Housing Prices and Consumer Spending: The Bank Balance-Sheet Channel

Nuno Paixão

Bank of Canada

Housing, Credit and Heterogeneity: New Challenges for Stabilization Policies

Stockholm, September 2018

Main Idea

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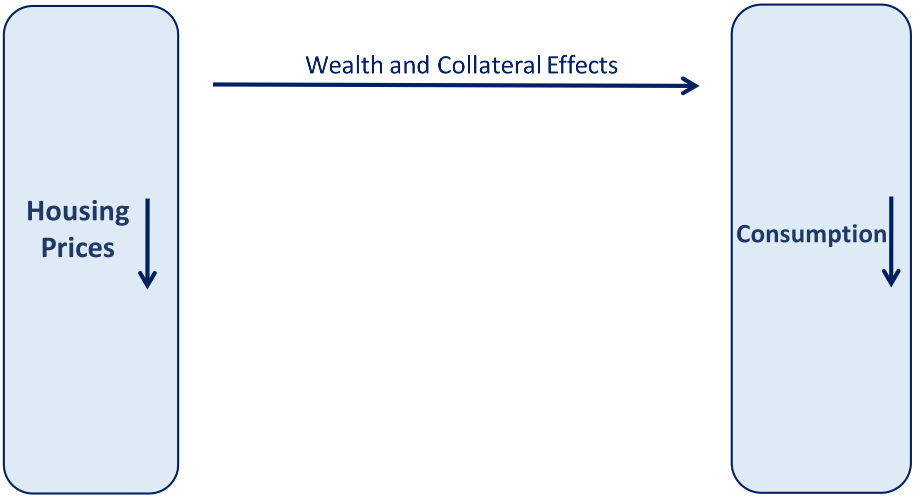
Housing Prices
Wealth and Collateral Effects
Consumption

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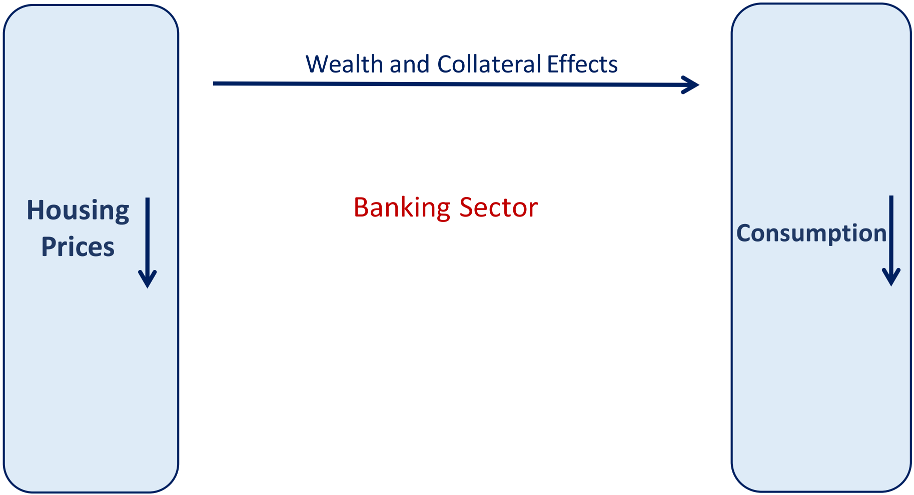
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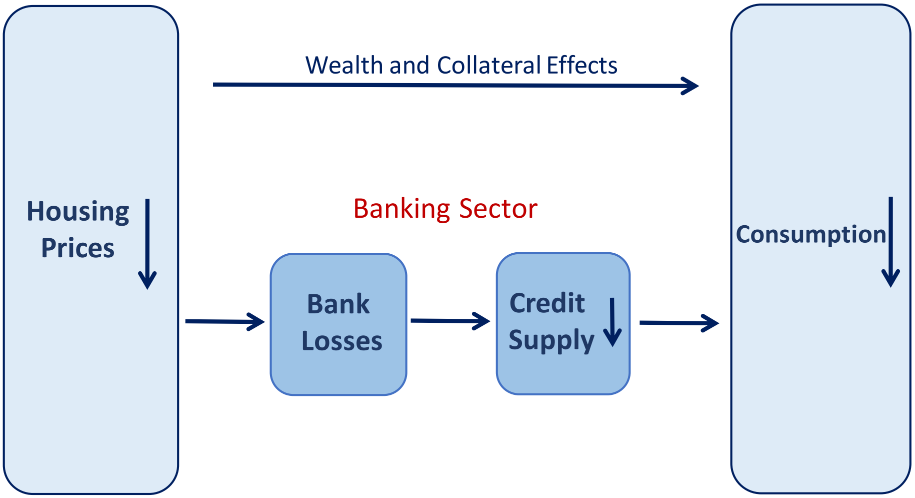
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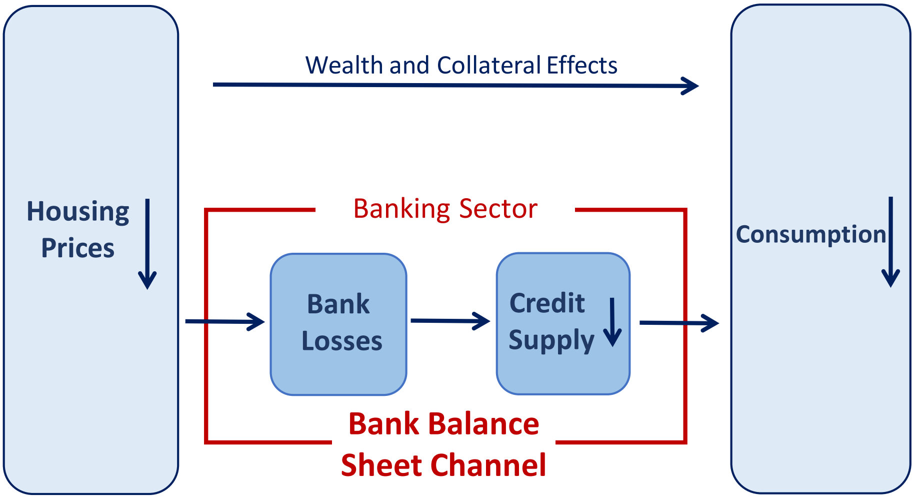

