Multiple Credit Constraints and Time-Varying Macroeconomic Dynamics

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Introduction

Setting

Standard way of modeling credit control on households: Loan-to-value constraints.

- E.g., Kiyotaki and Moore (1997) and Iacoviello (2005).

Simplest form of loan-to-value (LTV) constraint:

$$\text{debt} \leq \xi_{LTV} \cdot \text{value of house.}$$

Research Question

Banks also impose debt-service-to-income (DTI) requirements. Credit requirements on mortgage borrowers:

$$\text{debt} \leq \xi_{LTV} \cdot \text{value of house},$$
$$\text{debt} \cdot (\text{net interest rate} + \text{amortization rate}) \leq \xi_{DTI} \cdot \text{personal income}.$$

How do simultaneous LTV and DTI limits on homeowners' mortgage borrowing shape the macroeconomy?

The simultaneous imposition of LTV and DTI requirements warrants the following questions:

- When and why have LTV and DTI requirements historically restricted mortgage borrowing?
- Did looser DTI limits cause the credit booms prior to the Savings and Loan Crisis and the Great Recession?
- Is the credit cycle best controlled by adjusting LTV or DTI limits or monetary policy rates?
- How does the switching between LTV and DTI constraints affect the propagation and amplification of economic shocks?

Model

Overview of the Model

New Keynesian DSGE model with two representative households

- A patient (lends) and an impatient (borrows) household.
- Long-term fixed-rate mortgage contracts.
- A loan-to-value and a debt-service-to-income constraint.
- Cobb-Douglas goods production technology.
- Constant-returns-to-scale housing investment technology.
- Nominal price rigidity (Calvo).
- Monetary policy Taylor rule.

Households

Utility function of the patient household:

$$\mathbb{E}_0\Big\{ \sum_{t=0}^{\infty} \beta^t s_{I,t}\Big[\chi \log(c_t - \eta_C c_{t-1}) + \omega_H s_{H,t} \log(h_t - \eta_H h_{t-1}) - \tfrac{s_{L,t}}{1+\varphi} l_t^{1+\varphi}\Big]\Big\}.$$

Utility function of the impatient household:

$$\mathbb{E}_0\Big\{ \sum_{t=0}^{\infty} \beta'^t s_{I,t}\Big[\chi' \log(c'_t - \eta_C c'_{t-1}) + \omega_H s_{H,t} \log(h'_t - \eta_H h'_{t-1}) - \tfrac{s_{L,t}}{1+\varphi} l_t'^{1+\varphi}\Big]\Big\}.$$

Time preference heterogeneity:

$$\beta > \beta'.$$

In and close to the steady state, the impatient household is credit constrained.

Budget constraint of the patient household:

$$c_t + q_t[h_t - (1-\delta_H)h_{t-1}] + k_t + \frac{\iota}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1} + p_{X,t}[x_t - x_{t-1}]$$
$$= w_t n_t + div_t + b_t - \underbrace{\frac{1-(1-\rho)(1-\sigma)+r_{t-1}}{1+\pi_t} l_{t-1}}_{\text{Debt Expenses}}$$
$$+ (r_{K,t} + 1 - \delta_K)k_{t-1} + r_{X,t}x_{t-1}.$$

Budget constraint of the impatient household:

$$c'_t + q_t[h'_t - (1-\delta_H)h'_{t-1}] = w'_t n'_t + b'_t - \underbrace{\frac{1-(1-\rho)(1-\sigma)+r_{t-1}}{1+\pi_t} l'_{t-1}}_{\text{Debt Expenses}}.$$

Long-term fixed-rate mortgage contracts as in, e.g., Kydland, Rupert, and Sustek (2016) and Garriga, Kydland, and Sustek (2017).

Long-Term Fixed-Rate Mortgage Contracts

Net level of outstanding mortgage loans:

$$l_t = (1-\rho)(1-\sigma)\frac{l_{t-1}}{1+\pi_t} + b_t,$$

$$l'_t = (1-\rho)(1-\sigma)\frac{l'_{t-1}}{1+\pi_t} + b'_t.$$

Average nominal net interest rate on outstanding loans:

$$r_t = (1-\rho)(1-\sigma)\frac{l'_{t-1}}{l'_t} r_{t-1} + \left[1 - (1-\rho)(1-\sigma)\frac{l'_{t-1}}{l'_t}\right] i_t.$$

Parameters and variables:

- $\rho \in [0,1]$: Share of refinancing homeowners.
- $\sigma \in [0,1]$: Amortization rate on outstanding debt.
- i_t: Current long-term nominal net interest rate.

