\infty} \varepsilon dF(\varepsilon)\right],$$

where $n_{do,t}$ is the fraction of members with a long-distance job offer.

Mobility decisions. The two cutoff levels that determine the mobility rate are chosen optimally by the household. This decision is taken at the beginning of the period, jointly with consumption and borrowing decisions.[26] The corresponding first-order conditions are:

$$\psi = \frac{\zeta}{c_t} + \overline{\varepsilon}_t - \lambda_{cc,t}\left(\chi p_{h,t} h_t - d_{t-1}\right), \tag{6}$$

$$\overline{\varepsilon}_{do,t} - \overline{\varepsilon}_t = \frac{y_t}{c_t} - \kappa + \left(1 - \rho_u\right) G_t. \tag{7}$$

Equation (6) is the first-order condition for $\overline{\varepsilon}_t$, the moving cutoff for members *without a long-distance job offer*. The left- and the right-hand side of this equation are, respectively, the benefits and costs of moving, for a member who is exactly indifferent between moving and staying. On the left-hand side, ψ is the utility flow that is received for being at a new location. On the right-hand side, the first term is the utility loss arising from paying the moving cost ζ. The second term, $\overline{\varepsilon}_t$, is the utility flow received when staying at the current location, which is foregone when moving. The third term arises from the effect of mobility on the borrowing capacity of the household and can be either positive or negative. If the borrowing limit on old loans exceeds the borrowing limit on new loans, that is when $\chi p_{h,t} h_t < d_{t-1}$, there is an additional cost to mobility.

Equation (7) determines the cutoff level for members *with a long-distance job offer*, $\overline{\varepsilon}_{do,t}$, relative to the cutoff for members without a long-distance offer. The difference between $\overline{\varepsilon}_{do,t}$ and $\overline{\varepsilon}_t$ is determined by two factors. The first factor is the difference in utility gains from the wage income of an employed member, y_t/c_t, and the utility flow from unemployment, κ. The second factor stems from a dynamic composition effect. If more members with a long-distance job offer move, more members flow into employment, and this positively affects the fraction of members that is employed in future periods. This effect is captured by G_t, which is defined in Appendix B.

[26] When mobility decisions are taken, it is known what members have what type of job offers, because offers were received at the end of the previous period.

Equations (6) and (7) are essential in understanding the direct mechanism through which fluctuations in house prices affect real activity. Equation (6) reveals a direct and inverse relation between house prices and mobility among members without a long-distance job offer. Ceteris paribus, a decline in the house price, $p_{h,t}$, must be offset by a decline in the cutoff, $\bar{\varepsilon}_t$. Recall that members move when their individual location satisfaction is below the cutoff. Thus, with a lower cutoff, mobility declines. Equation (7) shows that, ceteris paribus, a decline in $\bar{\varepsilon}_t$ also leads to a decline in the cutoff for members *with* a long-distance job offer, $\bar{\varepsilon}_{do,t}$. When mobility of members with long-distance job offers declines, a larger fraction of job offers is turned down, pushing up unemployment.

Flow equations. The mobility rate among household members, $n_{m,t}$, follows from the mobility cutoffs, and is given by

$$n_{m,t} = n_{do,t} F\left(\bar{\varepsilon}_{do,t}\right) + \left(1 - n_{do,t}\right) F\left(\bar{\varepsilon}_t\right). \tag{8}$$

The fraction of members with a long-distance job offer, $n_{do,t}$, is determined by

$$n_{do,t} = \omega \widehat{g}_{t-1} n_{s,t}. \tag{9}$$

Here, $\widehat{g}_t$ is the probability that an unemployed member meets a firm and gets a job offer, ω is the fraction of all meetings in which a member is required to move to accept the offer, and $n_{s,t}$ is the fraction of members that is searching for a job, which is:

$$n_{s,t} = n_{u,t} + \rho_u \left(1 - n_{u,t}\right), \tag{10}$$

where ρ_u is the exogenous job destruction rate. So the group of job searchers consists of the members that are unemployed and the employed members who just became obsolete at their current job. The fraction of unemployed members is equal to the fraction of job searchers of the previous period that did not receive a job offer, or that did receive a job offer but rejects it because moving is too unattractive:

$$n_{u,t} = n_{s,t-1}\left(1 - \widehat{g}_{t-1} + \omega \widehat{g}_{t-1}\left(1 - F\left(\bar{\varepsilon}_{do,t}\right)\right)\right). \tag{11}$$

3.2.2 Patient households

Patient households are the same as impatient households, except that their discount factor, γ, is higher than the discount factor of the impatient households, β. In equilibrium, patient households therefore lend to the impatient households and as a consequence the borrowing constraint is not relevant to the patient households. Also, patient households own the firms and receive their profits.

The first-order conditions for the patient households are the same as those for the impatient households, with the important difference that for the patient households, the Lagrange multiplier on the borrowing constraint is zero at all times. Let the variables of the patient households be denoted by a tilde. The first-order condition for the moving cutoff for members of the patient household without a distant job offer, $\widetilde{\bar{\varepsilon}}_t$, is:

$$\psi = \frac{\zeta}{\widetilde{c}_t} + \widetilde{\bar{\varepsilon}}_t. \tag{12}$$

So for patient households, house prices are not directly relevant for mobility decisions. All fluctuations in this cutoff arise from fluctuations in the willingness of patient households to pay the moving cost ζ.

3.2.3 Labor market

Let aggregate variables be denoted by a hat, and let ν be the share of impatient households in the total population. The aggregate unemployment rate, and the aggregate number of job searchers are, respectively, given by

$$\widehat{n}_{u,t} = \nu n_{u,t} + (1-\nu)\,\widetilde{n}_{u,t}, \tag{13}$$

and

$$\widehat{n}_{s,t} = \nu n_{s,t} + (1-\nu)\,\widetilde{n}_{s,t}. \tag{14}$$

The labor market is characterized by a matching friction. The aggregate number of meetings between firms and job candidates $\widehat{m}_t$ is a Cobb-Douglas function of the total number of job searchers and the aggregate number of vacancies, $\widehat{v}_t$:

$$\widehat{m}_t = \mu \widehat{n}_{s,t}^{\eta} \widehat{v}_t^{1-\eta}, \tag{15}$$

where η is again the elasticity parameter, and μ the scale parameter. The probability that a job searcher meets with a firm is:

$$\widehat{g}_t = \frac{\widehat{m}_t}{\widehat{n}_{s,t}}. \tag{16}$$

The probability for a firm with a vacancy of meeting with a worker is:

$$\widehat{g}_{f,t} = \frac{\widehat{m}_t}{\widehat{v}_t}. \tag{17}$$

3.2.4 Firms

Firms that are matched to a worker produce $z_{a,t}$ per period, where $z_{a,t}$ is an exogenous productivity process with a steady-state level equal to one. The wage is simply a share ξ of total revenues, that is $y_t = \xi z_{a,t}$. The firm receives the remaining share $1-\xi$.[27] Since firms are owned by the patient households, they discount future profits using the stochastic discount factor of those households. To firms, the asset value of a match, V_t, is:

$$V_t = (1-\xi)\, z_{a,t} + (1-\rho_u)\, E_t \widetilde{\Lambda}_{t,t+1} V_{t+1}, \tag{18}$$

where $\widetilde{\Lambda}_{t,t+1}$ is the stochastic factor of the patient households, that is,

$$\widetilde{\Lambda}_{t,t+1} = \gamma \frac{\widetilde{c}_t}{\widetilde{c}_{t+1}}. \tag{19}$$

Firms that search for employees pay a vacancy cost ϑ per period. Free entry of firms in the goods market implies that the vacancy cost equals the expected benefit to the firm of posting a vacancy:

$$\vartheta = \widehat{g}_{f,t} \left(1 - \omega + \omega \frac{\nu n_{s,t}}{\widehat{n}_{s,t}} F\left(\overline{\varepsilon}_{do,t+1}\right) + \omega \frac{(1-\nu)\, \widetilde{n}_{s,t}}{\widehat{n}_{s,t}} F\left(\widetilde{\overline{\varepsilon}}_{do,t+1}\right) \right) \widetilde{\Lambda}_{t,t+1} V_{t+1}. \tag{20}$$

The term between large brackets in the free-entry condition is the fraction of meetings that is unsuccessful because the worker is unwilling to move. Aggregate firm profits are given by:

$$\widehat{\Pi}_t = (1 - \widehat{n}_{u,t})\, (1-\xi)\, z_{a,t} - \vartheta \widehat{v}_t. \tag{21}$$

[27] I deviate from the more standard assumption that firms and workers bargain over the surplus that is created by an employment relationship. Instead, I assume that firms post wage contracts in which the worker gets a fixed fraction of the revenues. This setup makes the model tractable but also seems reasonable, given that in this model the total surplus of the match is affected by the utility derived from mobility. It seems implausible that firms would be able to observe the entire surplus and engage in bargaining over it.

3.2.5 Exogenous processes

The housing preference shock and the productivity shock are common to all agents and evolve according to the following laws of motion:

$$
\begin{aligned}
\ln z_{h,t} &= \rho_h \ln z_{h,t-1} + \varepsilon_{h,t}, \\
\ln z_{a,t} &= \rho_z \ln z_{a,t-1} + \varepsilon_{a,t},
\end{aligned}
$$

where $\varepsilon_{h,t}$ and $\varepsilon_{a,t}$ are i.i.d. innovations that are normally distributed, with mean zero and standard deviations σ_h and σ_a, respectively.

3.2.6 Equilibrium

The supply of the total stock of housing is fixed and normalized to one. The housing market clearing condition is:

$$\nu h_t + (1-\nu)\widetilde{h}_t = 1. \tag{22}$$

Financial market clearing requires that aggregate debt is zero:

$$\nu d_t + (1-\nu)\widetilde{d}_t = 0. \tag{23}$$

Let Ξ_t denote the vector of variables that summarizes the economic state, which is given by $\Xi_t = [g_{t-1}n_{s,t-1}, g_{t-1}\widetilde{n}_{s,t-1}, d_{t-1}R_{t-1}, h_{t-1}, z_{h,t}, z_{a,t}]'$. A competitive equilibrium is defined by a set of functions for:

- non-durable consumption, housing and borrowing: $c(\Xi_t)$, $\widetilde{c}(\Xi_t)$, $h(\Xi_t)$, $\widetilde{h}(\Xi_t)$, $d(\Xi_t)$, $\widetilde{d}(\Xi_t)$, $\lambda_{cc}(\Xi_t)$,
- cutoff values for mobility: $\overline{\varepsilon}(\Xi_t)$, $\widetilde{\overline{\varepsilon}}(\Xi_t)$, $\overline{\varepsilon}_{do}(\Xi_t)$, $\widetilde{\overline{\varepsilon}}_{do}(\Xi_t)$,
- rates of mobility, unemployment, job searchers, and members with long-distance job offers: $n_m(\Xi_t)$, $\widetilde{n}_m(\Xi_t)$, $n_u(\Xi_t)$, $\widetilde{n}_u(\Xi_t)$, $\widehat{n}_u(\Xi_t)$, $n_s(\Xi_t)$, $\widetilde{n}_s(\Xi_t)$, $n_{do}(\Xi_t)$, $\widetilde{n}_{do}(\Xi_t)$, $\widehat{n}_s(\Xi_t)$,
- labor market matching variables: $\widehat{m}(\Xi_t)$, $\widehat{g}(\Xi_t)$, $\widehat{g}_f(\Xi_t)$, $\widehat{v}(\Xi_t)$,
- firm variables: $\widehat{V}(\Xi_t)$, $\widehat{\Pi}(\Xi_t)$, $\widetilde{\Lambda}_{+1}(\Xi_t)$,
- and market-clearing prices: $p_h(\Xi_t)$ and $R(\Xi_t)$.

These functions must satisfy the optimality conditions for the impatient households (2)-(11), the equivalent conditions for the patient households (9 equations), labor market equations (13)-(17), equations for the firms (18)-(21), and the housing and bond market clearing conditions (22)-(23). This gives a system of 30 equations in 30 endogenous variables.

