Collateral Constraints and Macroeconomic Asymmetries

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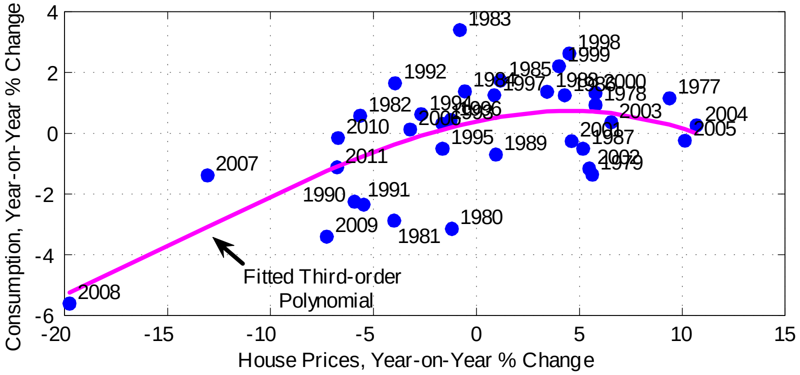

1. House Prices and Consumption are positively correlated in US data
2. Their correlation seems to get larger when house prices are low

This Paper

- How much do Housing Boom and Bust cycles contribute to movements in consumption?
  We address this question with a general equilibrium model estimated with Bayesian methods.
  In the model, housing collateral constraints may bind or not, depending on housing wealth, leverage, and the state of the economy.

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- We find that:
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  Housing collapse of 2006-2010: Tighter collateral constraints explain three quarters of the fall in consumption.

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  Housing collapse of 2006-2010: Tighter collateral constraints explain three quarters of the fall in consumption.
- Asymmetry is supported by regressions on state- and MSA-level data

The Basic Idea

- Household maximizes $U = E_0 \sum_{t=0}^{\infty} \beta^t \left(\log c_t + j \log h_t \right)$ subject to

$$\begin{aligned} c_t + q_t h_t &= y + b_t - R b_{t-1} + q_t h_{t-1} (1 - \delta) \\ b_t &\leq m q_t h_t \\ \log q_t &= \rho \log q_{t-1} + v_t, \; v_t \sim N\left(0, \sigma^2\right) \end{aligned}$$

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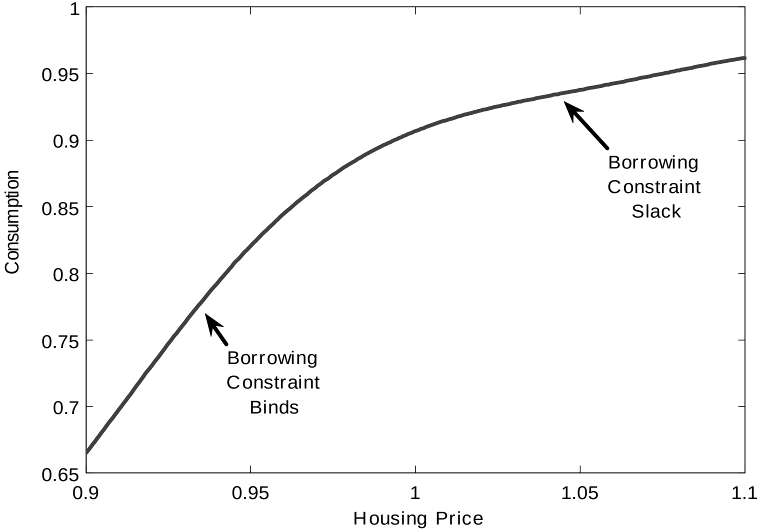
- Consumption function will have the property that consumption increases with house prices, but at a decreasing rate.
- When q is low, borrowing constraint binds, and consumption moves in lockstep with q
  When q is high, borrowing constraint is slack, and consumption is less sensitive to q

Model's solution. Consumption function, C(q,$\bar{b}$,$\bar{h}$)



In summary:

1. High house prices are associated with slack borrowing constraints, and with a lower sensitivity of consumption to changes in house prices.
2. When household borrowing is constrained – more likely when house prices are low and initial debt is high – the sensitivity of consumption to changes in house prices becomes large.

These ideas are developed further both in the full model and in the empirical analysis to follow.