Occasionally binding loan-to-value constraint:

$$b'_t \leq \rho\left(\kappa_{LTV}\xi_{LTV}\mathbb{E}_t\{(1+\pi_{t+1})q_{t+1}h'_t\} + (1-\kappa_{LTV})\xi_{DTI,t}\mathbb{E}_t\left\{\frac{(1+\pi_{t+1})w'_{t+1}n'_t}{\sigma+r_t}\right\}\right).$$

Occasionally binding debt-service-to-income constraint:

$$b'_t \leq \rho\left((1-\kappa_{DTI})\xi_{LTV}\mathbb{E}_t\{(1+\pi_{t+1})q_{t+1}h'_t\} + \kappa_{DTI}\xi_{DTI,t}\mathbb{E}_t\left\{\frac{(1+\pi_{t+1})w'_{t+1}n'_t}{\sigma+r_t}\right\}\right).$$

Parameters and variables:

- ξ_{LTV}: Loan-to-value limit.
- $\xi_{DTI,t} \equiv \frac{\tilde{\xi}_{DTI}s_{DTI,t}-\xi_O}{1-\tau_L}$: Front-end debt-service-to-income limit.
- $s_{DTI,t}$: Shock to the back-end DTI limit.

There is no shock to the LTV limit, since Fannie Mae and Freddie Mac data indicate strong historical stability in this ratio.

Intermediate Firm

The firm maximizes profits under perfect competition.

Profit function:

$$\frac{Y_t}{M_{P,t}} + q_t I_{H,t} - w_t n_t - w'_t n'_t - r_{K,t} k_{t-1} - g_t - r_{X,t} x_{t-1}.$$

Production functions:

$$Y_t = k_{t-1}^{\mu} (s_{Y,t} n_t^{\alpha} n_t'^{1-\alpha})^{1-\mu},$$
$$I_{H,t} = g_t^{\nu} x_{t-1}^{1-\nu}.$$

Retail Firms and Price Setting

Hybrid New Keynesian Price Phillips Curve:

$$\pi_t = \gamma_P \pi_{t-1} + \beta \mathbb{E}_t\{\pi_{t+1} - \gamma_P \pi_t\} - \lambda_P \left(\log M_{P,t} - \log \frac{\epsilon_P}{\epsilon_P - 1} \right) + \varepsilon_{P,t},$$

where $\lambda_P \equiv \frac{(1-\theta_P)(1-\beta\theta_P)}{\theta_P}$.

Dividends from retail firms:

$$div_t \equiv \left(1 - \frac{1}{M_{P,t}}\right) Y_t.$$

Monetary Policy and Market-Clearing Conditions

Monetary policy Taylor rule:

$$i_t = \tau_R i_{t-1} + (1-\tau_R) i + (1-\tau_R)\tau_P \pi_{P,t}.$$

Market-clearing conditions:

$$c_t + c'_t + k_t - (1-\delta_K)k_{t-1} + \frac{\iota}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1} + g_t = Y_t,$$
$$h_t + h'_t - (1-\delta_H)(h_{t-1} + h'_{t-1}) = I_{H,t},$$
$$b_t = -b'_t,$$
$$x_t = \mathcal{X}.$$

Solution and Estimation of the Model

Solution and Estimation of the Model

Solution

Piecewise linear solution: Four linear approximations of the four model regimes, around a steady state.

- Based on Guerrieri and Iacoviello (2015, 2017).

Parameterization

A few parameters are calibrated.

The remaining parameters and the shock processes are estimated by Bayesian maximum likelihood.

- Nonlinear solution $\Rightarrow$ Recursive filtering scheme, as in Fair and Taylor (1983).

Stochastic Singularity?

Calibration: Credit Limits

Debt-service-to-income limit: $\tilde{\xi}_{DTI} = 0.43$ and $\xi_O = 0.15$.

- 28 pct. front-end limit, as in Linneman and Wachter (1989) and Greenwald (2018).
- 43 pct. back-end limit, as in the Federal Housing Administration's Single Family Housing Policy Handbook.

Loan-to-value limit: $\xi_{LTV} \approx 0.82$.

- Realistic value, cf., Linneman and Wachter (1989) or Iacoviello and Neri (2010).
- Ensures that the LTV and DTI credit quantities are identical in the steady state, so that both constraints are binding.
  - Allows me to treat the credit constraints symmetrically.