3.3 Calibration

The model is calibrated to U.S. data. The frequency is monthly. Several parameters are calibrated to pin down essential steady-state properties of the model and one parameter is calibrated to match the volatility of home sales.

3.3.1 Steady-state targets

The calibration procedure targets six steady-state properties of the model. First, the aggregate unemployment rate in the steady state is five percent. Second, the steady-state aggregate mobility rate is 0.65 percent per month. This corresponds to an annual mobility rate of 7.5 percent, as measured for US homeowners using data from the Current Population Survey (CPS) for the period 2000-2005. Third, the steady-state mobility rate due to members with long-distance job offers is 0.10 percent per month. This choice is based data from the CPS for the period 2000-2005 as well. On average, about 15 percent of the owners who had moved, indicated that the move was primarily for employment reasons. Fourth, the steady-state value of housing wealth is 140 percent of annual output.[28] Fifth, the credit-constrained households consume the same amount of housing in the steady state as the patient households.[29,30] Sixth, the probability that a vacancy is filled is 0.34 in the steady state. This implies a quarterly probability of 0.71, as in Den Haan, Ramey and Watson (2000).

[28] This choice follows Iacoviello (2005) and is based on data from the Flow of Funds.

[29] This choice is supported by data from the According to the American Household Survey 2007. For households with the very lowest downpayment ratios (up to five percent), the median home value is below the median home value for the total sample of homeowners. However, the median home value for households with a downpayment ratio between six and twenty percent is higher than the median for the total sample.

[30] Note that when the steady-state value of the housing stock owned by patient households is pinned down, the borrowing constraint determines the steady-state level of mortgage debt. The steady-state level of aggregate debt relative to aggregate income is 22.4 percent.

3.3.2 Parameter values

The parameter values are presented in Table 3 and are discussed below.

Preferences and moving technology. The calibration of the discount factors for patient an impatient households follows Iacoviello and Neri (2010). The discount factor of the patient households, γ, is set to 0.9975, which implies a steady-state real interest rate of about three percent per annum. The discount factor of the impatient households, β, is set to 0.9899.

The weight of housing in the utility function, α, is set differently for patient and impatient households. The values follow from the steady-state targeting procedure described above. The value for the patient and impatient households are 0.043 and 0.139, respectively. The relatively high value for the impatient households is a direct consequence of the requirement that both types of households consume the same amount of housing in the steady state.[31]

The idiosyncratic location satisfaction shock is calibrated to be normally distributed with mean zero and standard deviation σ. The standard deviation is important for the volatility of geographical mobility. A lower value of σ means that preferences for household members' current locations are less spread out. I choose the value of σ to be such that in a version of the model with only technology shocks, mobility is about 2.4 times as volatile as the real house price, corresponding to the relative volatility found in the data for home sales. This requires setting $\sigma = 3.8$.

The roles of the moving cost parameter, ζ, and the utility flow from moving, ψ, are similar to each other. This can be seen from Equation (6), the first-order condition for the mobility cutoff $\bar{\varepsilon}_t$. The parameter ζ is meant to capture physical costs of moving, such as transaction costs and fees for real estate agents. Unlike the utility flow ψ, the effect of the physical cost depends on the marginal utility of consumption, which varies in response to shocks. Following Stokey (2009), ζ is set to eight percent of the steady-state value of a unit of housing. The parameter ψ is used in the steady-state targeting procedure and its

[31] Note that impatient households discount the future resale benefits from housing more heavily than patient households. This would lead them to consume much less housing in the steady state than the patient households. As a consequence, the steady state level of debt of the impatient households would be unrealistically low.

value is -7.905.

Labor market. The elasticity of matches with respect to the number of job searchers, η, is set equal to 0.5. The job destruction probability, ρ_u, is set to 0.035. These values are within the range of standard values considered in the literature and follow Gertler and Trigari (2009). The values of the scale parameter in the matching function, μ, and the vacancy cost, ϑ, follow from the steady-state targeting procedure, and are 0.536 and 0.181, respectively. The calibration implies that in the steady state 1.86 percent of output is devoted to vacancy costs.

The fraction of long-distance job offers, ω, is difficult to calibrate as there is no direct equivalent in the data. My strategy is to set ω to one third and check for robustness. Alternative values for ω turn out to generate very similar results.[32]

The parameter ξ controls the fraction of the revenues that flows to workers in the form of wages. I assume that accounting profits of the firms are two percent, that is, $\xi = 0.98$. This choice is in line with typical calibrations of matching models, see Hornstein et al. (2000).[33]

The parameter κ measures the utility flow received per unemployed worker, and is one of the parameters that are used to match the steady-state targets. Its value is -4.898. Thus, κ can be thought of as an unemployment stigma. The negative value for κ contrasts with standard models with Nash bargaining, in which the parameter is typically positive-valued. However, in those models, the main role of κ is to determine the surplus from a match, affecting the incentives for firms to post vacancies. In my model, κ is only relevant in that it affects the incentives for unemployed workers to accept long-distance job offers.[34]

[32] The reason is that the steady-state fraction of the workers accepting long-distance job offers is a direct target of the calibration procedure.

[33] Unlike standard models, my results are not very sensitive to this aspect of the calibration. In my model, fluctuations in profits are proportional to fluctuations in productivity. Standard models typically assume Nash bargaining. In these models, profits are propotional to the surplus of a match. How much this surplus responds to shocks depends heavily on the calibration. This, in turn, has large consequences for the volatility of vacancies and unemployment (Hagedorn and Manovskii (2008)).

[34] Note that κ only enters the first-order condition for the mobility cutoff for workers with a long-distance offer. Thus, in a version of the model in which unemployed workers would be able to accept all job offers without moving, the value of κ would be irrelevant, provided that it is low enough to ensure that unemployed workers always accept a job offer.

Therefore, a low value of κ ensures that in the steady state a realistic fraction of workers moves for employment reasons.[35]

Credit frictions. The fraction of credit-constrained households, ν, and the collateral requirement parameter, χ, are potentially very important for the dynamics of the model. In my benchmark calibration, I set ν and χ such as to represent average values over the period since 1970. In order to study the effects of structural changes in mortgage markets, I consider two alternative calibrations, denoted by "low-leverage economy" and "high-leverage economy".

Using data from the Survey of Consumer Finances (SCF), Cambell and Hercowitz (2009) document that during the period 1983-2001, the average equity stake in newly purchased homes declined from 22.6 percent to 16.4 percent.[36] In the model, $1 - \chi$ is the equity stake in the steady state. In my benchmark calibration, I set χ equal 0.8. For the low- and high-leverage economy, χ is set equal to 0.25 and 0.15, respectively.

The fraction ν is meant to capture the real-world fraction of borrowing-constrained households in the *total* population (including renters). Data from the SCF show that during the period 1989-2007, the fraction of households with a mortgage or home equity loan increased from 39 percent to 46 percent. But of course, not all of these households are actually *constrained* by a borrowing limit. In my benchmark calibration, ν is set equal to 0.2.[37] In the low- and high-leverage economies, I set $\nu = 0.15$ and $\nu = 0.25$, respectively, capturing an increase in the number of households that is eligible for a mortgage.

Exogenous shock processes. The calibration of the persistence parameter of the productivity process, ρ_a, follows Kydland and Prescott (1982), who set the autocorrelation coefficient of their technology process equal to 0.95 at a quarterly frequency. For my model, this implies setting $\rho_a = 0.983$, as the frequency is monthly.

[35] An important reason why the value of κ has to be so low, is that in the model there are complete insurance markets, and therefore unemployed agents do not suffer from lower levels of consumption than employed agents.

[36] The average is over home purchases with an equity stake of at most fifty percent.

[37] Data from the American Housing Survey (AHS) show that in 2007, 62 percent of all mortgagors had put in a downpayment of 15 percent or less at the time they purchased their home. Earlier observations are not available.

The persistence parameter of the housing preference process, ρ_h, is difficult to measure directly in the data. But since there are few a priori reasons to expect that the housing preference process is either more or less persistent than the productivity process, I set ρ_h equal to ρ_a.[38]

4 Model results

The model is solved using a first-order perturbation method and then simulated. Three types of simulations are analyzed. First, I simulate the model with random sequences of productivity shocks and calculate standard business cycle statistics, which are compared to those found in the data. Second, I discuss the dynamic responses to one-time shocks in productivity and housing preferences. Finally, I consider a series of productivity and housing preference shocks that is chosen such that the model replicates data series for output and real house prices, over the period 1970 - 2010. The main purpose of this experiment is to investigate to what extent the model can explain the puzzling dynamics of unemployment and vacancies during the aftermath of the Great Recession.

4.1 Business cycle statistics

The model of this paper is very stylized in many respects. For example, the model does not feature capital investment or nominal rigidities. Although the simplicity of the model helps to highlight its essential mechanisms, it reduces the extent to which the business cycle properties of the model can be expected to match the data. Moreover, the most interesting application of the model seems to be to simulate episodes of large falls in house prices, which do not occur very frequently. Nonetheless, it seems important to know how well this simple model can explain "regular" business cycles. I therefore analyze the business cycle properties of a version of the model with only productivity shocks.

Volatilities implied by the model are displayed in Table 4. These numbers can be compared to the volatilities found in the data (Table 1). The model correctly predicts that the unemployment rate, vacancies, and the outflow hazard are more volatile than

[38] Iacoviello and Neri (2010) estimate a model with both housing preference shocks and productivity shocks using Bayesian methods. For the autocorrelation coefficients of both shock processes, their posterior mean estimates are around 0.95 at a quarterly frequency.

house prices, and output is less volatile than house prices. Quantitatively, however, the predicted volatilities of unemployment, vacancies and the outflow hazard are very low compared to the volatility of output. This is a general problem of labor market matching models, as emphasized by Shimer (2005).

Table 4 also displays the correlations of the above mentioned variables. For all correlations, the model predicts the correct sign. Also, the correlation between vacancies and the outflow hazard, and between the unemployment rate and the outflow hazard, are comparable to their data equivalents. However, there are also quantitative discrepancies between the model and the data. The correlation between the unemployment rate and vacancies is -0.80, which is less negative than the correlation coefficient of -0.90 found in the data.[39] Most other correlations are much stronger than in the data. For example, the correlation between house prices and the unemployment rate is -0.93 in the model, whereas the correlation found in the data is -0.44.

4.2 Dynamic responses

This subsection discusses the dynamic responses to two types of shocks: housing preference shocks and productivity shocks. Although shocks to housing preferences are less common in the literature than shocks to productivity, this is not the first paper to consider housing preference shocks. For example, Iacoviello and Neri (2010) report that in their model with collateral constraints, housing preference shocks can have substantial effects on output. However, this holds even in version of their model without credit frictions, in which housing wealth effects are absent.[40] In contrast, the structure of my model is such that a housing preference shock has no effect on output when credit frictions are removed from the model, as will be shown below. This permits a clear view on the causal role of house prices in driving fluctuations in real activity.

[39] Thus, the model seems to predict a flatter Beveridge curve than is present in the data. This result, however, depends on the calibration of the autocorrelation parameter of productivity shock process. For higher values, the model predicts a steeper Beveredge Curve. In Subsection 4.3 it will be shown that the model is much better able to reproduce the Beveridge Curve than the analysis in this subsection may suggest.

[40] Their model does not feature frictions in the labor market, but they do include a variety of other frictions, including nominal rigidities. Also, the housing stock is not fixed in their model.

Productivity shock. Responses to a sudden one-percent decline in productivity are displayed in Figure 6, for several calibrations. First consider the benchmark calibration. After a fall in productivity, output and house prices fall. As in standard business cycle models with search and matching frictions in the labor market, there is a decline in vacancies and in the (average) unemployment outflow hazard, and an increase in the unemployment rate. The mobility rate falls after the decline in productivity.

To understand the effects of refinancing constraints, consider the responses for an economy in which there are no impatient households (no borrowers). In such an economy, all households have the same discount factor and there is no debt in equilibrium. Thus, refinancing constraints are irrelevant. The responses for this economy are plotted in Figure 6 as well. Without credit-constrained households, the decline in vacancies is very similar to the decline in vacancies in the benchmark model. The unemployment rate, however, does not increase as much as in the benchmark model. Thus, the presence of credit-constrained households implies a somewhat flatter Beveridge curve. This is directly related to the fact that the drop in the mobility rate is also much less pronounced than in the benchmark economy. The declines in output and house prices, however, are quite similar across the two versions of the model. This indicates that these declines are mainly driven by the direct effects of the fall in productivity.