The Full Model: Overview

- Standard monetary DSGE model augmented to include a housing collateral constraint along the lines of Kiyotaki and Moore (1997), Iacoviello (2005), and Liu, Wang, and Zha (2013).
  Allow for the dual role of housing as a durable good and as collateral for "impatient" households.
- To this framework, add two elements that generate important nonlinearities.
  1. Monetary policy may be constrained by the ZLB.
  2. Housing collateral constraint binds only occasionally.
- (Monetary DSGE model: RBC core with price and wage rigidities, habits in consumption, and investment adjustment costs)

The Model: Key equations

Within each group of patient and impatient households, a representative household maximizes:

$$E_0 \sum_{t=0}^{\infty} \beta^t \mathrm{z}_t \left(\Gamma \log \left(c_t - \varepsilon c_{t-1} \right) + \mathrm{j}_t \log h_t - \frac{1}{1+\eta} n_t^{1+\eta} \right),$$

$$E_0 \sum_{t=0}^{\infty} \left(\beta' \right)^t \mathrm{z}_t \left(\Gamma' \log \left(c'_t - \varepsilon c'_{t-1} \right) + \mathrm{j}_t \log h'_t - \frac{1}{1+\eta} n_t'^{1+\eta} \right).$$

z_t : intertemporal preference shock

j_t : housing preference/demand shock

Households

- Patient households maximize their utility subject to:

$$c_t + q_t h_t + i_t = \text{resources}_t - b_t,$$

where resources_t includes wage, capital income, housing wealth, dividends.

- Impatient households do not accumulate capital. Their maximum borrowing b_t is given by the value of their home times the LTV ratio $m = 0.9$:

$$c'_t + q_t h'_t = \text{resources}'_t + b_t,$$
$$b_t \leq \gamma \frac{b_{t-1}}{\pi_t} + (1-\gamma)\, \text{m} q_t h'_t$$

where resources_t includes wage and housing wealth

- Borrowing constraint allows for inertia, measured by γ

Monetary Policy and Supply Side

- Monetary policy follows Taylor rule that responds to annual inflation and GDP in deviation from trend, subject to the zero lower bound (ZLB):

$$R_t = \max\left[1, R_{t-1}^{r_R}\widetilde{\pi}_{a,t}^{(1-r_R)r_\pi}\widetilde{Y}_{t-1}^{(1-r_R)r_Y}\overline{R}^{1-r_R}\mathrm{u}_{r,t}\right].$$

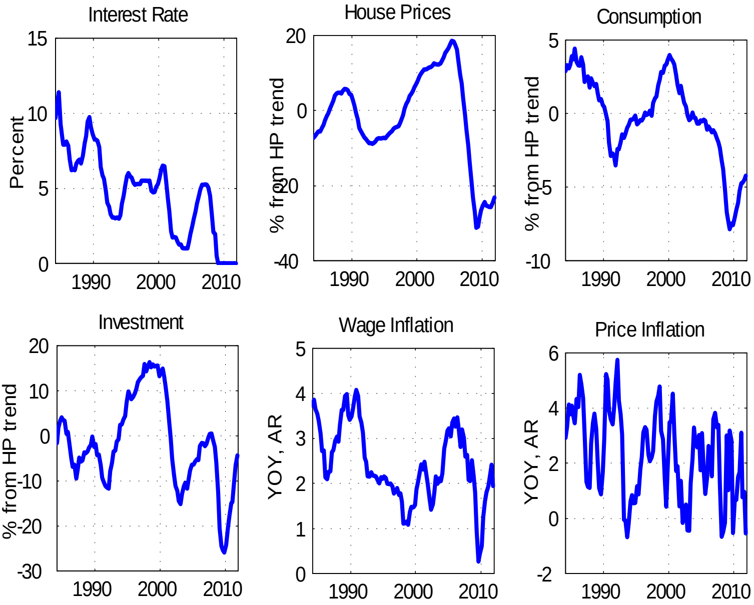
  where $\mathrm{u}_{r,t}$ is an iid monetary policy shock.
- The supply side of the model is completed by

$$Y_t = n_t^{(1-\sigma)(1-\alpha)} n_t'^{\sigma(1-\alpha)} k_{t-1}^{\alpha}$$

  and price and wage Phillips curves.
- The parameter σ measures the wage share of impatient households and – indirectly – the importance of collateral constraints. With $\sigma = 0$, the model is essentially like any other monetary model.