Wealth and Collateral Effects
Housing Prices
Banking Sector
Bank Losses
Credit Supply
Consumption
Bank Balance Sheet Channel

Contributions and Findings

- **Theoretical Contribution**
  - Introduce a *Banking Sector* with Balance Sheet Frictions in a model of collateralized debt with default
  - Credit supply depends on the capitalization of the entire banking sector.
  - Mortgage spreads and endogenous down payments increase in periods when banks are poorly capitalized
  - Quantify the Bank Balance Sheet Channel
    - Bank Balance Sheet explains 13% of the change in house prices, 9% change in foreclosures and 22% change in consumption

- **Empirical Contribution**
  - Document the Bank Balance Sheet Channel using an instrumental variable approach
    - Banks located in areas exposed to higher house price drop faced larger declines in their capital ratio
    - An 1p.p. decrease in the capital ratio induced by exogenous variation in housing prices leads to a decrease of supply of Home Purchase loans by 10.5% and Refinance by 15.2%

Related Work

- **Consumption response to Housing Price Shocks**
  - Mian et al. (2013), Kaplan et al. (2016), Mian and Sufi (2011, 2014)
  - Berger et al. (2016), Carrol and Dunn (1998)
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MODEL

Model Overview

- Time is discrete and infinite
- **Households**
  - Agents live forever
  - Homeowners or Renters
  - Long-term mortgages
- **Banks**
  - Issue and price individual mortgages
  - Bank balance sheet frictions
  - Credit supply depends on the banks' capitalization
- **Housing Sector**
  - Determine housing prices and rental rates
  - **Endogenous** House Prices

Households

- Income endowment (y) subject to temporary uninsured shocks

$$y_{it} = w.exp(z_{it}), \quad z_{it} = \rho z_{it-1} + \epsilon_{it}, \quad \epsilon_{it} \sim \mathcal{N}(0, \sigma_z)$$

- Utility over non-durable goods (c) and housing services (s)
  - Rented: $s = h$
  - Owned: $s = \upsilon h, \quad \upsilon > 1$

- **Housing** (h):
  - Rental Housing - p_t^r
  - Owned Housing- p_t
    - Transaction Costs
    - Random maintenance costs

Long-Term Mortgages

- **Long Term Collateralized Mortgages**
  - Mortgage face value (principal) originated at time τ: $m_\tau = m$
  - Borrower receives $q_\tau \left(y, a, h, m, r_\tau^m\right) m$

- Payments
  - **Contract terminates** (house sold or refinance): $X_t^s = m_{t-1}$
  - **Default** (Bank takes the house): $X_t^d = min\left\{\left(1-\chi_d\right) p_t h_t, m_{t-1}\right\}$
  - **Mortgage payment:**
    - $X_t = \frac{\mu + r_\tau^m}{1 + r_\tau^m} m_{t-1}$
    - μ amortization term, r_t^m the coupon (or interest) part
    - $m_t = (1-\mu) m_{t-1} = (1-\mu)^t m$

Households Decisions

- **Homeowners** $\Lambda_h = (y, a, h, \delta_h, m, r^m_\tau)$
  - Stays Home-owner: Pays Mortgage, Refinances or Changes House
  - Default - becomes a renter with no access to credit market
  - Sells house and becomes a Renter
- **Renter** $\Lambda_r = (y, a)$
  - Rents
  - Buys a house
    - If have Defaulted before may be restricted of mortgage market
- All decide Consumption (c) and Savings (a)

Value Functions Housing Sector

Banking Sector

- Representative Bank that behaves competitively

$$Q_t M_t = B_t + N_t$$
$$Q_t M_t = \int q_{it}(m_{it}) m_{it} di$$

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- **Frictions:**
- Low Capital ratio is costly

$$\Phi\left(\frac{N}{QM}\right) = \begin{cases} \kappa_0 + \kappa_1 \left(\tilde{K} - \frac{N}{QM}\right)^2 & \text{if } \frac{N}{QM} < \tilde{K} \\ 0 & \text{otherwise} \end{cases}$$