What are the consequences of structural changes in mortgage markets for the sensitivity of the economy to productivity shocks? Figure 6 plots the responses for the "low-leverage" and the "high-leverage" economies. Financial development clearly causes the mobility rate to be more sensitive to productivity shocks. For the other variables, the responses are more similar across the two economies.

Housing preference shock. How do shocks that originate in housing markets affect the real economy? Figure 7 displays the responses to a negative housing preference shock, generating a house price decline of about one percent on impact. First consider the benchmark calibration. Consistent with the VAR evidence, the model predicts a joint decline in house prices, mobility, output, vacancies and the unemployment outflow hazard, and an increase in the unemployment rate.

Interestingly, the increase in the unemployment rate is larger and much more persistent than the decline in vacancies. For example, fifteen quarters after the shock, vacancies are only about 0.05 percent below their steady-state level, but the unemployment rate is still about 0.18 percent above its steady-state level.[41]

Persistence is also observed in the decline of the mobility rate, which is much more prolonged than the fall in house prices. Six years after the shock, house prices have almost fully recovered, but the mobility rate is still one percent below its steady-state level.

What are the effects of collateral constraints? Figure 7 shows that in the economy without credit-constrained households, the decline in house prices is smaller than in the benchmark economy. But more importantly, real activity variables do not respond *at all* to the shock. To see why, note that the first-order condition for housing of the patient households is given by:

$$\frac{p_{h,t}}{\widetilde{c}_t} = \frac{\alpha z_{h,t}}{\widetilde{h}_t} + \gamma E_t \frac{p_{h,t+1}}{\widetilde{c}_{t+1}}. \tag{24}$$

In the absence of credit-constrained households, this is the only model equation in which the house price enters.[42] This implies that house prices and housing preferences are irrelevant for equilibrium allocations.[43]

Now consider the low-leverage and the high-leverage economies. Figure 7 makes clear that structural innovations in mortgage markets substantially increase volatilities. In particular, the maximum responses of the unemployment and mobility rates in the high-leverage economy are about double the size of those in the low-leverage economy. In contrast, the differences in the response of the real house price are small. Thus, real activity has become more sensitive to fluctuations in house prices as the amount of leverage in the economy increases, but the feedback on house prices seems limited.

4.3 Great Recession experiment

This subsection discusses how well the model can explain observed dynamics of unemployment and vacancies, and in particular the recent flattening of the Beveridge curve, as

[41] In a quantitative sense, the effects on real activity are very modest for a one percent fall in house prices. For example, the maximum increase in the unemployment rate is 0,012 percentage points. Thus, the model does not only generate little volatility in the unemployment rate conditional on productivity shocks, but also conditional on housing preference shocks. However, in the next subsection it will be shown that for large swings in house prices, the effects are substantial.

[42] Since the aggregate supply of housing is fixed, the house price drops out of the budget constraint.

[43] Note that one could simply remove Equation (24) from the system of equilibrium conditions, since one would loose one equation and one endogenous variable.

highlighted in Figure 1. For this purpose, the following experiment is conducted. Using data series on the real house price and GDP for the period 1970 - 2010, I back out realizations of the innovations to the productivity and housing preference shock processes.[44] This is simply done by inverting the equilibrium laws of motions for output and the real house price.[45]

The model is then simulated, using the shocks obtained from the inversion procedure. Column A of Figure 8 plots the simulated values of the real house price and output for the high-leverage economy for the period 2000 - 2010. By construction, the simulated data for house prices and output coincide with the real-world data. I also run a second, counterfactual simulation, in which housing preference shocks are shut off from 2005 onwards. In this simulation, house prices drop much less than in the benchmark simulation, and output slightly less. Column B plots both model simulations again, but now for the low-leverage economy. These simulations are very similar to those for the high-leverage economy.[46]

Simulated values for unemployment and vacancies, as well as their data counterparts are plotted in Figure 9, for the period 1970 - 2010. The model does a very reasonable job in tracing the ups and downs of unemployment and vacancies over time. But as expected from the analysis in the previous subsections, the magnitudes of fluctuations in unemployment and vacancies are much smaller than in the data.

How well can the model account for the flattening of the Beveridge curve observed in 2009? Panel A of Figure 10 plots the unemployment rate versus vacancies for the high-leverage economy. For the period 1970-2008, there is a strong negative comovement between unemployment and vacancies, although not as strong as in the data.[47] For 2009,

[44] Data were logged and linearly detrended. Quarterly GDP data were converted into monthly data by linear interpolation.

[45] I assume that at the beginning of the sample, just prior to 1970, the economy was at the steady state. The results are not very sensitive with respect to this assumption, especially given that my focus is on the realizations in recent years.

[46] For the sake of comparability, I do not back out a separate series of shock innovations for the low-leverage economy. Instead, I use the same shock innovations as for the high-leverage economy.

[47] The correlation between the unemployment rate and vacancies is -0.85, whereas it is -0.9 in the data. This seems related to the fact that there are some outliers with negative values for the unemployment rate. These are predictions for the late 1980's. Also, note that for this simulation, the comovement is much closer to the data than in the simulations in Subsection (4.1).

the model predicts that the Beveridge curve is essentially flat, or even somewhat upward sloping, precisely as observed in reality (see Figure 1). The predicted increase in the unemployment rate is 7.4 percent. This is thirty percent of the increase observed in the data. But recall that the model fails to generate sufficient volatility in unemployment. Scaled by the volatility of the unemployment rate, the model actually predicts a *larger* increase in the unemployment rate than observed in the data: the model generates an increase of 1.8 standard deviations, versus an increase of only 1.2 standard deviations in the data.

What has been the role of the bust in house prices in recent years? Panel A of 10 plots the values of unemployment and vacancies in the counterfactual simulation. With housing preference shocks shut off from 2005 onwards, the behavior of unemployment and vacancies is much less extreme. In particular, the unemployment rate only increases to ten percent above its trend level, versus sixteen percent including housing preference shocks. Thus, the effects of shocks arising in housing markets are substantial.

The simulation results for the low-leverage economy are plotted in Panel B of Figure 10. Precisely as in the data, the model generates a correlation between the unemployment rate and vacancies of -0.9.[48] Thus, for the overall sample, this version of the model may be more appropriate than its high-leverage counterpart. At the same time, the low-leverage version is less successful in explaining the sharp increase in the unemployment rate during the Great Recession. Moreover, the flattening of the Beveridge curve during 2009 is not as pronounced as in the high-leverage economy.

4.4 Understanding the interactions between housing and labor markets

In the presence of refinancing constraints, outcomes in housing markets are not just passively determined by economic conditions, but have an active role in shaping real economic outcomes. The purpose of this subsection is to better understand this interaction. I focus on housing preference shocks, because this allows me to study the roles of credit frictions and mobility in isolation.

I will answer three main questions that arise naturally from the analysis of dynamic responses in Subsection 4.2. First, why are the mobility effects propagated over time?

[48] Unlike the high-leverage economy, there are no large negative outliers for the unemployment rate.

Second, why do vacancies fall following a negative housing preference shock? And finally, what determines feedback effects of fluctuations in real activity on house prices?

4.4.1 Sources of propagation

An interesting model prediction is that the responses of mobility and unemployment to a housing preference shock are more persistent than the response of house prices (Figure 7). But what drives this propagation?

Recall that Equation (6), the first-order condition for the moving cutoff for impatient households, is essential in determining fluctuations in the mobility rate. This equation relates the cutoff, $\overline{\varepsilon}_t$, directly to the real house price, $p_{h,t}$, but also to the stock of housing owned by impatient households, h_t, and their debt level, d_{t-1}.[49] Panel A of Figure 11 plots the responses of h_t and d_{t-1} to a negative housing preference shock, and shows that the reduction in h_t is larger than the fall in d_{t-1}. More importantly, the gap widens during the first four years, indicating that impatient households gradually become poorer, and thus less capable of providing downpayments.

To obtain a clearer view on the roles of $p_{h,t}$, h_t and d_{t-1} in driving propagation effects, consider the response of the moving cutoff $\overline{\varepsilon}_t$, which is plotted in Panel B of Figure 11.[50] Note that this response can be reconstructed from the responses of the other variables in Equation (6). As a mechanical exercise, I reconstruct the response of $\overline{\varepsilon}_t$, but consider two variations. First, I keep all other variables in Equation (6) except for $p_{h,t}$ at their steady-state levels. This reconstructed response is also plotted in Panel B of Figure 11. Initially, the fall in the cutoff is about as large as observed in the original response. However, the reconstructed response is much less persistent than the original one and it is also not hump-shaped. So clearly, propagation effects are not driven by the real house price itself. Second, I repeat the exercise, but no keep all variables except for $p_{h,t}$, h_t and d_{t-1} at their steady-state levels. This reconstructed IRF is quite similar to the original one and in particular, it shows a persistent and hump-shaped decline of the cutoff. Thus, the fall in housing assets owned by the impatient households is essential in driving the propagation

[49] Equation (Equation (6) also relates the cutoff to the marginal utility of consumption, $\frac{1}{c_t}$, and the Lagrange multiplier on the borrowing constraint, $\lambda_{cc,t}$. But fluctuations in these variables are of secondary importance in terms of understanding the main sources of propagation, as will be discussed below.

[50] The shape of this response is very similar to one of the overall mobility rate.

effects.

Why do impatient households sell housing stock *in equilibrium*, following a negative preference shock?[51] Note that Equation (4), the first-order condition for housing of the impatient households, can be rewritten as:

$$\frac{p_{h,t}}{c_t} = E_t \sum_{k=0}^{\infty} \beta^k \frac{\alpha z_{h,t+k}}{h_{t+k}} + E_t \sum_{k=0}^{\infty} \beta^k \lambda_{cc,t+k} n_{m,t+k} \chi p_{h,t+k}, \tag{25}$$

and recall that the right-hand side of this equation is the shadow value of housing. The first term on the right-hand side is the present value of all future marginal utility delivered by a unit of housing in the future. The second present value arises from the fact that housing serves as collateral for loans. Figure 12 plots the response of the shadow value of housing for both types of households and shows that there is a larger fall for impatient households.

To understand why incentives to buy housing decrease more for those who are credit-constrained, note the following. For the patient households, the second present value in the first-order condition for housing always equals zero, because for them the borrowing constraint never binds (i.e., $\widetilde{\lambda}_{cc,t} = 0$ in each period t). For impatient households, however, there is a decline in the second present value following a negative housing preference shock, because the house prices, $p_{h,t}$, and the mobility rate, $n_{m,t}$, both decline.[52] Figure 12 also plots the response of the shadow value for impatient households, reconstructed from Equation (25), but with the second present value is kept at its steady-state level. Without the effects of the refinancing constraint, the decline in the shadow value is much more similar for patient and impatient households.

The intuition behind the propagation effects is that as house prices decline, a unit of housing provides fewer collateral services, creating disincentives for credit-constrained households to hold housing stock. Moreover, these households expect to move less, and thus rely more on old debt. For those reasons, they gradually decumulate housing assets. But this means that by the time house prices have recovered, they are poorer than before the shock. The patient households, who purchased additional housing stock, have become richer.[53]

[51] Recall that the aggregate stock of housing is fixed, so any reduction in housing stock owned by the impatient households must be absorbed by the patient households.

[52] The Lagrange multiplier on the refinancing constraint, $\lambda_{cc,t}$, increases following the shock, but this effect does not dominate.