Data and Shocks

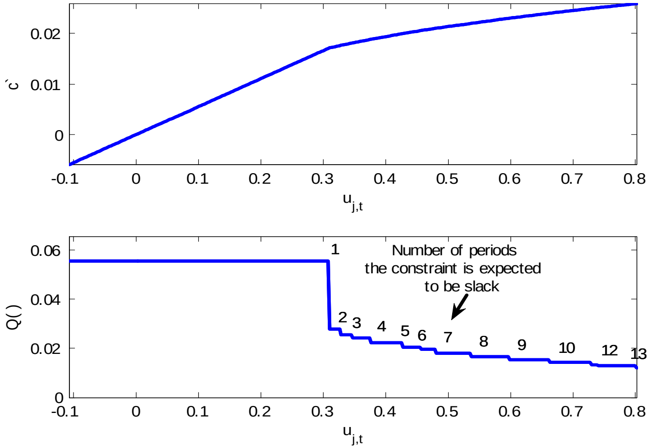
- The estimation is based on observations from 1985Q1 to 2011Q4:
  1. total real household consumption,
  2. price (GDP deflator) inflation,
  3. wage inflation (compensation per hour, nonfarm),
  4. real business fixed investment,
  5. real housing prices (Corelogic),
  6. Federal Funds Rate.
- Six shocks – investment-specific shocks, wage markup, price markup, monetary policy, intertemporal preferences, and preferences for housing.


Interest Rate
Percent
15
10
5
0
1990
2000
2010
House Prices
% from HP trend
20
0
-20
-40
1990
2000
2010
Consumption
% from HP trend
5
0
-5
-10
1990
2000
2010
Investment
% from HP trend
20
10
0
-10
-20
-30
1990
2000
2010
Wage Inflation
YOY, AR
5
4
3
2
1
0
1990
2000
2010
Price Inflation
YOY, AR
6
4
2
0
-2
1990
2000
2010

Solution Method

- We solve the model using the Occbin algorithm (see Guerrieri and Iacoviello, forthcoming JME): the algorithm extends a first-order perturbation approach and applies it in a piecewise fashion to handle occasionally binding constraints.
- Depending on whether the zero lower bound binds or not, and depending on whether the collateral constraint binds or not, we identify four regimes.
- The solution method links the first-order approximation of equilibrium conditions describing each regime.
- The dynamics in each regime depend on how long one expects to be in that regime. How long one expects to be in that regime depends on the state vector.
- The advantage of the method is its accuracy and speed. Speed is what allows us to compute the model's likelihood in seconds.

How the Policy Functions Look Like...



Computing the Likelihood

- The solution of the model takes the form:

$$X_t = \mathbf{P}(X_{t-1}, \epsilon_t)X_{t-1} + \mathbf{D}(X_{t-1}, \epsilon_t) + \mathbf{Q}(X_{t-1}, \epsilon_t)\epsilon_t$$

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- ... and in terms of observables, through the observation equation $Y_t = \mathbf{H}_t X_t$,.we have:

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We initialize X_0, and can recursively solve for ϵ_t, given X_{t-1} and the current realization of Y_t.

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- Given that ϵ_t is $NID(0, \mathbf{\Sigma})$, a change in variables argument implies that the log likelihood for Y given parameters can be written as:

$$\log f(Y^T) = -\frac{T}{2} \log(\det(\mathbf{\Sigma})) - \frac{1}{2} \sum_{tt}^{T} \epsilon' \left(\mathbf{\Sigma}^{-1} \right) \epsilon_t - \sum_{t}^{T} \log(|\det(\mathbf{H}_t \mathbf{Q}_t)|)$$

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- We impose standard prior on the parameters and estimate them using random walk Metropolis-Hastings algorithm.

Calibration

m	Maximum LTV	0.9
η	labor disutility	1
β	discount factor, patient agents	0.995
$\overline{\pi}$	steady-state gross inflation rate	1.005
α	capital share in production	0.3
δ	capital depreciation rate	0.025
$\bar{j}$	housing weight in utility	0.04
X_p, X_w	average price and wage markup	1.2

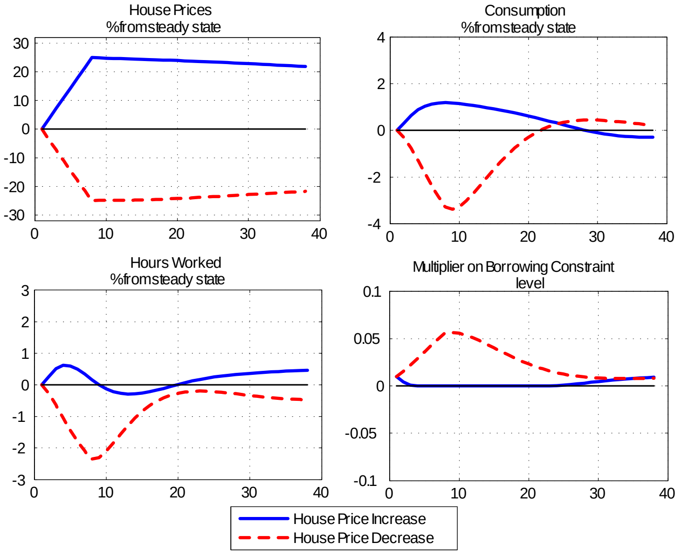
We estimate:

- the parameters governing the shocks processes;
- the parameters governing the nominal and real rigidities;
- the parameters governing the monetary policy rule;
- the wage share of impatient households, and their discount rate.