- Net worth is accumulated through retained earnings

$$N_{t+1} = (1-\omega)\left[N_t + \Pi_{t+1}\right]$$

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$$N_{t+1} = (1-\omega)\left[N_t + \Pi_{t+1}\right]$$

$$\Pi_{t+1} = r^m_{t+1} Q_t M_t - rB_t - \Phi\left(\frac{N_t}{Q_t M_t}\right)$$

Banking Sector

- Maximize the present discounted value of future dividends Bank's Problem
  - Given N_t, decides M_t and B_t

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- Maximize the present discounted value of future dividends Bank's Problem
  - Given N_t, decides M_t and B_t

- If No frictions

$$r^m_{t+1} - r = 0$$

- With Frictions

$$\left\{ r^m_{t+1} - \underbrace{r - \Phi\left(\frac{N_t}{Q_t M_t}\right) - \Phi'\left(\frac{N_t}{Q_t M_t}\right)\frac{N_t}{Q_t M_t}}_{r^c_{t+1}} \right\} = 0$$

- High Leverage
  - Cost of funding increases $r^c_{t+1} \uparrow$

Individual Mortgage

- Competition: zero expected discounted profit

$$q_t(y, a', h', m', r_t^m)m' = \frac{1}{(1 + r_{t+1}^c)} E_t^i\{z_{t+1}m' + (1 - d_{it+1} - s_{it+1})\, q_{t+1}(y', a'', h', (1-\mu)m', r_t^m)(1-\mu)m'\}$$

- Mortgages price decrease when banks are constraint (higher leverage ratio)
  - Cost of funding increases $r_{t+1}^c \uparrow$

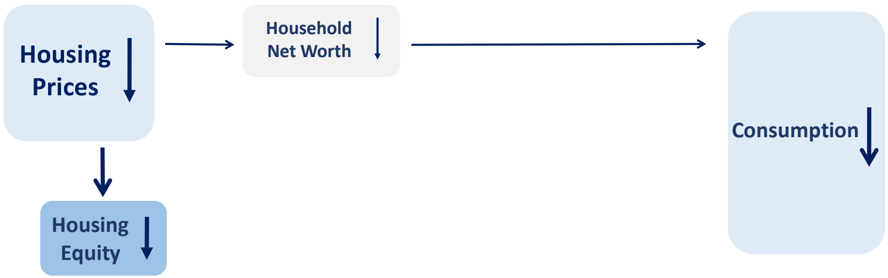
HS

Mechanism

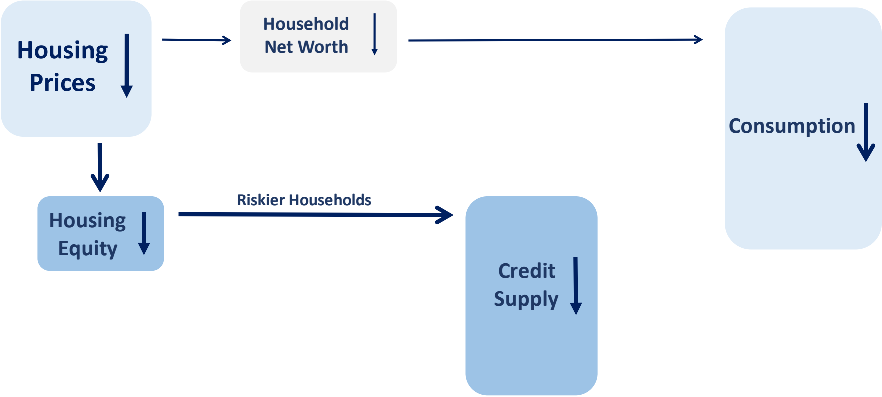
Housing Prices ↓

Mechanism

Mechanism


Housing Prices
Household Net Worth
Consumption
Housing Equity

Mechanism



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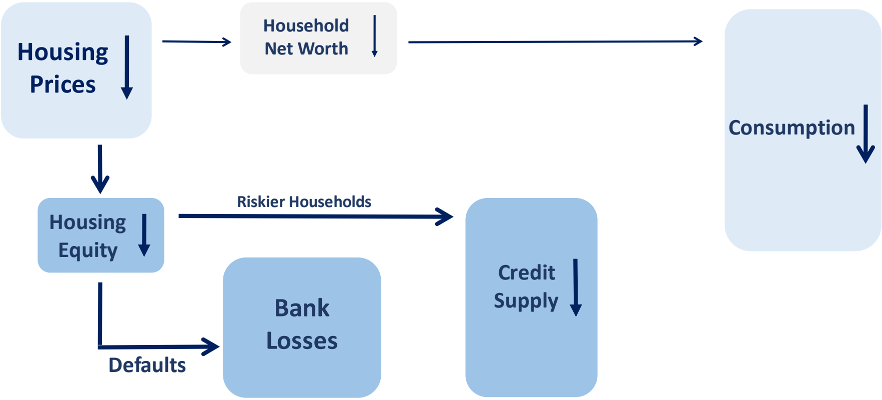
Riskier Households
Credit Supply