[53] In the model, low mobility does not deter trade in housing stock. In reality, it is difficult for non-movers

4.4.2 The role of vacancies

Why is there a fall in vacancies following a negative housing preference shock? This decline is related to the fact that the patient households purchase housing stock from the impatient households. In order to finance these purchases, the patient households cut back on non-durable consumption expenditures, implying a decrease in their stochastic discount factor, $\widetilde{\Lambda}_{t,t+1}$. Since the firms are owned by the patient households, a decrease in $\widetilde{\Lambda}_{t,t+1}$ implies that the benefits from posting a vacancy are more heavily discounted. Therefore, vacancy posting decreases. This effect becomes clear when observing the free-entry condition, Equation (20). The intuition is that in order to take advantage of the increase in returns on housing, impatient households reduce their investments in vacancies.

4.4.3 Feedback on house prices

An advantage of the DSGE framework adopted in this paper is that one cannot only study the effects of house prices on real activity, but also feedback effects. However, it turns out that the response of the house price is quite similar across simulations with small and large mobility effects (Figure 7). To understand why feedback effects are quantitatively limited, note that the first-order condition for the patient households, Equation (24), needs to be satisfied in any of the model versions. This equation makes clear that all possible feedback effects of real activity on house prices must operate through the marginal utility of non-durable consumption of the patient households. Whereas impatient households suffer income losses when job offer rejection increases, patient households are not directly affected.[54]

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to decrease their housing stock beyond cutting back on maintanance. But in reality there do exist other assets in which non-movers can trade much more flexibly. For example, households can take on credit card debt or decumulate savings that were initially intended for the downpayment needed for a future home purchase.

[54] An increase in job offer rejection affects patient households via a decline in firm profitability, but this effect is small.

5 Concluding remarks

Both the empirical and the theoretical evidence presented in this paper support the idea that geographical mobility can be an important channel through which changes in house prices spill over to the real economy. The model that was developed captures the essence of the mobility channel, but has been kept relatively simple in order to retain transparency and tractability. But it would be worthwhile to enrich the way in which housing and labor markets are modeled.

One obvious simplification of the current model is that it does not feature an endogenous choice between renting and owning. This would endow unemployed homeowners with the opportunity to accept a job offer and move into a rental home. In reality, however, homeowners and renters, as well as their homes, have different characteristics. Also, due to information asymmetries between landlords and tenants, renters typically have limited discretion over their homes. So the extent to which effects might be dampened depends on how willing homeowners are to move into rental homes. Moreover, an increase in the relative demand for rental homes can be expected to push up prices in rental markets, relative to prices in markets for owner-occupied housing.

Another interesting extension would be to introduce search frictions in the housing market. In the current model, the housing stock is essentially traded on a spot market. Ngai and Tenreyro (2009) show that a model with search frictions in the housing market can generate joint (seasonal) movements in house prices and transaction volumes. One could expect that in the presence of such frictions, a decline in mobility among credit-constrained households creates a fall in mobility among the other households.

A final simplification of my model is that is remains within the complete insurance markets paradigm. This has the benefit of simplicity. However, since housing wealth and financial wealth have been shown to be important drivers of fluctuations in mobility, dynamics are potentially even richer in a model with wealth heterogeneity.

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Appendix

A. Individual versus joint housing shocks

In section 2.2, a joint shock to house prices and home sales in the VAR was discussed. Figures 13 and 14 display the responses to a house price shock and a home sales shock individually. The IRFs are qualitatively very similar. In particular, house prices, home sales and the unemployment outflow hazard fall significantly. An interesting difference is that following a home sales shock, the real house price declines more persistently. Also, the decline in the outflow hazard declines is more prolonged following a home sales shock, while this is hardly the case for vacancies.

B. Optimization problem of the impatient households

The optimization problem reads:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_t + \alpha z_{h,t} \ln h_t + \kappa n_{u,t} + u_{lo,t} \right\},$$

$$s.t. \quad c_t + p_{h,t}\left(h_t - h_{t-1}\right) + n_{m,t}\zeta + R_{t-1}d_{t-1} = \left(1 - n_{u,t}\right) z_{\theta,t}\theta\xi + d_t,$$

$$d_t = n_{m,t}\chi p_{h,t} h_t + \left(1 - n_{m,t}\right) d_{t-1},$$

$$n_{s,t} = n_{u,t} + \rho_u \left(1 - n_{u,t}\right),$$

$$n_{u,t} = n_{s,t-1}\left(1 - \widehat{g}_{t-1} + \omega \widehat{g}_{t-1}\left(1 - F\left(\overline{\varepsilon}_{do,t}\right)\right)\right),$$

$$n_{m,t} = \omega \widehat{g}_{t-1} n_{s,t-1} F\left(\overline{\varepsilon}_{do,t}\right) + \left(1 - \omega \widehat{g}_{t-1} n_{s,t-1}\right) F\left(\overline{\varepsilon}_t\right),$$

where

$$u_{lo,t} = \omega \widehat{g}_{t-1} n_{s,t-1} \left[\psi F\left(\overline{\varepsilon}_{do,t}\right) + \int_{\overline{\varepsilon}_{do,t}}^{\infty} \varepsilon dF\left(\varepsilon\right) \right] + \left(1 - \omega \widehat{g}_{t-1} n_{s,t-1}\right) \left[\psi F\left(\overline{\varepsilon}_{t}\right) + \int_{\overline{\varepsilon}_{t}}^{\infty} \varepsilon dF\left(\varepsilon\right) \right].$$

The first-order conditions are:

$$\begin{aligned}
\frac{\alpha z_{h,t}}{h_t} - \frac{p_{h,t}}{c_t} + \beta E_t \frac{p_{h,t+1}}{c_{t+1}} + \lambda_{cc,t} n_{m,t} \chi p_{h,t} &= 0, \\
\frac{1}{c_t} - \lambda_{cc,t} + \beta E_t \left(\lambda_{cc,t+1} \left(1 - n_{m,t+1}\right) - \frac{R_t}{c_{t+1}} \right) &= 0, \\
\beta E_t \left(\begin{array}{c} +\omega \widehat{g}_t \left[\psi F\left(\overline{\varepsilon}_{do,t+1}\right) + \int_{\overline{\varepsilon}_{do,t+1}}^{\infty} \varepsilon dF\left(\varepsilon\right) \right] - \omega \widehat{g}_t \left[\psi F\left(\overline{\varepsilon}_{t+1}\right) + \int_{\overline{\varepsilon}_{t+1}}^{\infty} \varepsilon dF\left(\varepsilon\right) \right] \\ -\lambda_{nu,t+1} \left(1 - \widehat{g}_t + \omega \widehat{g}_t \left(1 - F\left(\overline{\varepsilon}_{do,t+1}\right)\right)\right) \\ -\lambda_{nm,t+1} \omega \widehat{g}_t \left(F\left(\overline{\varepsilon}_{do,t+1}\right) - F\left(\overline{\varepsilon}_{t+1}\right)\right) \end{array} \right) &= \lambda_{ns,t}, \\
\frac{\zeta}{c_t} - \lambda_{cc,t} \left(\chi p_{h,t} h_t - d_{t-1}\right) - \lambda_{nm,t} &= 0, \\
\psi - \overline{\varepsilon}_t - \lambda_{nm,t} &= 0, \\
\psi - \overline{\varepsilon}_{do,t} + \lambda_{nu,t} - \lambda_{nm,t} &= 0, \\
\kappa - \frac{z_{\theta,t} \theta \xi}{c_t} + \lambda_{ns,t} \left(1 - \rho_u\right) + \lambda_{nu,t} &= 0,
\end{aligned}$$

where $\lambda_{cc,t}$, $\lambda_{ns,t}$, $\lambda_{nm,t}$, and $\lambda_{nu,t}$ are the Lagrange multipliers of the constraints for borrowing, job searchers, mobility and unemployment, respectively. These conditions can be combined to obtain:

$$\begin{aligned}
\frac{\alpha z_{h,t}}{h_t} - \frac{p_{h,t}}{c_t} + \beta E_t \frac{p_{h,t+1}}{c_{t+1}} + \lambda_{cc,t} n_{m,t} \chi p_{h,t} &= 0, \\
\frac{1}{c_t} - \lambda_{cc,t} + \beta E_t \left(\lambda_{cc,t+1} \left(1 - n_{m,t+1}\right) - \frac{R_t}{c_{t+1}} \right) &= 0, \\
\frac{\zeta}{c_t} - \lambda_{cc,t} \left(\chi p_{h,t} h_t - d_{t-1}\right) + \overline{\varepsilon}_t - \psi &= 0, \\
\kappa - \frac{z_{\theta,t} \theta \xi}{c_t} + \overline{\varepsilon}_{do,t} - \overline{\varepsilon}_t + \left(1 - \rho_u\right) G_t &= 0,
\end{aligned}$$

where

$$G_t = \beta E_t \left(\begin{array}{c} -\omega \widehat{g}_t \int_{\overline{\varepsilon}_{t+1}}^{\overline{\varepsilon}_{do,t+1}} \varepsilon dF\left(\varepsilon\right) + \left(\overline{\varepsilon}_{do,t+1} - \overline{\varepsilon}_{t+1}\right) \left(1 - \widehat{g}_t + \omega \widehat{g}_t \left(1 - F\left(\overline{\varepsilon}_{do,t+1}\right)\right)\right) \\ +\overline{\varepsilon}_{t+1} \omega \widehat{g}_t \left(F\left(\overline{\varepsilon}_{do,t+1}\right) - F\left(\overline{\varepsilon}_{t+1}\right)\right) \end{array} \right).$$

The location satisfaction shock follows a normal distribution with mean zero and standard deviation σ^2. It can be shown that:

$$\int_{\overline{\varepsilon}_{t+1}}^{\overline{\varepsilon}_{do,t+1}} \varepsilon dF(\varepsilon) = \frac{\sigma}{\sqrt{2\pi}} \left(\exp\left(-\frac{1}{2}\frac{\overline{\varepsilon}_{t+1}^2}{\sigma^2} \right) - \exp\left(-\frac{1}{2}\frac{\overline{\varepsilon}_{do,t+1}^2}{\sigma^2} \right) \right).$$

Tables and Figures

Table 1: Standard deviations and correlations: data.

	house pr.	GDP	home sales	unemp.rate	vacancies	outfl.haz.
Standard deviations						
relative to house price	1	0.368	2.445	2.675	3.008	2.524
Correlations						
	house pr.	GDP	home sales	unemp.rate	vacancies	outfl.haz.
gdp	0.554	1				
home sales	0.552	0.608	1			
unemploment rate	−0.437	−0.858	−0.331	1		
vacancies	0.400	0.819	0.472	−0.895	1	
unemp. outflow hazard	0.464	0.861	0.360	−0.966	0.888	1

Notes: Data are quarterly. Following Shimer (2005), variables are logged and HP-detrended with smoothing parameter value 10^5.

Table 2: Correlations of forecast errors implied by the VAR.

	1 year ahead		3 years ahead		5 years ahead	
	RHP	HS	RHP	HS	RHP	HS
A. Unconditional						
real house price (RHP)	1	-	1	-	1	-
home sales (HS)	0.619	1	0.510	1	0.148	1
unemployment outflow hazard	0.308	0.404	0.584	0.190	0.613	0.043
B. Conditional on housing shocks						
real house price (RHP)	1	-	1	-	1	-
home sales (HS)	0.596	1	0.467	1	0.078	1
unemployment outflow hazard	0.633	0.719	0.895	0.471	0.884	0.269

Notes: Following Den Haan (2000), the unconditional measure of comovement between two variables is constructed as the products of their IRFs, summed over all nine shocks. The conditional comovement measure is constructed by summing only over the two housing market shocks.

Table 3: Parameter theoretical model (benchmark calibration).