Model Results: Selected Estimated Parameters

		Prior type [mean, std]	Posterior Mode
β'	discount factor, impatients	normal [0.99, .0015]	**0.9895**
ε	habit in consumption	beta [0.5, 0.1]	**0.6399**
ϕ	investment adjustment cost	gamma [5, 2]	**5.0307**
σ	wage share, impatients	beta [0.5, 0.20]	**0.4151**
r_π	inflation resp. Taylor rule	normal, 1.5, 0.25]	**1.7385**
r_R	inertia Taylor rule	beta [0.75, 0.1]	**0.5200**
r_Y	output response Taylor rule	beta [0.125, 0.025]	**0.0796**
θ_π	Calvo parameter, prices	beta [0.5, 0.075]	**0.9190**
θ_w	Calvo parameter, wages	beta [0.5, 0.075]	**0.9170**
γ	inertia borrowing constraint	beta [0.5, 0.1]	**0.4547**

Model Results: Effect of housing demand shocks



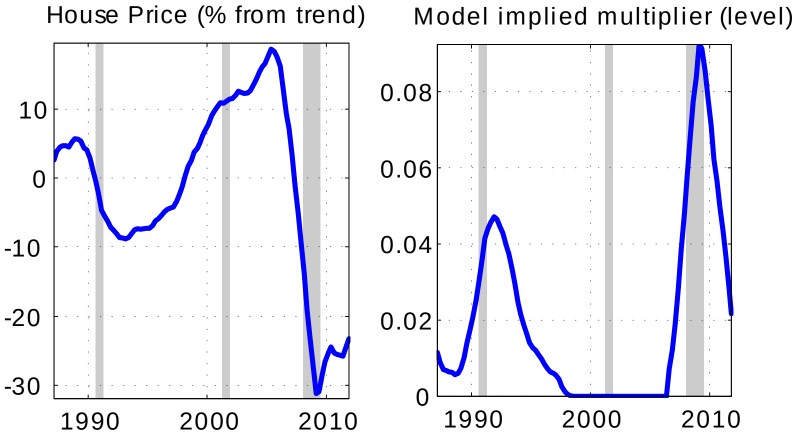
Specification Checks and Sensitivity Analysis

1. Re-estimate model assuming different initialization scheme
2. Filter shocks assuming true parameters are known
3. Estimate shocks and parameters from data generated by artificial model
4. Use different detrending method
5. Allow for TFP shocks and variable capital utilization
6. Check errors of intertemporal equations and compare policy functions against a much slower version of the model that allows for precautionary behavior stemming from future shocks.

Consumption and the Housing Boom and Bust

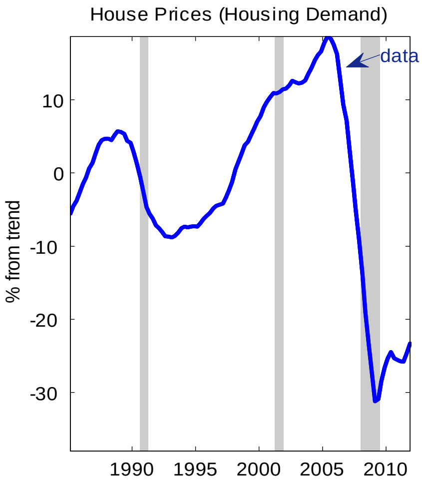
- How much did collateral constraints contribute to the decline in consumption?
- By construction, estimated model explains everything in sample. However, it is important to study which shocks and frictions are important in driving the model's dynamics.
- To understand the importance of collateral constraints, we estimate the restricted model with $\sigma = 0$, and run a horse race between baseline model and model with $\sigma = 0$.