Mechanism



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Bank Losses
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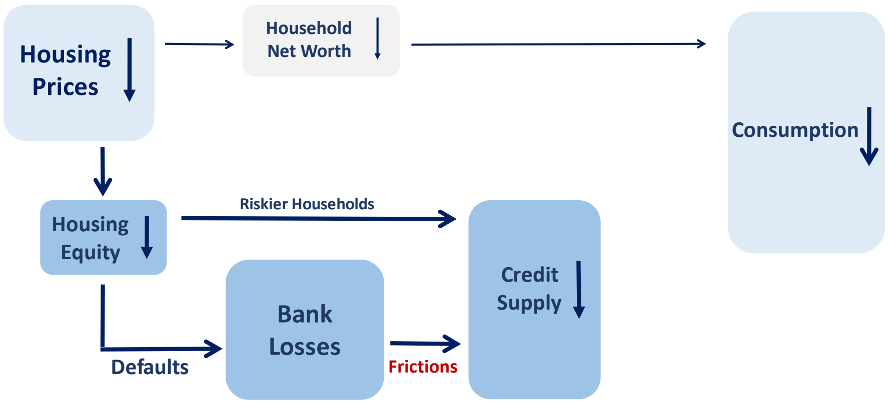

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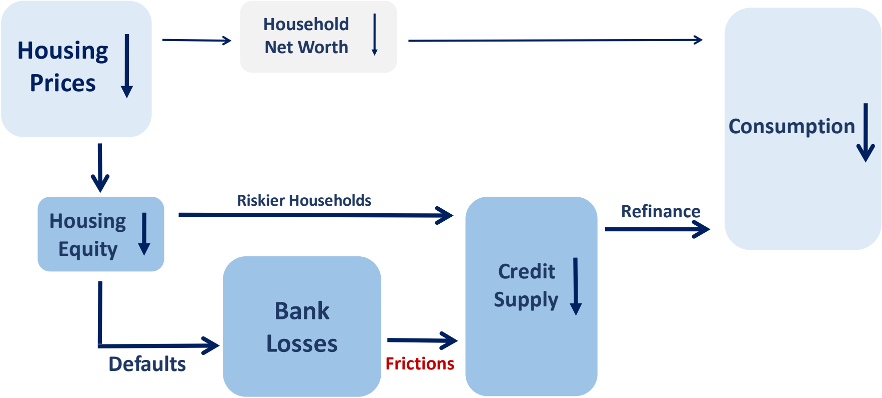
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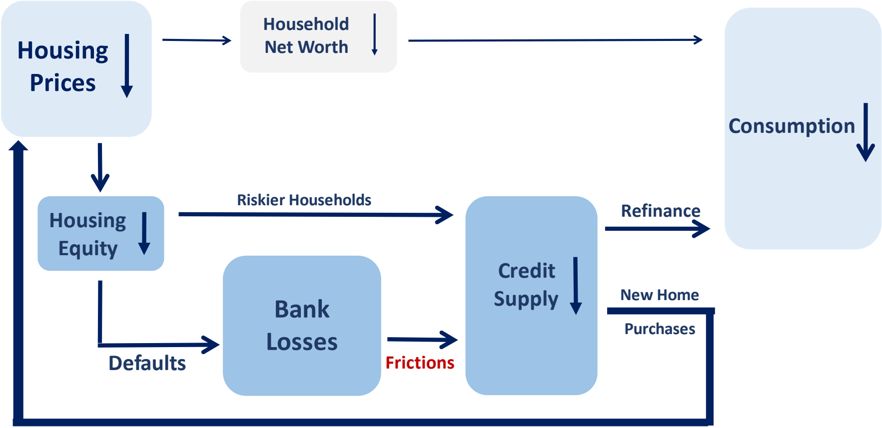

Housing Prices
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New Home
Purchases
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Frictions

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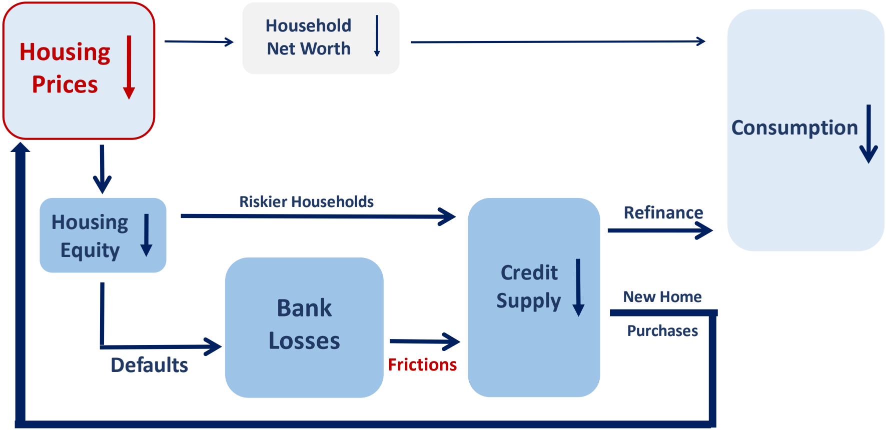