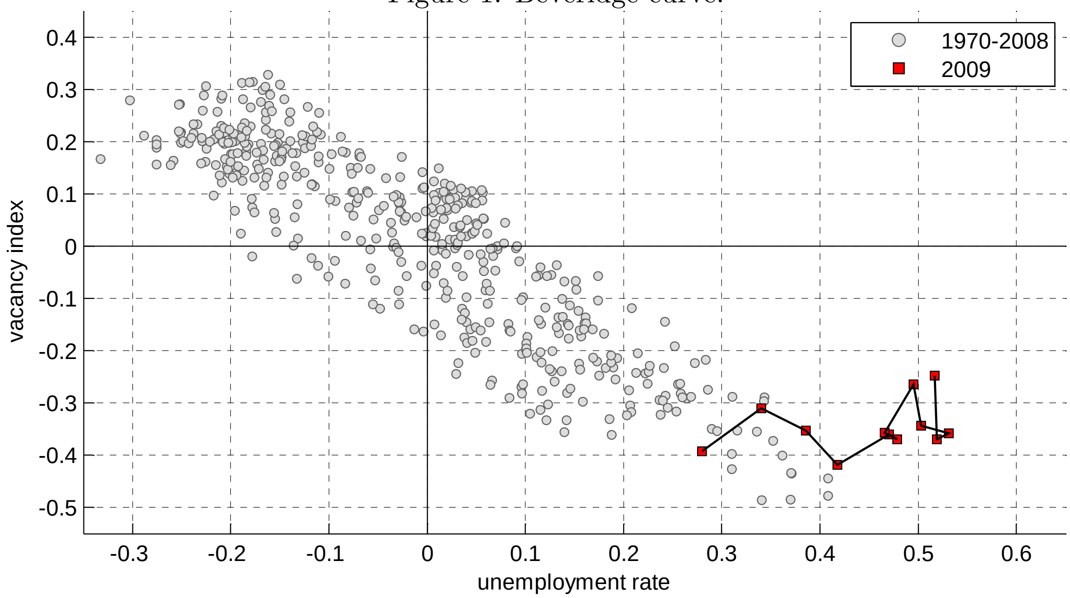
parameter	description	value	source/target
β	discount factor impatient h.h.	0.9899	Iacoviello and Neri (2010)
γ	discount factor patient h.h.	0.9975	Iacoviello and Neri (2010)
α^{imp}	housing pref. impatient h.h.	0.139	steady state
α^{pat}	housing pref. patient h.h.	0.043	steady state
ψ	utility from new location	-7.905	steady state
σ	stdev. location preference shock	3.5	volatility mobility
ζ	moving cost	1.6	Stokey (2009)
ρ_u	rate of job destruction	0.035	Gertler and Trigari (2009)
η	elasticity parameter matching function	0.5	Gertler and Trigari (2009)
μ	level parameter matching function	0.536	steady state
ϑ	vacancy cost	0.181	steady state
ω	fraction of long-distance job offers	1/3	no source, check for robustness
ξ	wage rule parameter	0.98	2% accounting profits
κ	utility from unemployment	-4.898	steady state
ν	share impatient h.h.	0.2	AHS / SCF data
χ	collateral requirement	0.8	Cambell and Hercowitz (2009)
ρ_h	autocorr. housing pref. process	0.983	same as tech. process
ρ_a	autocorr. technology process	0.983	Kydland and Prescott (1982)

Table 4: Standard deviations and correlations. Model with only productivity shocks.

	house pr.	output	mob.rate	unemp.rate	vacancies	outfl.haz.
Standard deviations						
relative to house price	1	0.926	2.408	1.566	1.125	1.208
	(0)	(0.006)	(0.136)	(0.024)	(0.041)	(0.007)
Correlations						
	house pr.	output	mob.rate	unemp.rate	vacancies	outfl.haz.
output	0.999	1	-	-	-	-
	(0.001)	(0)				
mobility rate	0.966	0.969	1	-	-	-
	(0.014)	(0.012)	(0)			
unemploment rate	−0.931	−0.932	−0.933	1	-	-
	(0.019)	(0.020)	(0.020)	(0)		
vacancies	0.961	0.962	0.914	−0.798	1	-
	(0.008)	(0.008)	(0.016)	(0.050)	(0)	
outflow hazard	0.960	0.961	0.948	−0.979	0.860	1
	(0.012)	(0.012)	(0.014)	(0.006)	(0.034)	(0)

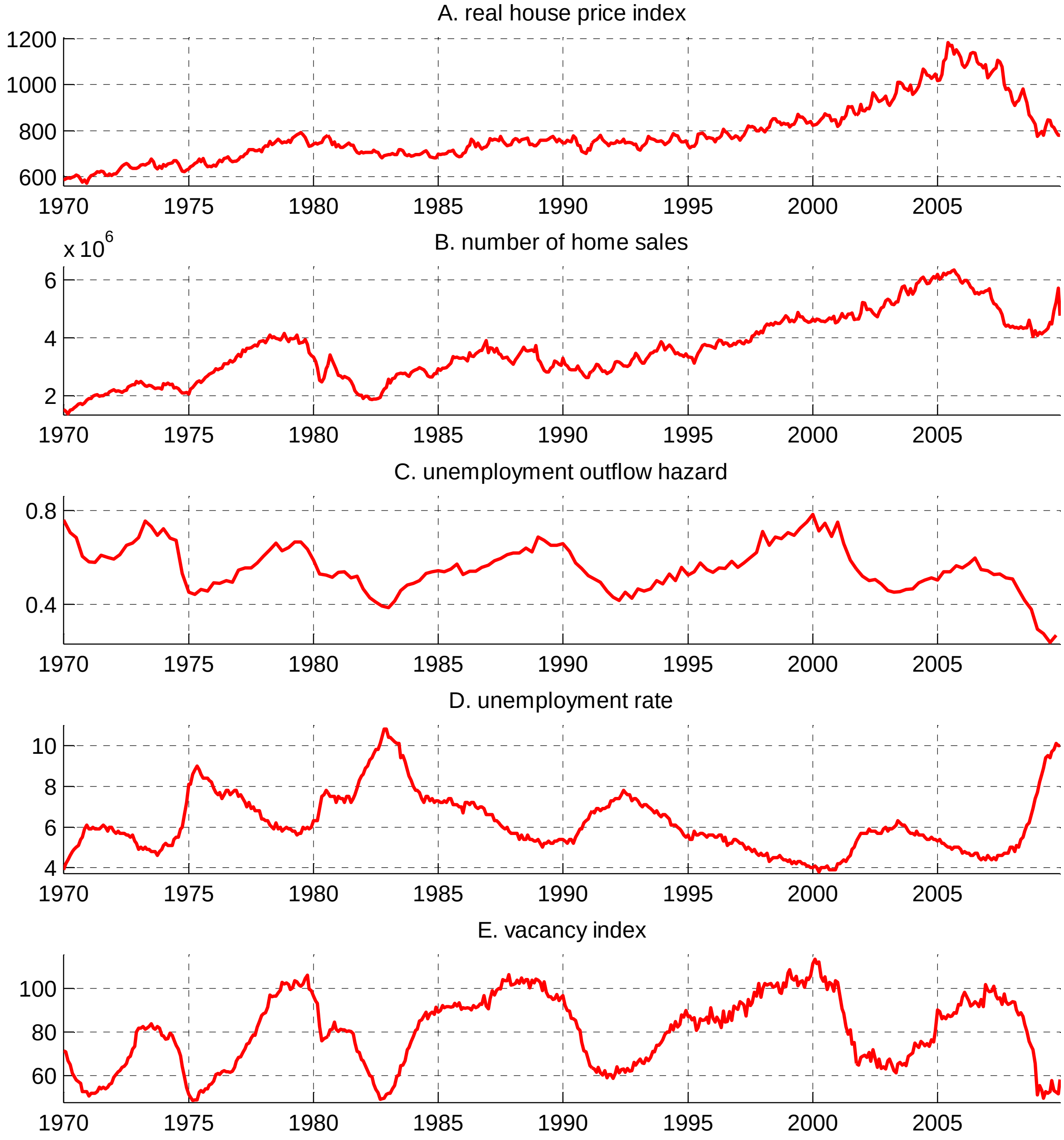
Notes: The business cycle statistics are averages across 10000 simulations. Standard deviations over these simulations are displayed between brackets. Each simulation has a monthly frequency, has length 1480 and starts from the steady state. For each simulation, the first 1000 timer periods were discarded so that 40 years of data remained. Variables were logged and HP-detrended with smoothing parameter value $81{\cdot}10^5$. This value corresponds to the one used by Shimer (2005) for quarterly data, but is adjusted for the frequency using the factor recommended by Ravn and Uhlig (2002).

Figure 1: Beveridge curve.



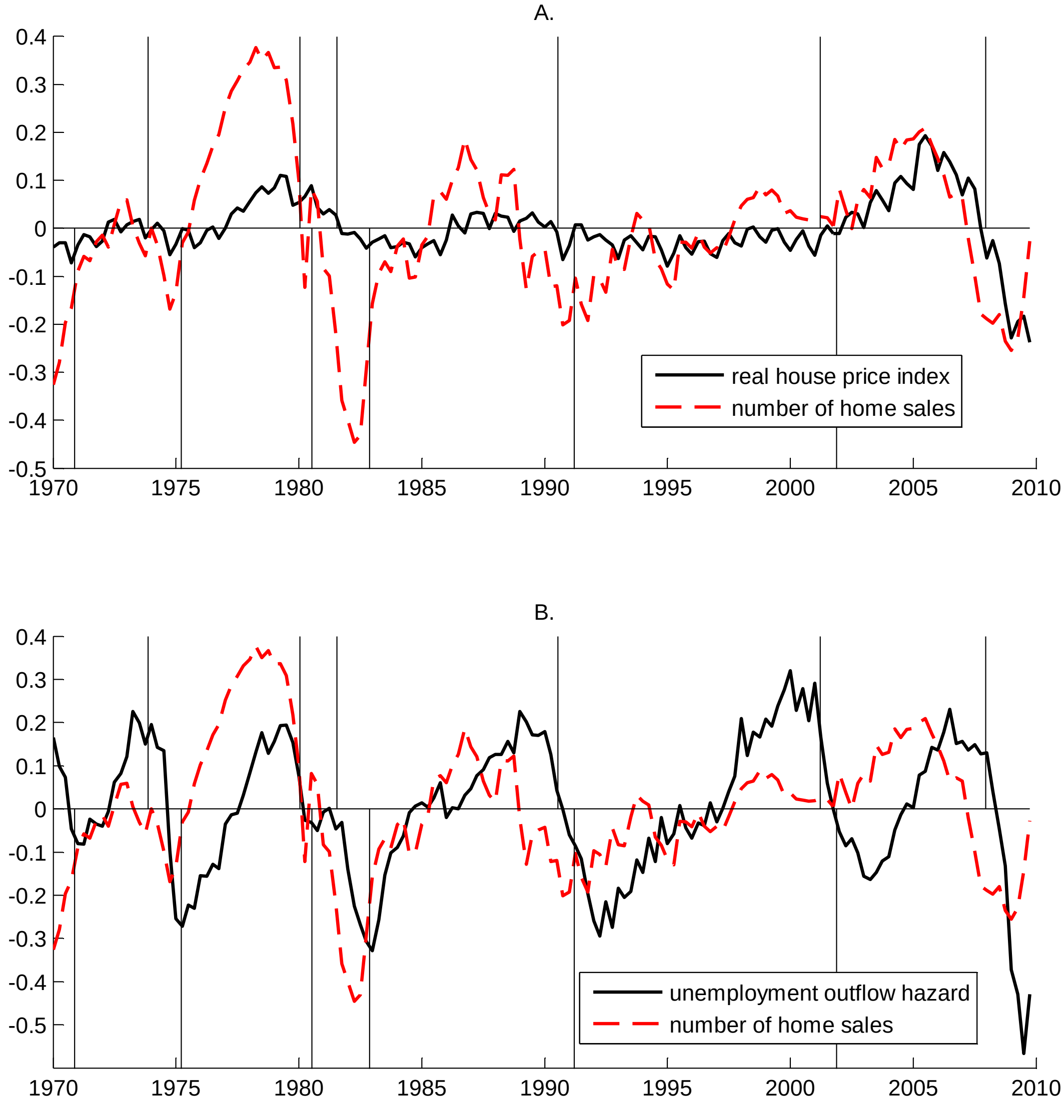
Notes: Log deviations from trend. Data are monthly and cover the period from January 1970 until December 2009. Variables were logged and HP-detrended with smoothing parameter value $81{\cdot}10^5$. This value corresponds to the one used by Shimer (2005) for quarterly data, but is adjusted for the frequency using the factor recommended by Ravn and Uhlig (2002). Source unemployment rate: U.S. Department of Labor. Source vacancy index: Barnichon (2009).