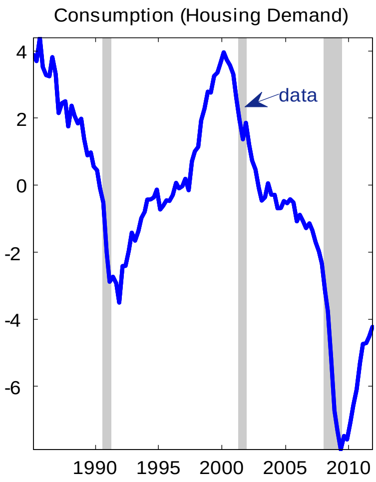
The estimated simulated multiplier



Consumption and House Prices: Data and Model

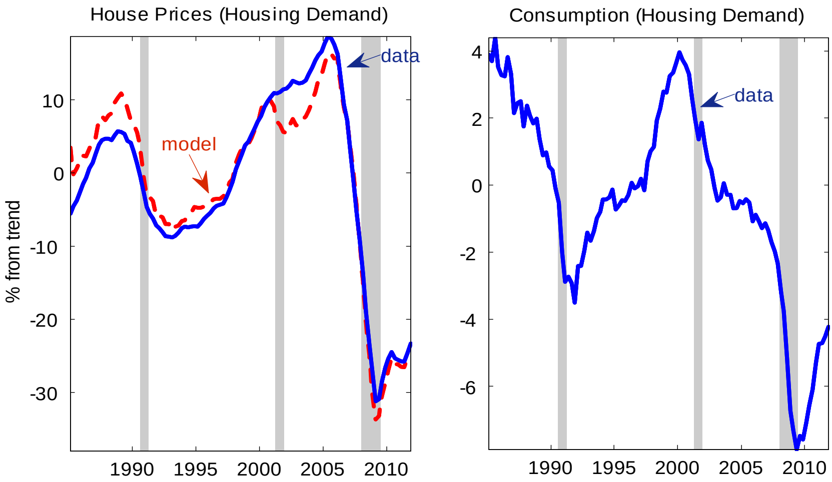
(Data, and all shocks)





Consumption and House Prices: Data and Model

(Housing Demand Shocks Only)



Consumption and House Prices: Data and Model

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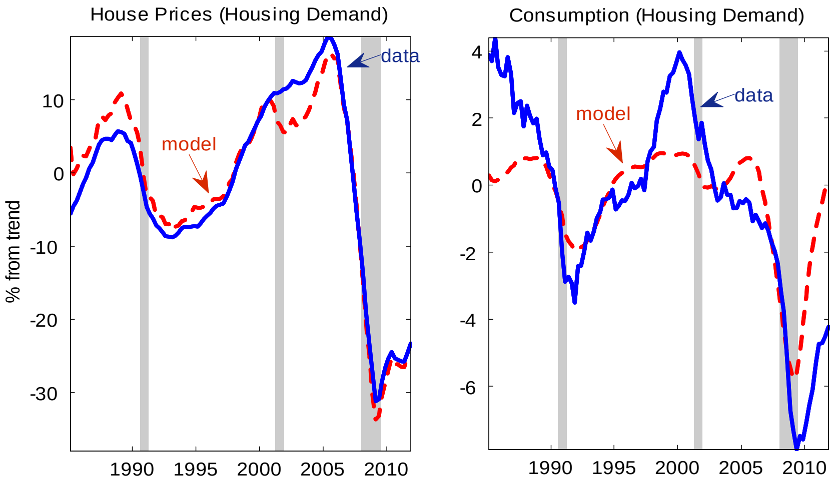
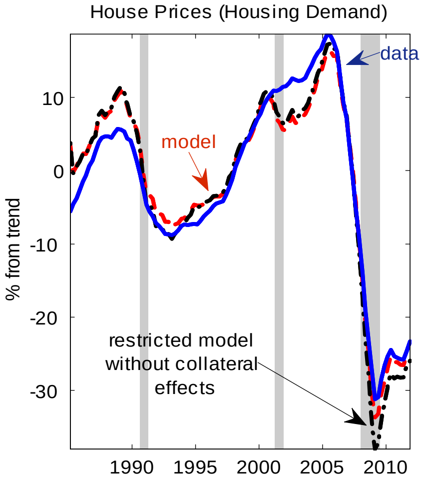
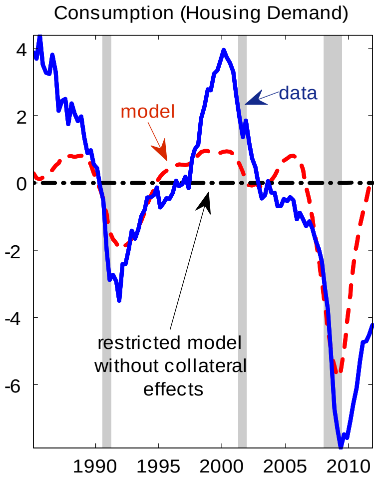


Consumption and House Prices: Data and Model

(Housing Demand Shocks Only - model w/o frictions)





Summary of Comparison

- The baseline model comes close to matching the evolution of both housing and consumption with just the housing shocks,
- By contrast, housing shocks have no bearing on consumption for the model without the collateral constraints.
- Restricted model is completely dependent on a sequence of large consumption shocks to match the consumption data.
- The posterior odds ratio favors the baseline model that does not call for the additional sequence of consumption shocks.