Calibration

Estimation

Sample covering the U.S. economy in 1984Q1-2019Q4:

- Real personal consumption expenditures p.c.
- Real total home mortgage loan liabilities p.c.
- Real house prices.
- Real disposable personal income p.c.
- Aggregate weekly hours p.c.
- Log change in the GDP price deflator.

Structural shocks:

- Intertemporal preference shock.
- Housing preference shock.
- DTI shock.
- Labor-augmenting technology shock.
- Labor preference shock.
- Price markup shock.

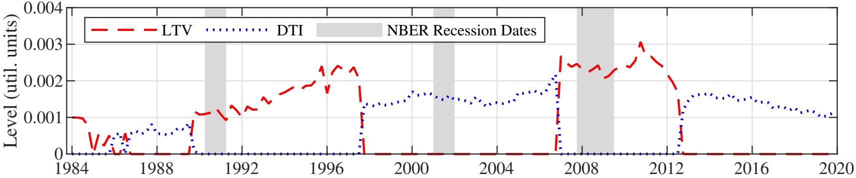
The first five shocks follow AR(1) processes. The price markup shock is a single-period innovation.

Estimation

The Historical Evolution in Credit Conditions

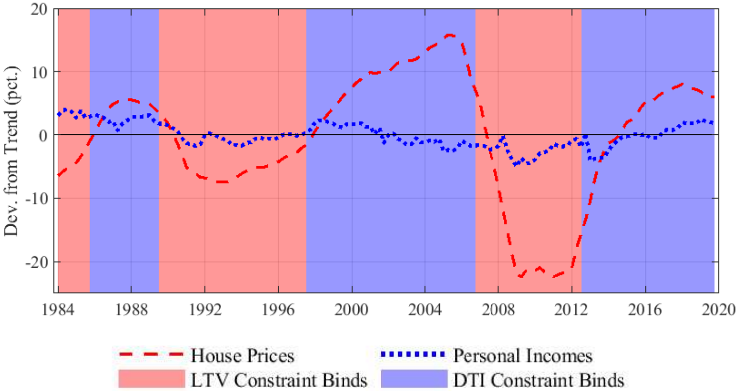
Result 1: Historical Credit Regimes

Figure: Posterior Lagrange Multipliers



Note: The Lagrange multipliers are identified at the posterior mode.

Figure: House Prices, Personal Incomes, and Binding Constraints

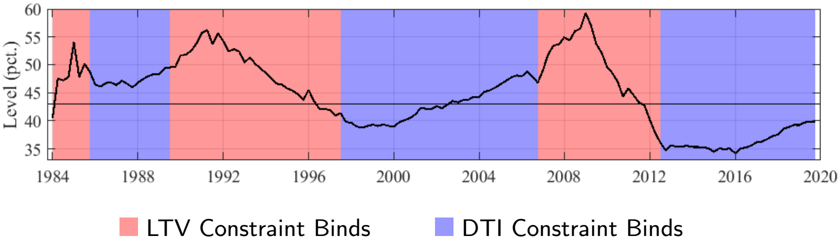


Note: The model is identified at the baseline posterior mode. The data series has been log-transformed and detrended by a one-sided HP filter, with the smoothing parameter equal to 100,000.

Shock Decomposition | Effect of Monetary Policy

Result 2: Debt-Service-to-Income Cycles

Figure: Back-End DTI Limit



Note: The figure plots the smoothed back-end DTI limit ($\tilde{\xi}_{DTI} s_{DTI,t}$), identified at the baseline posterior mode. The horizontal line indicates its steady-state value ($\tilde{\xi}_{DTI}$).

Loan-Level Data

Macroprudential Implications

Macroprudential Implications

Credit expansions – not, e.g., asset price inflation – predict subsequent banking and housing market crises.

- E.g., Mian and Sufi (2009), Schularick and Taylor (2012), and Baron and Xiong (2017).

I now examine the ability of credit limits and monetary policy to stabilize deviations of credit from its long-run trend.