Figure 2: Raw data series.



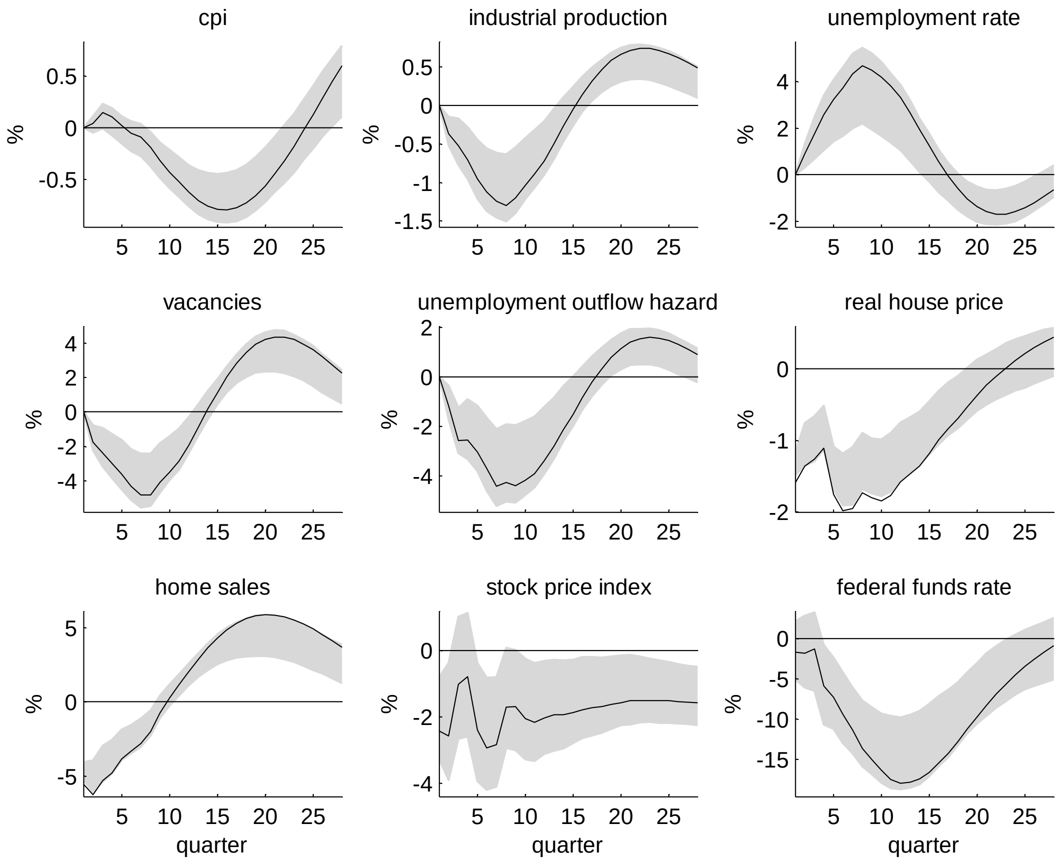
Notes: Quarterly observations. Monthly series for house prices, home sales, the unemployment rate and the vacancy index were converted into quarterly series by simple averaging. Sources: see main text.

Figure 3: Cyclical components.



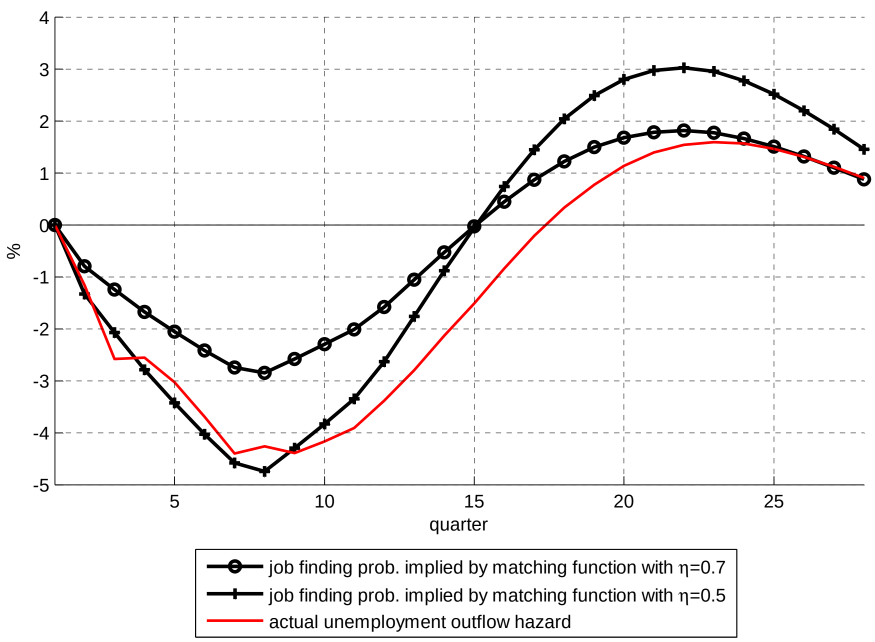
Notes: Log deviations from trend. Following Shimer (2005), variables are HP-detrended with smoothing parameter value 10^5. The vertical lines above (below) the x-axes denote business cycle peaks (troughs) as dated by the NBER.

Figure 4: Structural VAR: housing market shock.



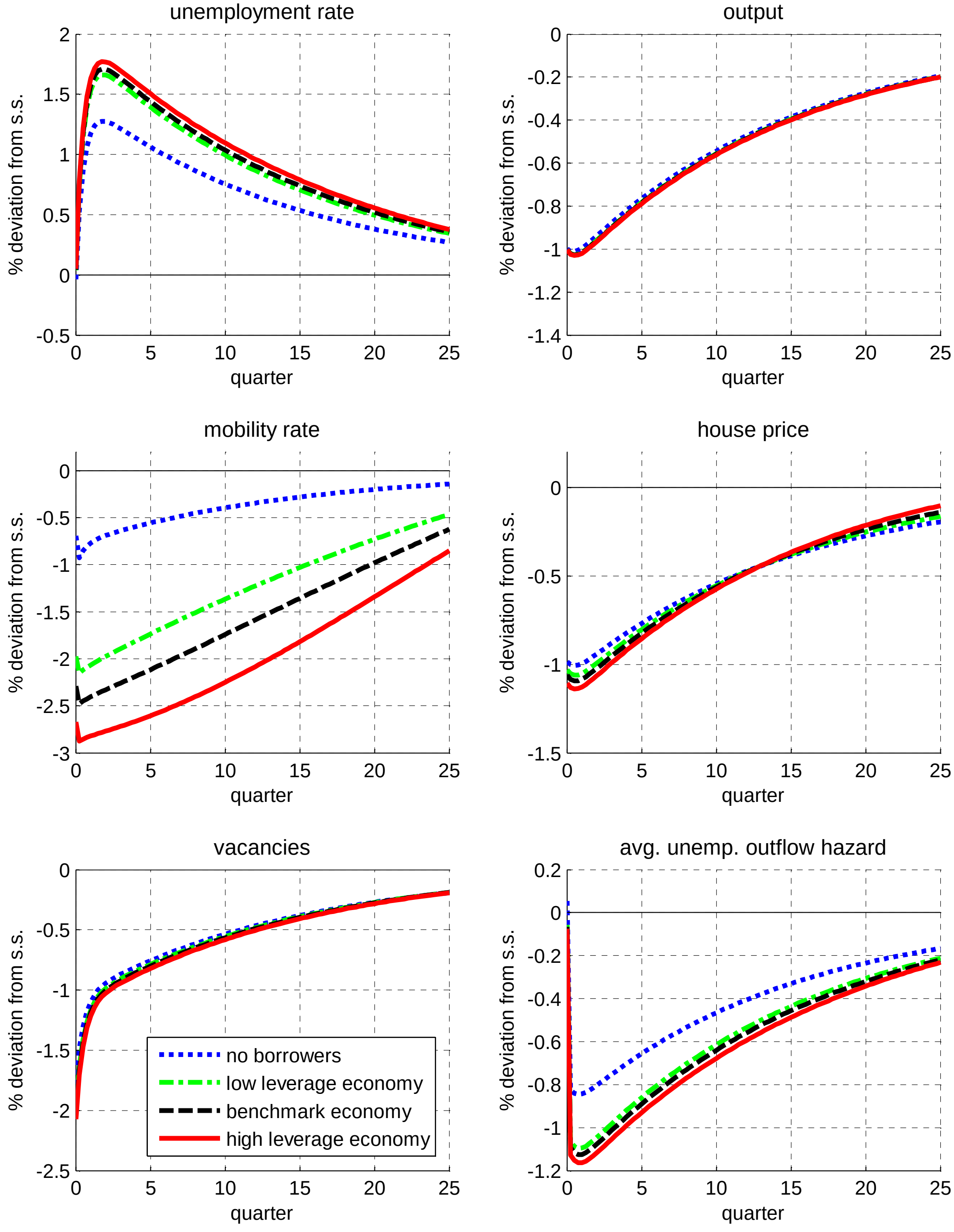
Notes: Responses to a joint and negative one standard deviation shock in real house prices and homesales. Grey areas are 90% confidence intervals, which are obtained by a bootstrap procedure.

Figure 5: Structural VAR: housing market shock. Unemployment ouflow hazard implied by the matching function versus the actual outflow hazard.



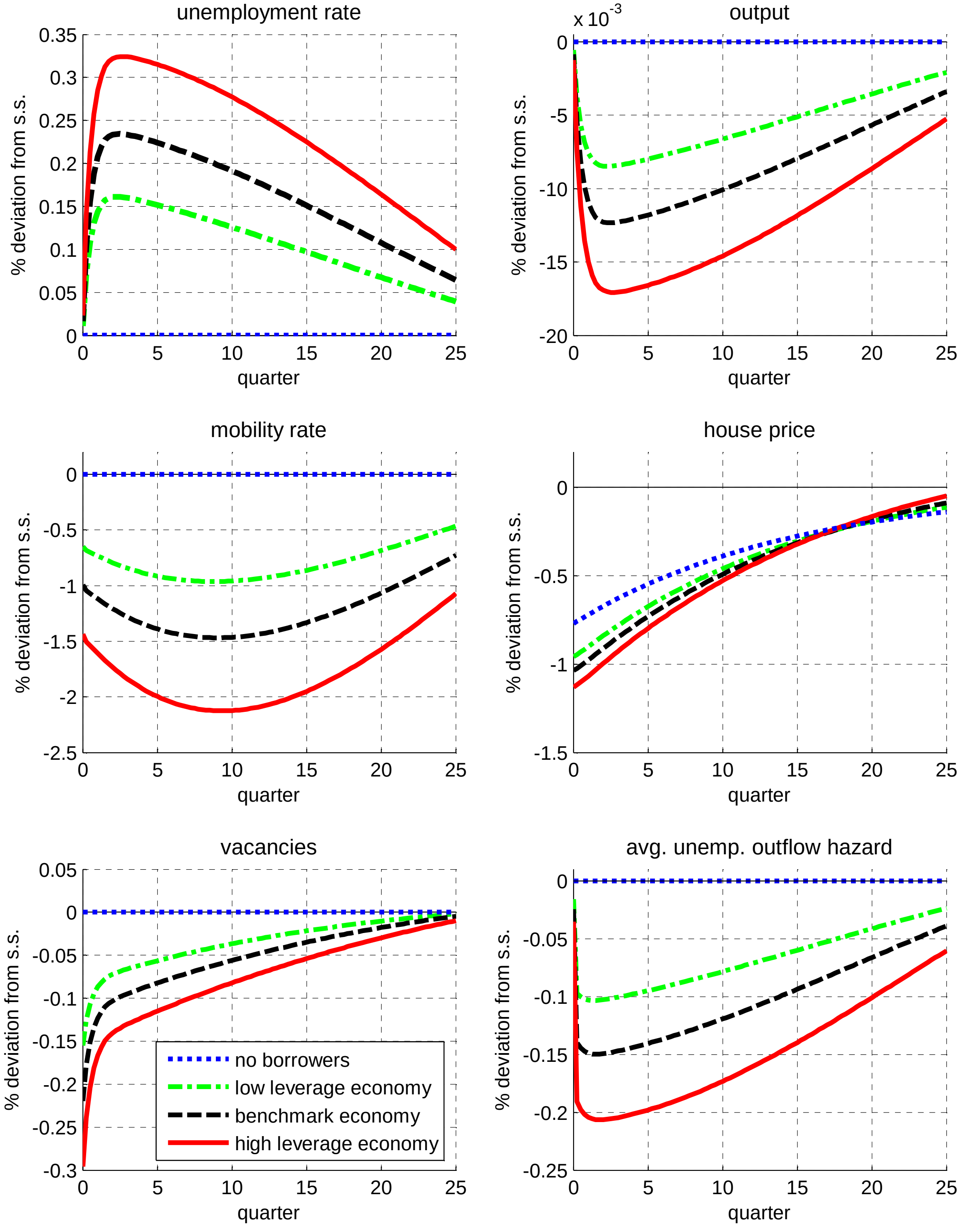
Notes: Responses to a joint and negative one standard deviation shock in real house prices and homesales. VAR responses are plotted for the unemployment outflow hazard and the job finding probability implied by a matching function of the form $f(n_{u,t}, v_t) = \mu n_{u,t}^{\eta} v_t^{1-\eta}$, for various values of η.