Checks on Solution Algorithm

- We assess the accuracy of the solution method for the full model by computing the errors of the model's intertemporal equations.
- The errors arise both because of the linearization of the original nonlinear model, and because the method abstracts from precautionary motives due to possibility of future regime switches.
- We focus on the intertemporal errors for the consumption and housing demand equations of patient and impatient agents
- We compute the errors using standard monomial integration for the expectation terms and simulating the model under the estimated filtered shocks
- Across these equations, the mean absolute errors – expressed in consumption units – are about 4×10^{-4}, that is, $4 for every $10,000 spent, a level that can be deemed negligible.

An Alternative Solution Method

- The small intertemporal errors indicate that precautionary motives, while potentially important, are, on average, quantitatively small.
- Nonetheless, one may suspect that, in the housing boom that preceded the crisis, agents would have wanted to engage in precautionary saving to insure against bad shocks.
- Similarly during the crisis, uncertainty about the path and duration of the zero lower bound on interest rates would have affected macroeconomic outcomes through precautionary behavior.
- To assess this possibility, we modify our solution algorithm to account for the possibility of future shocks.
- At each point for which the solution is sought, this alternative algorithm augments the state space with sequences of anticipated shocks and corrects current decisions by gauging the difference between the augmented expectations and the original expectations.

A Simple Example

- To understand the modifications, consider a forward-looking equation of the form:

$$q_t = \max\left(0, \beta E_t q_{t+1} + \varepsilon_t\right), \quad \varepsilon_t \sim \text{NIID}\left(0, \sigma^2\right).$$

- The perfect foresight solution assumes that the variance of ε_{t+j} is zero for $j > 0$.
- Under this assumption, $E_t^{PF} q_{t+1} = 0$, where E^{PF} denotes the expectation operator under perfect foresight.
- Accordingly, the solution under perfect foresight is $q_t = \varepsilon_t$ if $\varepsilon_t \geq 0$, and $q_t = 0$ if $\varepsilon_t < 0$ or, more succinctly:

$$q_t^{PF} = \max\left(0, \varepsilon_t\right).$$

An alternative expectation operator

- We modify the solution by extending the expectation operator E_t.
- We augment the time-t state space with two anticipated shocks to ε_{t+1} of equal size, opposite sign and equal probability. When integrating the expectations of ε_{t+1}, this approach is equivalent to considering two integration nodes and weights.
- Under this scheme, the two integration nodes are σ are $-\sigma$, each with weight $1/2$.
- Accordingly, the expectation of q_{t+1} can be defined as follows:

$$E_t^{RE1} q_{t+1} = (1/2)\max(0,\sigma) + (1/2)\max(0,-\sigma) = (1/2)\,\sigma,$$

where E_t^{RE1} denotes the expectation taken assuming knowledge that additional shocks will occur in period $t+1$.

Revisiting the Solution

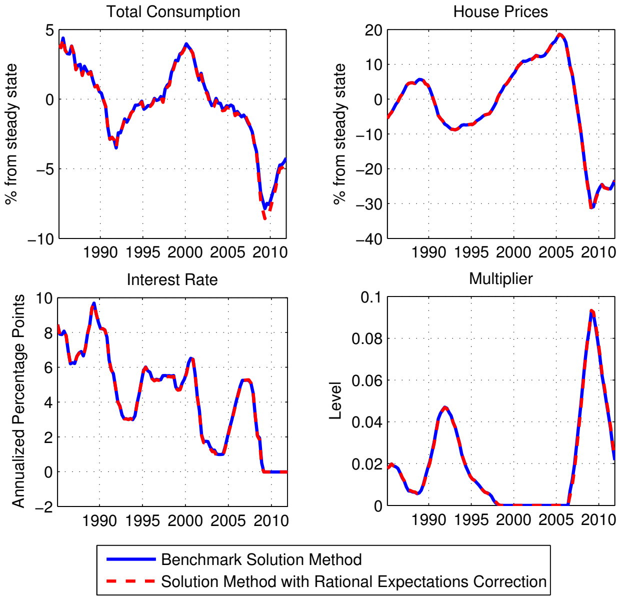
- The solution for q_t becomes:

$$q_t^{RE1} = \max\left(0, \beta\sigma/2 + \varepsilon_t\right).$$

- We can proceed in similar fashion to add $n-$period ahead anticipated shocks (to ε_{t+1}, ε_{t+2}, ... ε_{t+n}).
- For the full model, we have found that 4-period ahead anticipated shocks yield the largest decline in the errors to the intertemporal equations in the proximity of regime switches.