Result 3: Countercyclical Credit Limits

The credit constrains are now:

$$b_t' \leq \rho\left(\kappa_{LTV}\xi_{LTV}\hat{s}_{LTV,t}\mathbb{E}_t\left\{(1+\pi_{t+1})q_{t+1}h_t'\right\} + (1-\kappa_{LTV})\xi_{DTI,t}\mathbb{E}_t\left\{\frac{(1+\pi_{t+1})w_{t+1}'n_t'}{\sigma+r_t}\right\}\right),$$

$$b_t' \leq \rho\left((1-\kappa_{DTI})\xi_{LTV}\hat{s}_{LTV,t}\mathbb{E}_t\left\{(1+\pi_{t+1})q_{t+1}h_t'\right\} + \kappa_{DTI}\xi_{DTI,t}\mathbb{E}_t\left\{\frac{(1+\pi_{t+1})w_{t+1}'n_t'}{\sigma+r_t}\right\}\right),$$

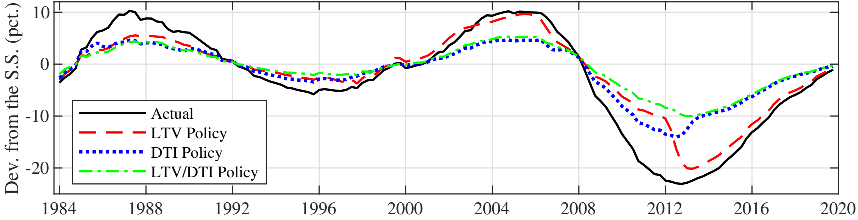
where $\xi_{DTI,t} \equiv \frac{\tilde{\xi}_{DTI}s_{DTI,t}\hat{s}_{DTI,t}-\xi_O}{1-\tau_L}$.

Countercyclical loan-to-value and debt-service-to-income limits:

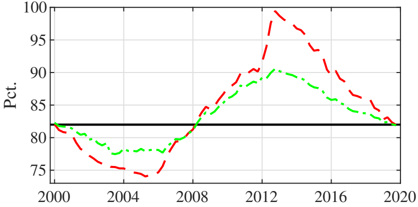
$$\log \hat{s}_{LTV,t} = -\left(\mathbb{E}_t \log l_{t+1}' - \log l'\right),$$
$$\log \hat{s}_{DTI,t} = -\left(\mathbb{E}_t \log l_{t+1}' - \log l'\right).$$

I simulate the model at the posterior mode with and without the counterfactual credit policies.

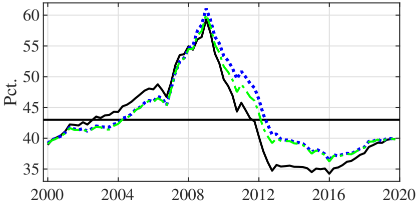
Figure: Countercyclical Credit Limits



(a) Mortgage Debt



(b) LTV Limit



(c) Back-End DTI Limit

Note: The simulations are performed at the baseline posterior mode. Figures 5b-5c plot the LTV limit ($\xi_{LTV}\hat{s}_{LTV,t}$) and the back-end DTI limit ($\tilde{\xi}_{DTI}s_{DTI,t}\hat{s}_{DTI,t}$), with horizontal lines indicating the steady-state values (ξ_{LTV} and $\tilde{\xi}_{DTI}$).

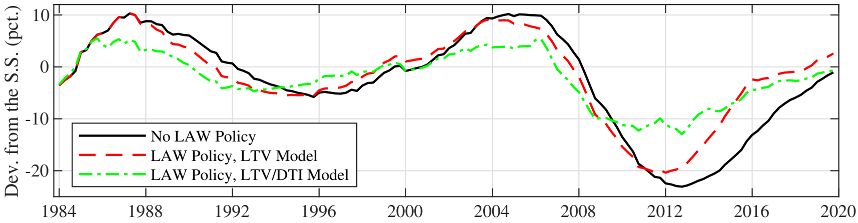
Result 4: Leaning Against the Wind (LAW)

The monetary policy rule is now:

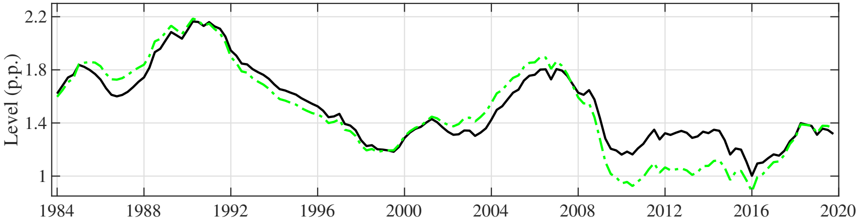
$$i_t = \tau_R i_{t-1} + (1-\tau_R)i + (1-\tau_R)\tau_P \pi_{P,t} + 0.0075 \cdot \left(\mathbb{E}_t \log l'_{t+1} - \log l'\right).$$

I simulate the model at the posterior mode with and without the counterfactual monetary policy.