Figure 6: Responses to a productivity shock in the theoretical model.



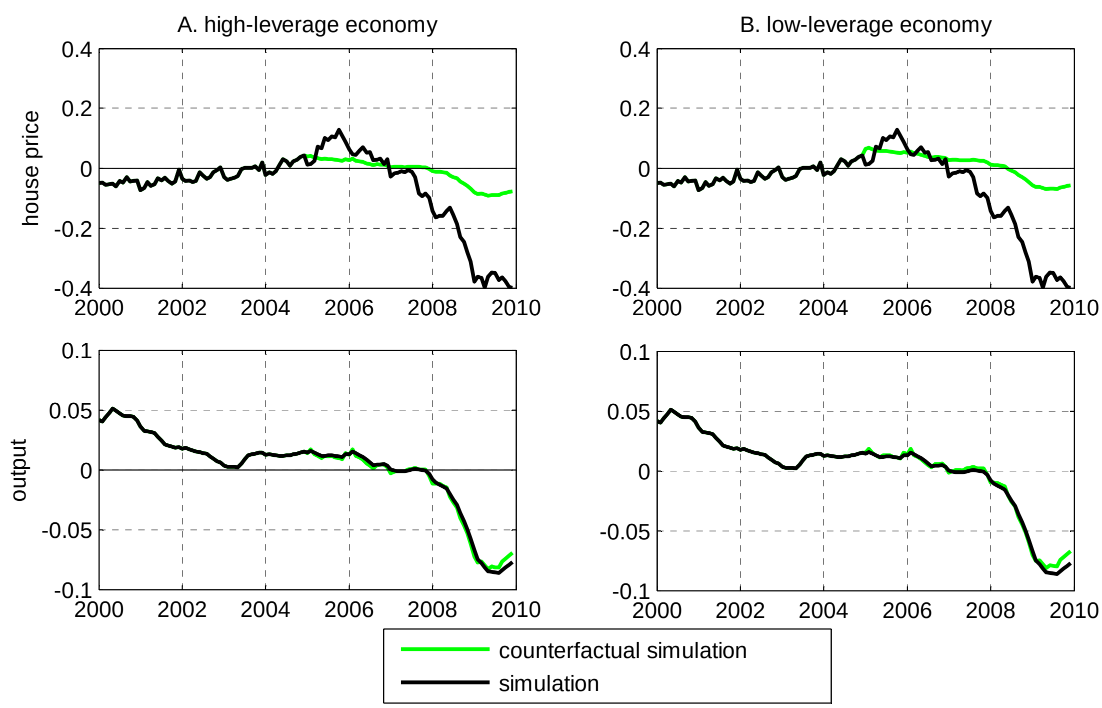
Notes: Responses to a 1% decline in productivity for the high-leverage economy ($\nu = 0.25, \chi = 0.85$), the benchmark economy ($\nu = 0.2, \chi = 0.8$), the low-leverage economy ($\nu = 0.15, \chi = 0.75$), and the economy without borrowers ($\nu = 0$).

Figure 7: Responses to a housing preference shock in the theoretical model.



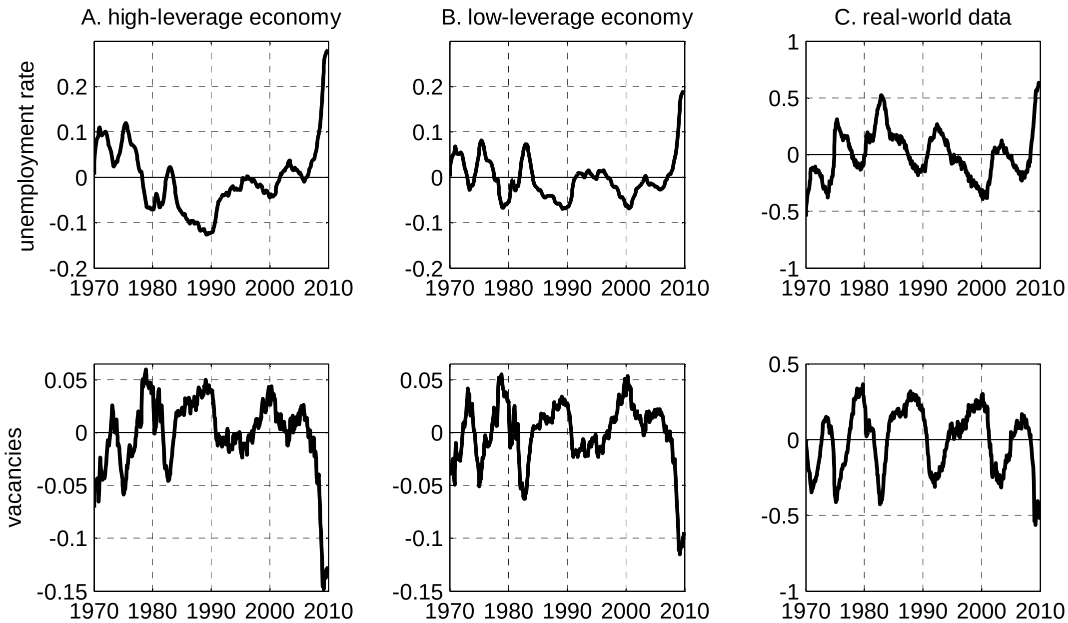
Notes: Responses to a housing preference shock for the high-leverage economy ($\nu = 0.25, \chi = 0.85$), the benchmark economy ($\nu = 0.2, \chi = 0.8$), the low leverage-economy ($\nu = 0.15, \chi = 0.75$), and the economy without borrowers ($\nu = 0$).

Figure 8: Great recession experiment: model simulations.



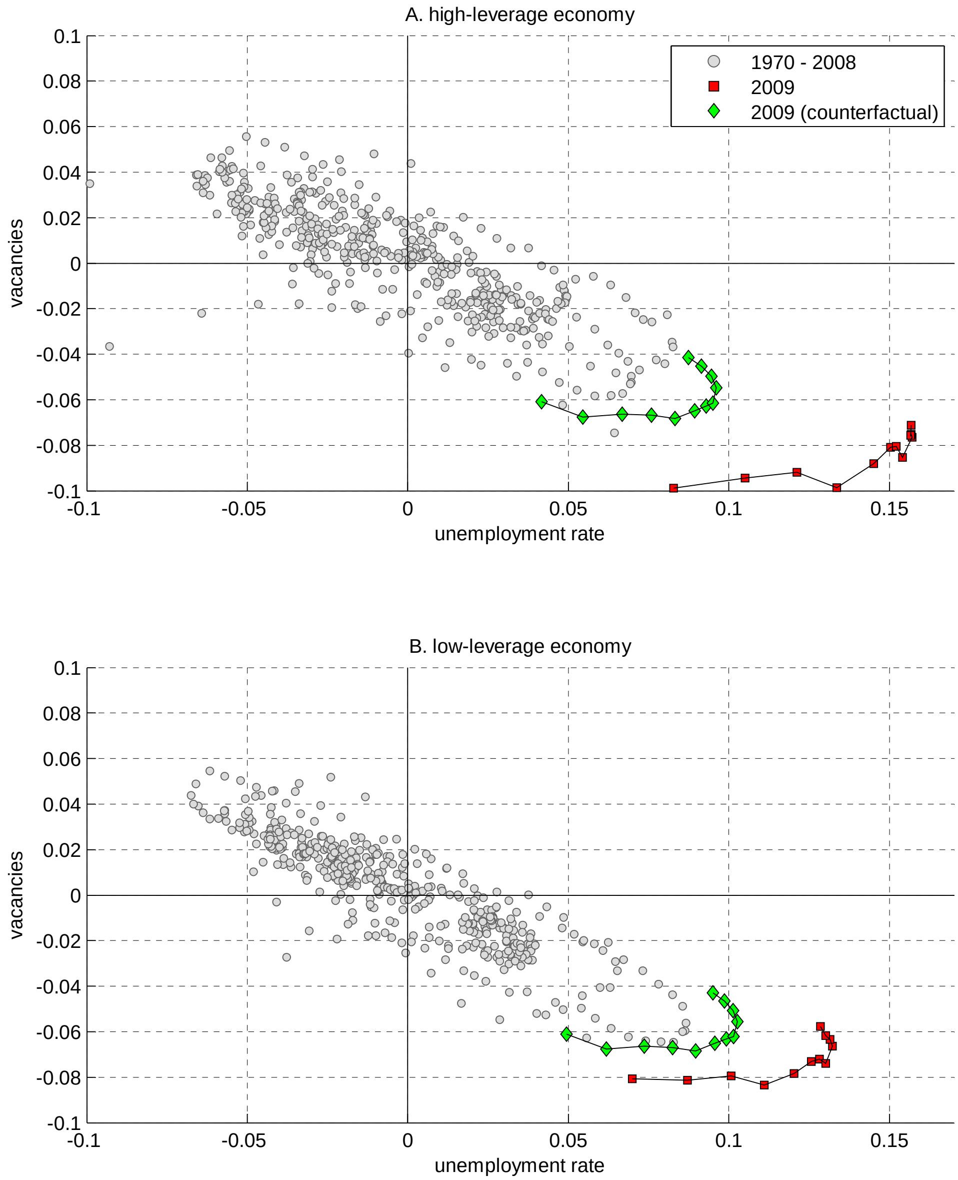
Notes: Model simulations for the high-leverage economy ($\nu = 0.25, \chi = 0.85$) and the low-leverage economy ($\nu = 0.15, \chi = 0.75$). "Counterfactual" denotes simulations with housing preference shock innovations set to zero from 2005 onwards. Numbers on the y-axes are log deviations from the steady state.

Figure 9: Great recession experiment: simulations and real-world data.