Solution Checks Under the Modified Solution

- The modified algorithm reduces the errors of the intertemporal equations, particularly in periods when the constraints are close to switching, an occurrence which happens, according to our estimates, with some frequency between 1998 and 2006.
- When the collateral constraint is slack but expected to bind in the future, or vice versa , the consumption Euler errors (expressed in base 10 logs) for the borrower and saver fall from -2.5 and -3.9 to -2.9 and -4.3, respectively.
- Despite the smaller intertemporal errors, the modified solution method implies only negligible differences in the model's business cycle properties.


Total Consumption
% from steady state
5
0
−5
−10
1990 1995 2000 2005 2010
House Prices
% from steady state
20
10
0
−10
−20
−30
−40
1990 1995 2000 2005 2010
Interest Rate
Annualized Percentage Points
10
8
6
4
2
0
−2
1990 1995 2000 2005 2010
Multiplier
Level
0.1
0.08
0.06
0.04
0.02
0
1990 1995 2000 2005 2010
Benchmark Solution Method
Solution Method with Rational Expectations Correction

Evidence from Regional Data

- We use state-level and MSA-level data from 1990 to 2010
  Regressions (y is log EMP/CARS/ELE, hp is log house prices)

$$\begin{aligned}\Delta y_{i,t} &= \alpha_i + \gamma_t + \beta_{HI} \mathcal{I}_{i,t} \Delta hp_{i,t-1} + \beta_{LO} \left(1 - \mathcal{I}_{i,t}\right) \Delta hp_{i,t-1} \\ &\quad + \delta X_{i,t-1} + \varepsilon_{i,t}\end{aligned}$$

$\mathcal{I}_{i,t} = 1$ if house prices are high, 0 if they are low
high: above state-specific trend

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  $\mathcal{I}_{i,t} = 1$ if house prices are high, 0 if they are low
  high: above state-specific trend
- **States**: employment in services (EMP), **auto sales (CARS)**, electricity usage (ELE)
- **MSAs**: employment (EMP) and **auto registrations (CARR)**

US States: Auto Sales and House Prices

	% Change in Auto Sales ($\Delta auto_t$)				
Δhp_{t-1}	**0.24*** **				
	(0.03)				
Δhp_high_{t-1}		**-0.05**	**0.16*** **	**0.11*** **	0.07**
		(0.04)	(0.04)	(0.03)	(0.03)
Δhp_low_{t-1}		**0.62*** **	**0.33*** **	**0.27** **	0.20**
		(0.05)	(0.06)	(0.11)	(0.09)
$\Delta auto_{t-1}$				**0.23**	**0.21**
				(0.17)	(0.17)
$\Delta income_{t-1}$					**0.34*** **
					(0.11)
Time effects	**no**	**no**	**yes**	**yes**	**yes**
Observations	969	969	969	918	918
R-squared	0.02	0.06	0.86	0.87	0.88

Instrumenting House Prices, MSA

We instrument housing price using housing supply elasticity at the MSA level (data from Albert Saiz), as in Mian and Sufi (2011).

	Cross-sectional Regressions			
	Sample 2002-2006 (Housing Boom)		Sample 2006-2010 (Housing Bust)	
	Δhp	Δcar	Δhp	Δcar
Elasticity	**-7.26***** (0.87)		**4.69***** (0.57)	
Δhp		0.24*** (0.06)		0.49*** (0.08)
Method	OLS	IV	OLS	IV
Observations	254	254	254	254
R-squared	0.22	0.35	0.21	0.48

Summary of the Empirical Evidence

Average elasticities measured from the various regressions

	State			MSA
	$\Delta empl$	$\Delta auto$	$\Delta elec$	$\Delta empl$
Δhp_high	0.02	0.07	0.12	0.04
Δhp_low	0.07	0.20	0.19	0.09

1. Average sensitivity of demand to changes in house prices around 0.10
2. Conditioning for low and high prices, sensitivity is around 0.06 when house prices are high, 0.14 for negative changes
3. MSA elasticities after instrumenting house prices and focusing on 2002-2010 period even larger

Conclusions

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  These asymmetries can be found in national, US state and MSA level data, using Bayesian estimation, panel and cross-sectional regressions.