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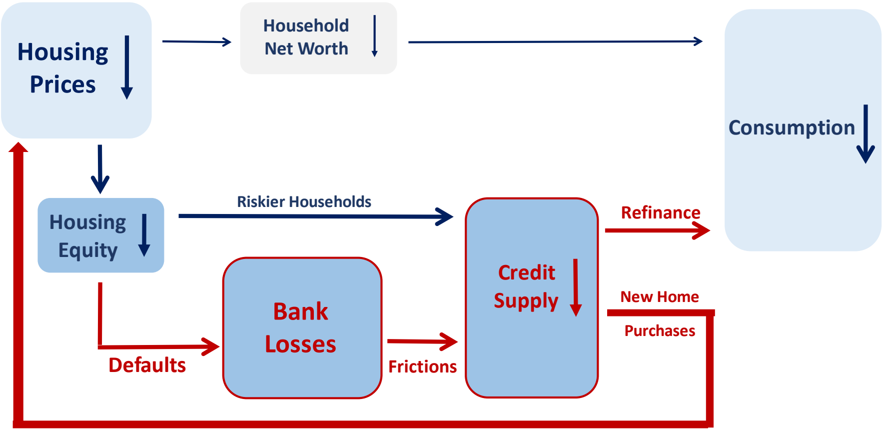
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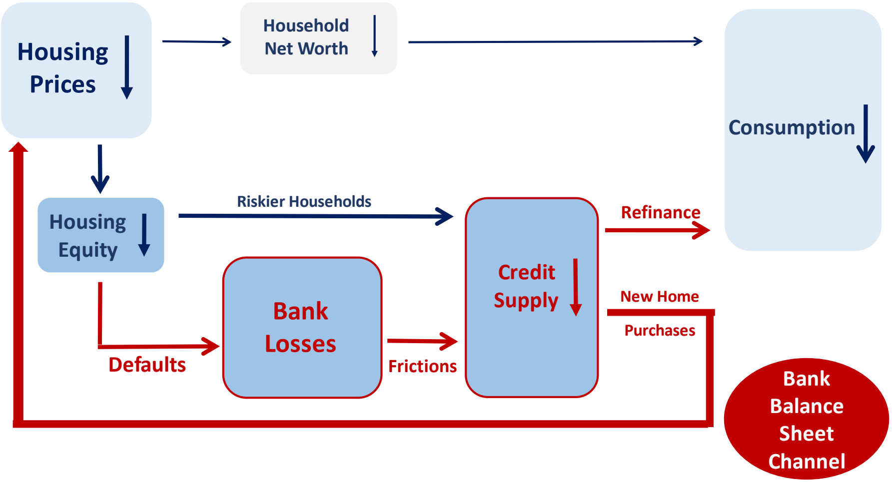

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Frictions
Bank Balance Sheet Channel

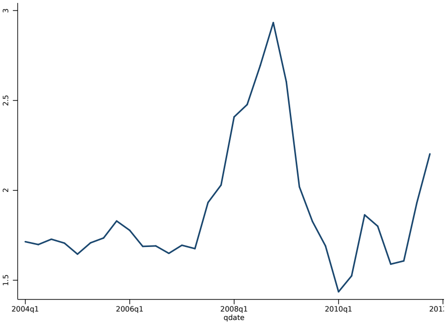
Calibration - Target Moments

Moments	Data	Model	Parameters	Value
Homeownership	68%	68.1%	Own-house add utility	$\upsilon = 1.06$
LTV$\geq$ 90%	7.02%	7.51%	Discount Factor	$\beta = 0.945$
Average Equity	62%	63.7%	Mortgage amortization	$\mu = 0.018$
Default Rate	1.5%	1.45%	High Depreciation shock	$\delta = 0.22$
Depreciation rate	1.06%	1.06%	Prob High Maintenance	$p_\delta = 0.048$
Refinance Rate	24%	25.7%	Refinance Cost	$\chi_r = 5.1\%$
Mortgage Spread	165b.p.	160b.p.	Capital ratio target	$\tilde{K} = 15\%$
Increase in spread	128b.p.		Leverage Cost Param.	$\kappa_0 = 0.0103$, $\kappa_1 = 3.37$