Figure: Leaning Against the Wind



(a) Mortgage Debt



(b) Nominal Policy Rate

Note: The simulations are performed at the respective posterior modes.

Comparing the Policies: Consumption-at-risk

Table: Consumption-at-Risk under Alternative Macroprudential Regimes

	Historical	LTV/DTI Policy	LAW Policy
Pt. household	-3.7	-4.5	-3.6
Impt. household	-15.7	-11.0	-16.2

Note: The simulations are performed at the baseline posterior mode.

Consumption-at-risk:

- 5 percentile deviation of consumption from its steady-state level.
- Captures that negative deviations of consumption constitute a worse problem than positive deviations.

Consumption Paths

Panel Evidence on State-Dependent Credit Elasticities

The DSGE model implies (see Figure 3 in the paper)

When the housing-wealth-to-income ratio is relatively low:

- A majority of borrowers are LTV constrained.
- House price growth has a relatively strong effect on credit growth.

When the housing-wealth-to-income ratio is relatively high:

- A minority of borrowers are LTV constrained.
- House price growth has a relatively weak effect on credit growth.

Empirical Strategy and Results

I estimate the following second-stage regression on a county-level panel dataset covering 1991-2017:

$$\begin{aligned}\Delta \log d_{i,t} = \delta_i + \zeta_{j,t} + \beta_{hp} \Delta \widehat{\log hp}_{i,t-1} + \beta_{inc} \Delta \widehat{\log inc}_{i,t-1} \\ + \tilde{\beta}_{hp} \mathcal{I}^{LTV}_{i,t} \Delta \widehat{\log hp}_{i,t-1} + \tilde{\beta}_{inc} \mathcal{I}^{DTI}_{i,t} \Delta \widehat{\log inc}_{i,t-1} + u_{i,t},\end{aligned}$$

with

$$\mathcal{I}^{LTV}_{i,t} \equiv 1 - \mathcal{I}^{DTI}_{i,t} \equiv \begin{cases} 0 & \text{if } \log\left(\frac{hp_{i,t}}{inc_{i,t}}\right) \geq \overline{\log\left(\frac{hp_{i,t}}{inc_{i,t}}\right)} \\ 1 & \text{else,} \end{cases}$$

where $\overline{\log\left(\frac{hp_{i,t}}{inc_{i,t}}\right)}$ denotes a separately estimated county-specific quadratic or cubic time trend.

I use Bartik-type house price and income instruments, in addition to the county and state-year fixed effects.

- E.g., Guren, McKay, Nakamura, and Steinsson (2018).

Predicted values: $\Delta \widehat{\log hp}_{i,t}$ and $\Delta \widehat{\log inc}_{i,t}$.

First-Stage Regressions

Table: Catalysts for Credit Origination: Level Shifters (1991-2017)

	$\Delta \log b_t$				
Detrending Method	N/A	Quadratic		Cubic	
	(1)	(2)	(3)	(4)	(5)
$\Delta \log \widehat{hp}_{i,t-1}$	0.523***	0.331***	0.330***	0.207	
	(0.0926)	(0.115)	(0.116)	(0.130)	
$\Delta \log \widehat{inc}_{i,t-1}$	0.0906	-0.0610		-0.0778	
	(0.193)	(0.203)		(0.198)	
$\mathcal{I}^{LTV}_{i,t} \Delta \log \widehat{hp}_{i,t-1}$		0.317**	0.315**	0.483***	0.553***
		(0.127)	(0.125)	(0.148)	(0.117)
$\mathcal{I}^{DTI}_{i,t} \Delta \log \widehat{inc}_{i,t-1}$		0.400***	0.396***	0.509***	0.547***
		(0.112)	(0.108)	(0.116)	(0.0999)
Observations	62424	62424	62424	62424	62424
Adjusted R^2	0.674	0.674	0.674	0.674	0.674

Note: County and state-year fixed effects are always included. Observations are weighted by the county population in a given year. Standard errors are clustered at the county level, and reported in parentheses.

Robustness

The results are broadly robust to:

- Not using the Bartik-instruments.
- Not weighing out the local contributions to the nationwide indices.
- Using current house price and income variables.
- Omitting the county fixed effects.
- Replacing the state-year fixed effects with year fixed effects.
- Growth indicators instead of level indicators.