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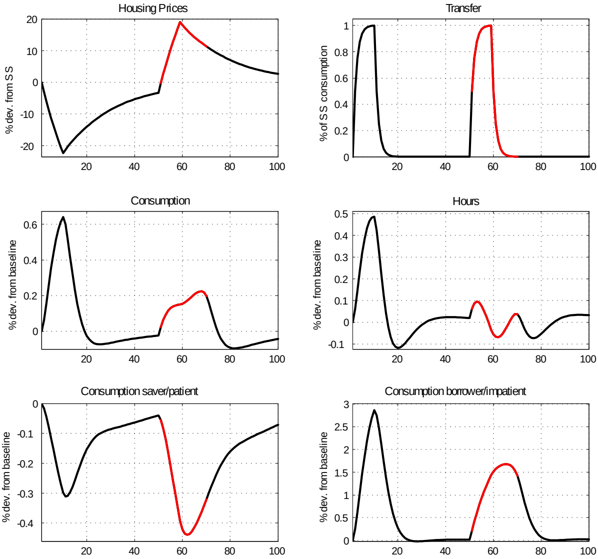
- Ignoring this asymmetry underestimates the effects of shocks to asset prices during recessions.
- The existence of the asymmetry reinforces the findings of many models with collateral constraints that have assumed the asymmetry away.
- Estimated model shows that, as collateral constraints became slack during the housing boom of 2001-2006, expanding housing wealth made little contribution to consumption growth.
  By contrast, the subsequent housing collapse tightened collateral constraints and sharply exacerbated the recession of 2008-2009.

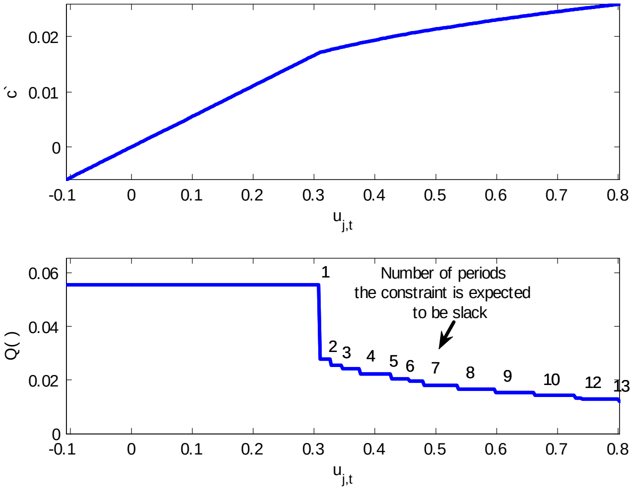
An application to mortgage relief

- Consider a simple proposal such as mortgage relief for debtors
- The marginal effects of mortgage relief depend drastically on whether house prices are high (and few people are constrained) or low (and many people are constrained)
- With low house prices, debt relief can have substantial expansionary effects.

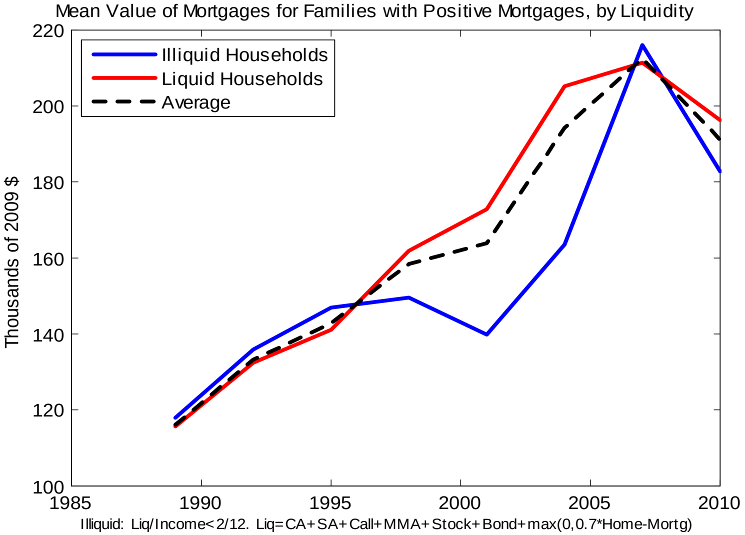
Two transfers from saver to borrower under different house price scenarios



Local linearity of Q



Deleveraging in SCF



Deleveraging in Aggregate Data and the Model