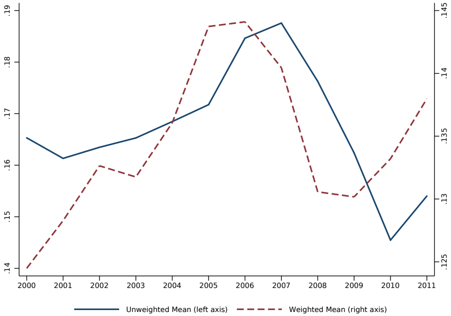
Exogenous Calibration

Calibration

Mortgage Spreads



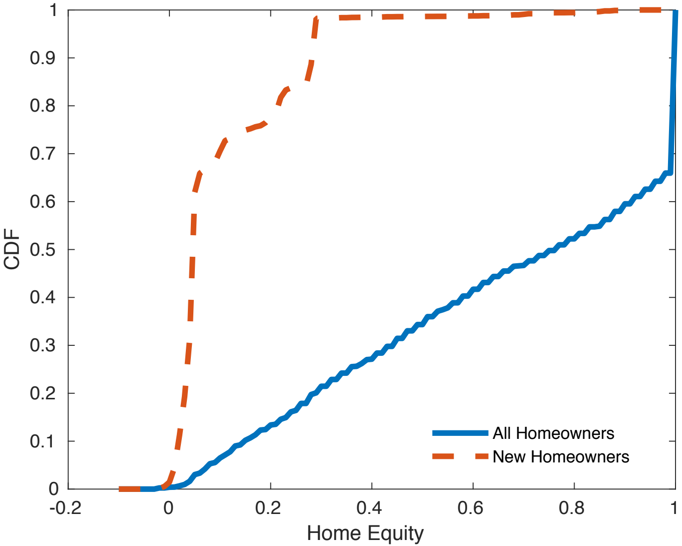
Capital to Assets Ratio



Non Target Moments

Moments	Data	Model
Mortgage Holder Rate	66%	67%
Avg. Income Homeowners / renters	2.05	3.34
Avg. Housing Wealth /Avg. Income	1.69	2.54
Cash Buyers	19	19.41
% Homeowners with 0% equity	1.81	0.39
% Homeowners with $\leq$ 10% equity	7.02	6.5
% Homeowners with $\leq$ 20% equity	14.07	13.04
% Homeowners with $\leq$ 30% equity	22.4	21.05
% Homeowners with 100% equity	28.75	34.05

Home Equity



CDF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.2
0
0.2
0.4
0.6
0.8
1
Home Equity
All Homeowners
New Homeowners

Quantification of Bank Balance Sheet

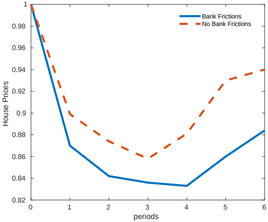
- Unanticipated Decrease in Demand for Housing
- Negative Productivity shock (4.7% cumulative over 3 periods)
- Delays in foreclosure process

$\triangle$**Cumulative**	**Data**	**Model (a)**	**No Fric (b)**	**(a-b)/a**
House prices	-18%	-18%	-16.6%	13%
Default Rate	13p.p.	11.2p.p.	10.2p.p.	9%
Consumption	-11.5%	-10.6%	-8.2 %	22%
Refinancing	-43%	-38.5%	-24.9%	35%
Bank Capital	-1.4p.p.	-1.15p.p.	-0.72p.p.	38%
Mortgage spread	133b.p.	109b.p.	0	

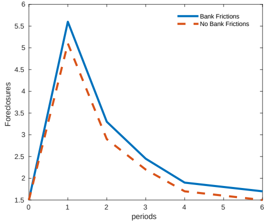
Heterogeneity

Results

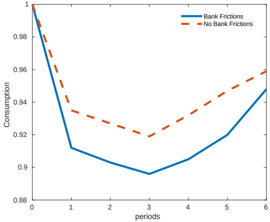
House Prices



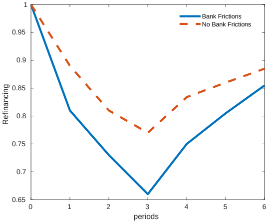
Foreclosures



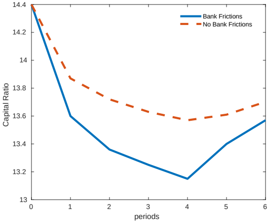
Consumption



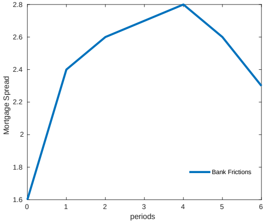
Refinancing



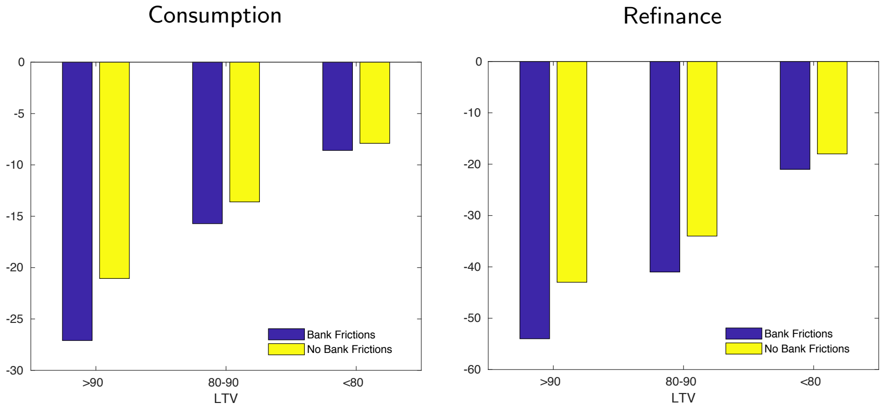
Capital Ratio



Mortgage Spreads



Heterogeneity



EMPIRICAL EVIDENCE

Empirical Evidence

- **Goal:** Estimate how changes in Housing Prices affect **Mortgage Supply** through **Banks'Balance Sheets**