Specification with Growth Indicators

Summary

Summary

- Build and estimate a NK-DSGE model with loan-to-value and debt-service-to-income requirements on mortgage borrowing.
- The estimation infers that:
  - LTV constraint binds in contractions.
  - DTI constraint binds in expansions.
  - DTI limit relaxed from 39 pct. in 1998 to 56 pct. in 2008.
- The countercyclical macroprudential policy simulations show that:
  - DTI tool effective in expansions: can curb credit growth.
  - LTV tool effective in contractions: can support credit availability.
  - Leaning against the wind is always effective, but it redistributes consumption risk from savers to borrowers.
- County panel data attest to multiple credit constraints as a source of state-dependent dynamics.

Thank you for your attention!

Appendix

Appendix: Calibration

Table: Calibrated Parameters

Description		Value	Source or Steady-State Target
Time disc. factor, pt. hh.	β	0.985	Ann. net real interest rate: 6.2 pct.
Housing utility weight	ω_H	0.69	Steady-state target*
Marg. disut. of lab. sup.	φ	1.00	Standard value
LTV limit	ξ_{LTV}	0.8200	See text
S.S. back-end DTI limit	$\tilde{\xi}_{DTI}$	0.43	See text
Non-mort. DTI limit	ξ_O	0.15	See text
Labor tax rate	τ_L	0.231	Jones (2002)
Amortization rate	σ	1/80	Loan term: 80 qrt. or 20 yr.
Depr. rate, res. capital	δ_H	0.01	Standard value
Depr. rate, nonres. capital	δ_K	0.025	Standard value
Capital income share	μ	0.33	Standard value
Housing trans. elast.	ν	0.65	Std. dev. of res. investment: 0.18†
Price elast. of goods dem.	ϵ	5.00	Standard value
Stock of land	$\mathcal{X}$	1.00	Normalization

*Average ratio of res. fixed assets to nondurable goods consumption expend. (27.2).
†Std. dev. of res. fixed gross investment. The correlation between the series is 63 pct.

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Appendix: Estimation

Table: Prior and Posterior Distributions

	Prior Distribution			Posterior Distribution		
	Type	Mean	S.D.	Mode	5 pct.	95 pct.
Structural Parameters						
α	B	0.66	0.10	0.6932	0.6794	0.7070
β'	B	0.9740	0.006	0.9806	0.9804	0.9807
η_C	B	0.70	0.10	0.6266	0.6081	0.6450
η_H	B	0.70	0.10	0.5490	0.5365	0.5614
ρ	B	0.25	0.05	0.3925	0.3565	0.4285
ι	N	10.0	10.0	60.113	47.519	72.707
γ_P	B	0.50	0.20	0.9513	0.9280	0.9745
θ_P	B	0.80	0.05	0.8922	0.8855	0.8989
τ_R	B	0.75	0.05	0.8814	0.8759	0.8870
τ_P	N	1.50	0.25	2.0006	1.9078	2.0934
κ_{LTV}	B	0.75	0.25	0.7423	0.7249	0.7597
κ_{DTI}	B	0.75	0.25	0.8753	0.8695	0.8811
υ	N	1.00	0.50	0.9674	0.8680	1.0668

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Table: Prior and Posterior Distributions

	Prior Distribution			Posterior Distribution		
	Type	Mean	S.D.	Mode	5 pct.	95 pct.
Autocorrelation of Shock Processes						
IP	B	0.50	0.20	0.9800	0.9785	0.9816
HP	B	0.50	0.20	0.8928	0.8827	0.9028
DTI	B	0.50	0.20	0.9824	0.9798	0.9851
AY	B	0.50	0.20	0.9934	0.9919	0.9949
LP	B	0.50	0.20	0.9888	0.9839	0.9938
Standard Deviations of Innovations						
IP	IG	0.010	0.10	0.0351	0.0237	0.0465
HP	IG	0.010	0.10	0.0649	0.0419	0.0879
DTI	IG	0.010	0.10	0.0408	0.0295	0.0522
AY	IG	0.010	0.10	0.0209	0.0159	0.0258
LP	IG	0.010	0.10	0.0037	0.0031	0.0043
PM	IG	0.010	0.10	0.0098	0.0064	0.0131

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Appendix: Stochastic Singularity?

There is no stochastic singularity when both constraints are slack.