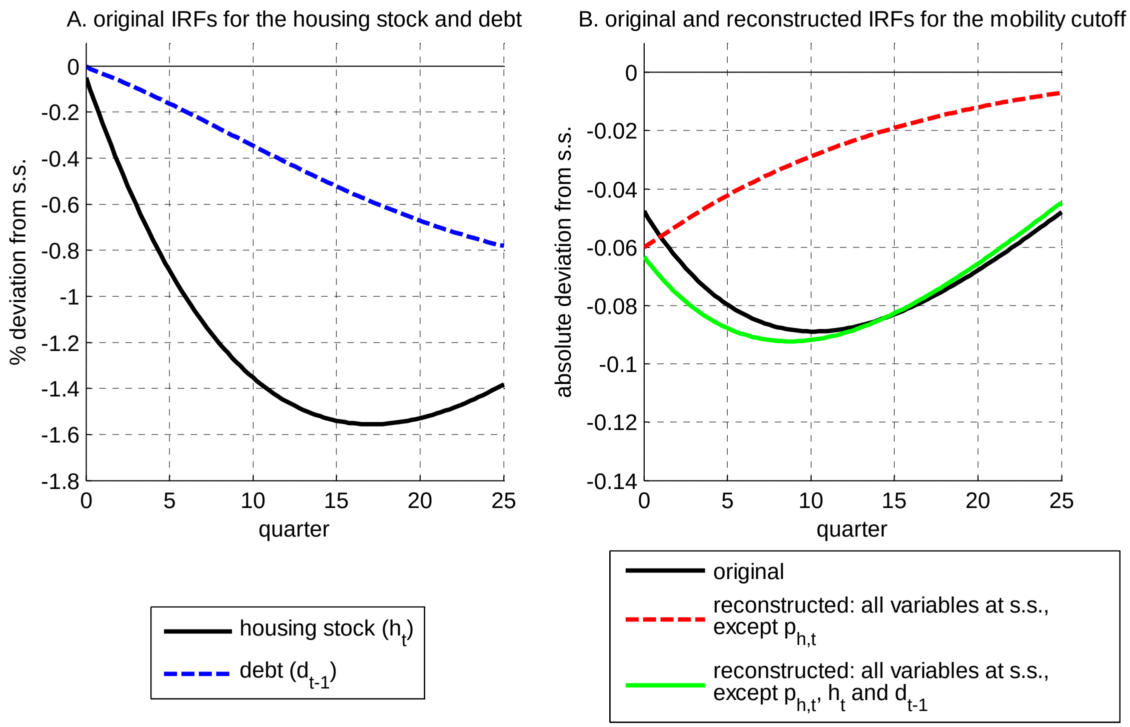
Notes: Data and model simulations for the high-leverage economy ($\nu = 0.25, \chi = 0.85$) and the low-leverage economy ($\nu = 0.15, \chi = 0.75$). The real-world data series are in logs and are linearly detrended. Numbers on the y-axes are log deviations from the steady state / trend.

Figure 10: Great recession experiment: Beveridge curves predicted by the model.



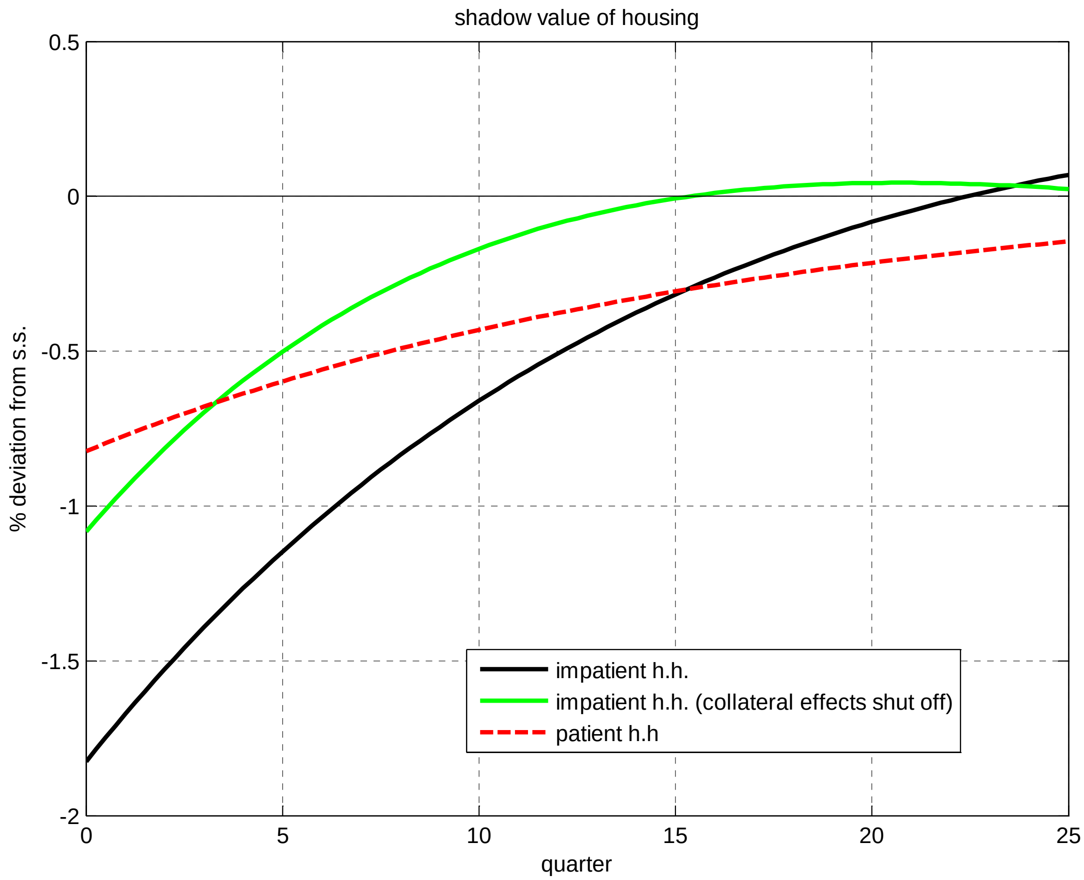
Notes: Log deviations from the steady state. Model simulations for the high-leverage economy ($\nu = 0.25, \chi = 0.85$) and the low-leverage economy ($\nu = 0.15, \chi = 0.75$). "Counterfactual" denotes simulations with housing preference shock innovations set to zero from 2005 onwards. For the sake of comparability, simulated data are HP-detrended as in Figure 1. The smoothing parameter value is $81 \cdot 10^5$.

Figure 11: Responses to a housing preference shock in the benchmark model : impatient households.



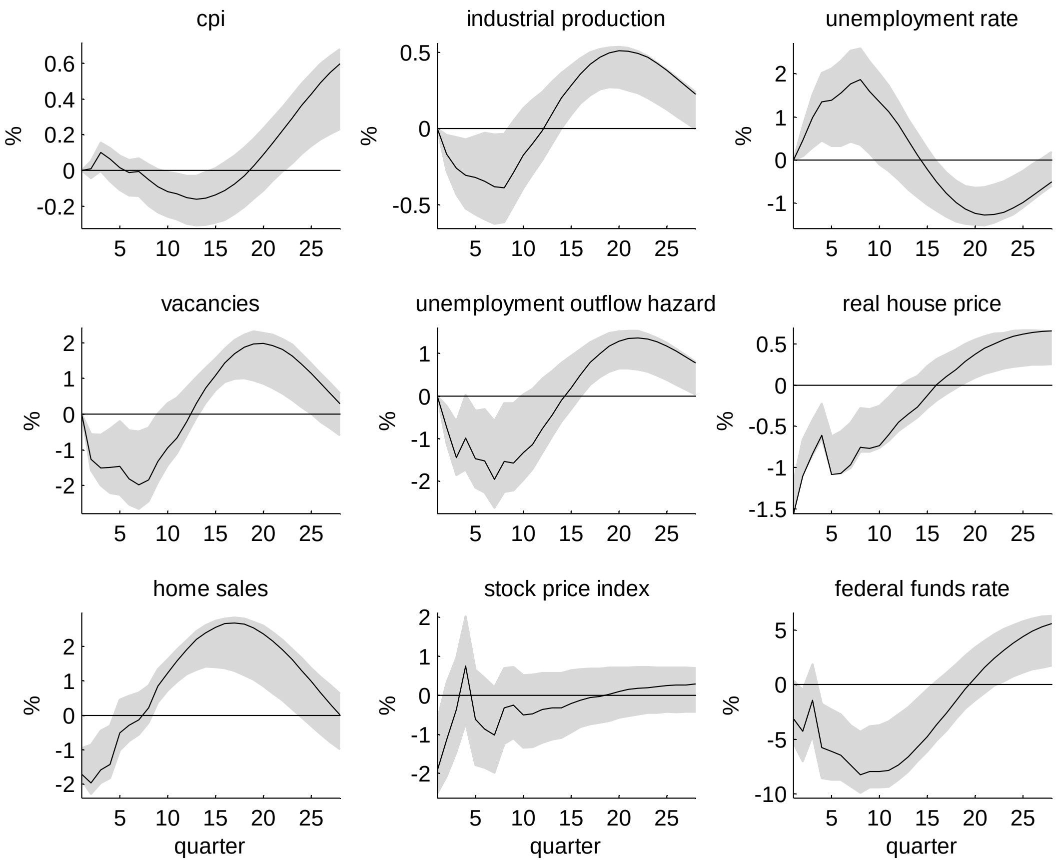
Notes: Responses of housing stock and debt of the impatient household (Panel A), and of the mobility cutoff (Panel B) to a negative housing preference shock. The reconstructed responses in Panel B are obtained using Equation (6), but with the indicated variables kept at their steady-state levels.

Figure 12: Responses to a housing preference shock in the benchmark model.



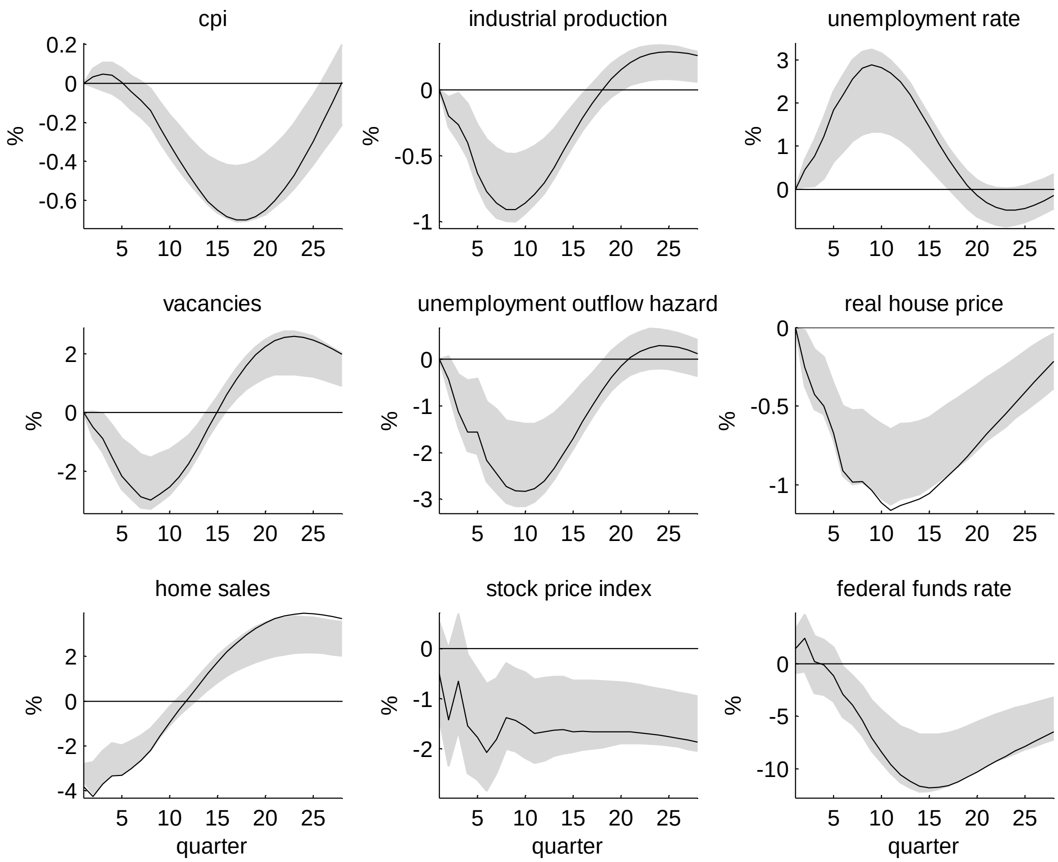
Notes: Responses of the shadow value of housing for the patient and impatient households to a negative housing preference shock. The figure also shows the IRF for the shadow value of the impatient households when collateral effects are shut off. This IRF is constructed from equation (25), but with the second present value term kept equal to its steady state level.

Figure 13: House price shock.



Notes: Responses to a negative one standard deviation shock in real house prices. Grey areas are 90% confidence intervals, which are obtained by a bootstrap procedure.

Figure 14: Home sales shock.



Notes: Responses to a negative one standard deviation shock in home sales. Grey areas are 90% confidence intervals, which are obtained by a bootstrap procedure.