- **Part I**: Impact of decline in house prices on Capital Ratio

$$\Delta K_{k,t} = \beta_1 + \beta_2 RES_{k,t} + \beta_3 X_{k,05} + \epsilon_{k,t}$$

  - **Challenge:** Reverse Causality
  - **Solutions:**
    - Exploit variation in banks' exposure to different housing markets
    - Instrumental variable approach - structural breaks in house prices evolution 2000-2006 (Charles, Hurst and Notowidigdo (2017))

- **Part II**: Impact of decline in Capital Ratio (induced by house price drop) on Credit Supply
  - Control for Demand characteristics at county level

$$\Delta VolOrig_{j,t} = \beta_1 + \beta_2 \Delta \Upsilon_{j,t} + \beta_3 \Delta H_{j,t} + \beta_4 X_{j,05} + \epsilon_{j,t}$$
$$\Delta \Upsilon_{j,t} = \sum_k \alpha_{k,j} \widehat{\Delta K_{k,t,-j}}$$

Results - Part I: $\Delta K_{k,t} = \beta_1 + \beta_2 RES_{k,t} + \beta_3 X_{k,05} + \epsilon_{k,t}$

	OLS	IV	OLS	IV
RES(t)	0.088***	0.091***	0.061***	0.082**
	(0.009)	(0.022)	(0.009)	(0.026)
Observations	4908	4908	4888	4888
Adjusted R^2	0.031	0.031	0.117	0.116
SD	robust	robust	robust	robust
Bank controls	No	No	Yes	Yes
Year FE	No	No	Yes	Yes

- If a bank faces an average shock (-4.6p.p. per year), capital decreases by -0.38p.p..
- From 90th to 10th percentile of change in RES implies that Capital Ratio decreases 0.85p.p. more

Results - Part II: $\Delta VolOrig_{j,t} = \beta_1 + \beta_2 \Delta Y_{j,t} + \beta_3 \Delta H_{j,t} + \beta_4 X_{j,05} + \epsilon_{j,t}$

	Banks in sample		All Originations	
	(1a)	(2a)	(1b)	(2a)
Home Purchase				
$\Delta Y_{j,t}$	141.031***	47.090**	37.701***	10.489*
	(21.241)	(17.293)	(4.514)	(4.352)
Refinance				
$\Delta Y_{j,t}$	60.902***	78.385***	24.908***	15.184*
	(13.507)	(12.809)	(6.453)	(6.038)
Observations	2850	2850	3010	3010
cluster	State	State	State	State
Year FE	No	Yes	No	Yes
State FE	No	Yes	No	Yes

- Going from the 90th to the 10th percentile of change in capital ratio induced by a real estate shock distribution (-0.57p.p.) in the cross-section implies a decrease in **Refinance of 8.55% and Home Purchases of 5.98%.**

Conclusion

- Model of long-term collateralized debt with risk of default with a *Banking Sector* with balance sheet frictions
  - Endogenous Credit Supply
- Bank Balance Sheet Channel is important to explain changes in house prices, foreclosures and consumption between 2006-2009
- Empirical Evidence that Bank's balance sheet are affected by change in house prices
  - More constrained banks contracted credit supply by more

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  - **Mortgage payment**:$X_t = \frac{\mu + r^m_\tau}{1+r^m_\tau} m_{t-1}$
    - μ amortization term, r^m_t the coupon (or interest) part
    - $m_t = (1-\mu) m_{t-1} = (1-\mu)^t m$

HH

Homeowners

- **Keeps House (Refinance or not)**

$$V^{HH}(\Lambda_h, \Lambda_{at}) = max_{\{c,a',h',m'\}} U(c,h') + \beta \mathbf{E}_{(y',\delta_h')|y}\left[V^H(\Lambda_h^{'}, \Lambda_{at+1})\right]$$

$$\begin{aligned} c + a' + \delta_h p_t h = w.y + a(1+r) &+ \left[q_t(y, a', m', h', \Lambda_{at})m' - m - \chi_m\right]_{m' \neq (1-\mu)m, h'=h} \\ &+ \left[(1-\chi_s)\, p_t h - (1+\chi_b)\, p_t h' + q_t(y, a', m', h', \Lambda_{at})m' - m - \chi_m\right]_{h' \neq h} \\ &- \left[x_\tau m\right]_{m'=(1-\mu)m, h'=h} - T(y, h', m, r_\tau^m) \end{aligned}$$

- **Defaults**

$$V^D(\Lambda_h, \Lambda_{at}) = max_{\{c,h',a'\}} U(c,h') + \beta E_{y'|y}\left[(1-\theta)\, V^M(\Lambda_r^{'}, \Lambda_{at+1}) + \theta V^{NM}(\Lambda_r^{'}, \Lambda_{at+1})\right]$$

$$s.t.\ c + p_t^r h' + a' = y + a(1+r) + max\left\{(1-\chi_d-\tau_h)\, p_t h - m, 0\right\} - T(y, 0, 0, 0)$$