FOC of the impatient household with respect to borrowing:

$$u'_{c,t} + \beta'(1-\rho)\mathbb{E}_t\left\{ s_{I,t+1} \frac{\lambda_{LTV,t+1} + \lambda_{DTI,t+1}}{1+\pi_{t+1}} \right\}$$
$$= \beta'\mathbb{E}_t\left\{ u'_{c,t+1} \frac{1+r_t}{1+\pi_{t+1}} \right\} + s_{I,t}(\lambda_{LTV,t} + \lambda_{DTI,t}).$$

Recursive substitution: Current consumption and borrowing are pinned down by the current and expected future Lagrange multipliers.

- $\lambda_{LTV,t} = \lambda_{DTI,t} = 0$ when both constraints are slack.
- Expected future multipliers are positive at some forecast horizon.

The current credit shock can affect the expected future multipliers and ultimately current consumption and borrowing.

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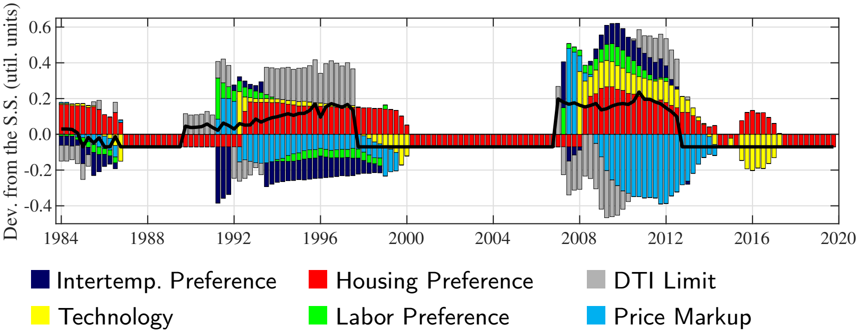
Appendix: Historical Shock Decomposition

Figure: Shock Decomposition: LTV Lagrange Multiplier



Note: The decomposition is performed at the baseline posterior mode. The shocks were marginalized in the following order: (1) housing preference, (2) labor-augmenting technology, (3) price markup, (4) labor preference, (5) intertemporal preference, and (6) DTI limit.

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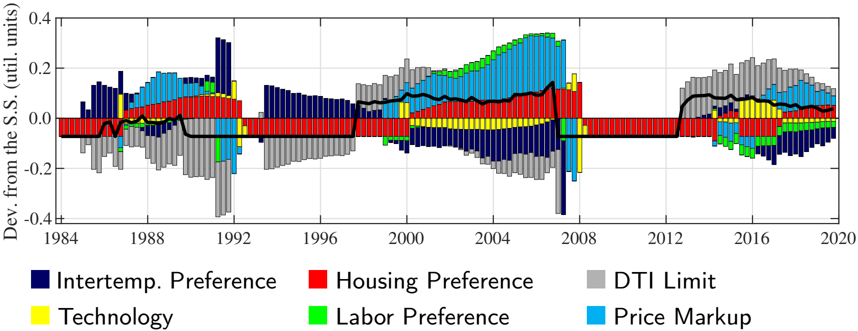
Figure: Shock Decomposition: DTI Lagrange Multiplier



Note: The decomposition is performed at the baseline posterior mode. The shocks were marginalized in the following order: (1) housing preference, (2) labor-augmenting technology, (3) price markup, (4) labor preference, (5) intertemporal preference, and (6) DTI limit.

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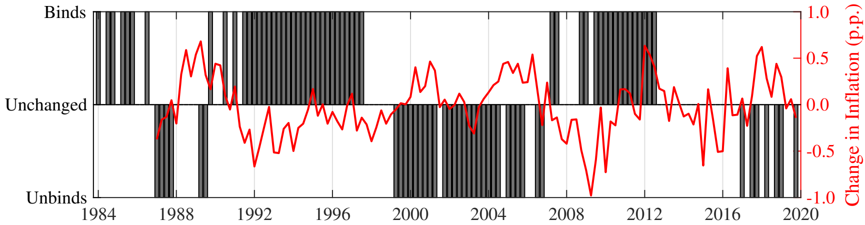
Appendix: Effect of Countercyclical Monetary Policy

Figure: Subdued Monetary Policy: Effect on DTI Constraint



Note: The figure reports the effect on the DTI constraint of setting the monetary policy response to price inflation to $\tau_P = 1.01$, so that the Taylor principle is just barely fulfilled. The figure superimposes the change in inflation over the past 12 quarters. The simulations are performed at the baseline posterior mode.

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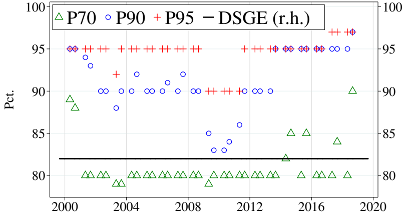
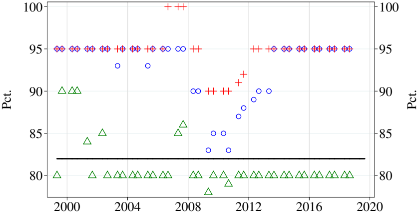
Appendix: Loan-Level Data

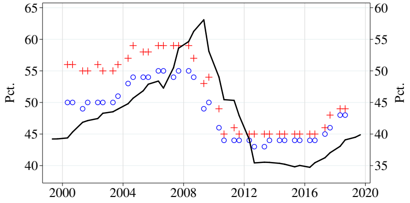
Figure: LTV and DTI Ratios: Loan-Level Data and DSGE Estimation



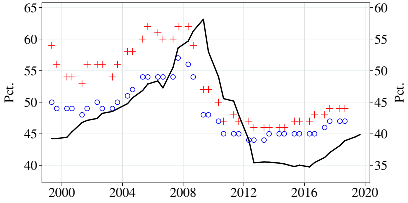
(a) LTV Ratios: Fannie Mae



(b) LTV Ratios: Freddie Mac



(c) DTI Ratios: Fannie Mae



(d) DTI Ratios: Freddie Mac

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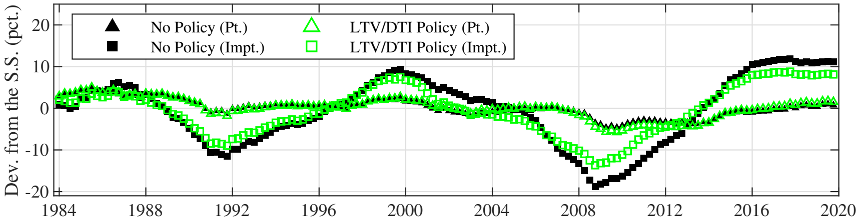
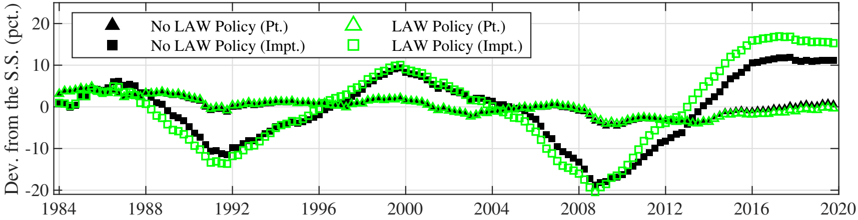
Appendix: Alternative Household Consumption Paths

Figure: Household Consumption Paths



(a) Countercyclical Credit Limits



(b) Leaning Against the Wind

Note: The simulations are performed at the baseline posterior modes.

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Appendix: First-Stage Regressions

First-stage regression for each county i:

$$\Delta \log hp_{i,t} = \gamma_{i,hp} + \beta_{i,hp} \Delta \log hp_{-i,t} + v_{i,t,hp},$$
$$\Delta \log inc_{i,t} = \gamma_{i,inc} + \beta_{i,inc} \Delta \log inc_{-i,t} + v_{i,t,inc},$$

where $\mathbb{E}\{v_{i,t,hp}\} = \mathbb{E}\{v_{i,t,inc}\} = 0$.

Identification under two assumptions:

- Nationwide house price and income cycles yield predictive power over local house prices and incomes (relevance)
- Nationwide house price and income cycles are not influenced by local shocks to credit originations conditional on FEs (exogeneity).

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First-stage regression for each county i:

$$\Delta \log hp_{i,t} = \gamma_{i,hp} + \beta_{i,hp} \Delta \log hp_{-i,t} + v_{i,t,hp},$$
$$\Delta \log inc_{i,t} = \gamma_{i,inc} + \beta_{i,inc} \Delta \log inc_{-i,t} + v_{i,t,inc},$$

where $\mathbb{E}\{v_{i,t,hp}\} = \mathbb{E}\{v_{i,t,inc}\} = 0$.

Results:

- $\beta_{i,hp} = 0$ is rejected at a one-percent confidence level in 84 pct. of all counties. The average t-statistic is 5.28 across all counties.
- $\beta_{i,inc} = 0$ is rejected at a one-percent confidence level in 97 pct. of all counties. The average t-statistic is 9.65 across all counties.

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