- **Becomes a Renter**

$$V^{HS}(\Lambda_h, \Lambda_{at}) = max_{\{c,h',a'\}} U(c,h') + \beta E_{y'|y} V^{GR}(\Lambda_r^{'}, \Lambda_{at+1})$$

$$s.t.\ c + p_t^r h' + a' = y + a(1+r) + (1-\delta_h-\chi_s)\, p_t h - m$$

$$V^H(\Lambda_h, \Lambda_{at}) = max\left\{V^{HH}(\Lambda_h, \Lambda_{at}), V^{HD}(\Lambda_h, \Lambda_{at}), V^{HS}(\Lambda_h, \Lambda_{at})\right\}$$

HH Decisions

Renters ($m' = 0 \;\; if \; w = NM$)

- Buys a House

$$V^{RHw}\left(\Lambda_r, \Lambda_{at}\right) = max_{\{c,a',h',m'\}} U(c,h') + \beta E_{y'|y}\left[V^{HH}(\Lambda_h^{'}, \Lambda_{at+1})\right]$$
$$s.t. \; c + a' + (1+\chi_b)\, p_t h' = y + a(1+r) + q(y,a',h',m',r_t^m)m' - T(y,0,h',0)$$
$$m' = 0 \;\; if \; w = NM$$

- Rents

$$V^{RRw}\left(\Lambda_r, \Lambda_{at}\right) = max_{\{c,h',a'\}} U(c,h') + \beta E_{y'|y}\left[V^{Rw}(\Lambda_r^{'}, \Lambda_{at+1})\right]$$
$$c + p_t^r h' + a' = y + a(1+r)$$

where $V^{RM}\left(\Lambda_r, \Lambda_{at}\right) = max\left\{V^{RHM}\left(\Lambda_r, \Lambda_{at}\right), V^{RRM}\left(\Lambda_r, \Lambda_{at}\right)\right\}$ and $V^{RNM}\left(\Lambda_r, \Lambda_{at}\right) = max\left\{V^{RHNM}\left(\Lambda_r, \Lambda_{at}\right), V^{RRNM}\left(\Lambda_r, \Lambda_{at}\right)\right\}$

HH Decisions

Housing Sector

- **Composite Consumption**

$$Y_c = AN_c \qquad w = A$$

- **Construction sector**

$$Y_h = Y_c^{\alpha_h} L^{1-\alpha_h} \qquad S_t^h = (\alpha_h p_t)^{\frac{\alpha_h}{1-\alpha_h}} L_t$$

- **Rental Sector:**
  - Every period faces a maintenance cost $\delta_r . p_t^h h$
  - Can buy/sell housing at the equilibrium price
  - No transaction cost: Arbitrage Condition determines equilibrium rents (p^r)

$$p_t^r - (\delta_r + \tau_h) p_t^h + E_t \left[\frac{p_{t+1}^h}{1+r} \right] = p_t^h$$

HH Decisions

Calibration - Exogenous Parameters

Parameters	Value
Housing share	$\alpha = 0.15$
Elasticity substituition c and h	$\frac{1}{\gamma} = 1.25$
Intertemporal elasticity	$\sigma = 2$
House sizes	$\mathcal{H}^h = \{1.43, 1.79, 2.3, 2.9, 3.6, 4.2\}$
Rental sizes	$\mathcal{H}^r = \{1.1, 1.43, 1.79\}$
Autocorrelation earning shocks	$\rho_z = 0.97$
S.D. of earning shocks	$\sigma_z = 0.2$
Buying Costs	$\chi_b = 0.01$
Selling Costs	$\chi_s = 0.06$
Liquidation cost	$\chi_d = 0.25$
Rental Maintenance cost	$\delta_r = 0.0165$
World Interest Rate	$r = 0.03$
Probability of reentering credit mkt	$\theta = 0.25$
Dividend	$\omega = 0.115$

Empirical Evidence

- **Part 1:** Fluctuations in housing prices impact banks' balance sheets
- **Part 2:** banks react to losses induced by changes in housing prices by contracting mortgage loan supply

- **Data**
  - 2007-2010 period
  - **Housing Prices:** Zillow Median Home Value Index for All Homes
  - **Mortgages:** Home Mortgage Disclosure Act (HMDA)
  - **Banks' balance sheets:**
    - Report of Condition and Income (Call Reports)
    - Summary of Deposits (SOD)
  - County level Unemployment (BLS) and Income (IRS)

Empirical Strategy - Part I

- Change in house prices and banks balance sheets

$$\Delta K_{k,t} = \beta_1 + \beta_2 RES_{k,t} + \beta_3 X_{k,05} + \epsilon_{k,t}$$
$$RES_{k,t} = \sum_j \omega_{kj05} \Delta P_{jt}$$

  - $\Delta K_{k,t}$ change of Capital Ratio of bank k
  - RES_{kt}: **Real Estate Shock** to bank k at time t

- **Instrumental variable approach**
  - **Estimated structural breaks in the house price evolution** between 2000 and 2006, Charles, Hurst and Notowidigdo (2017)
  - Assumption: variation in housing prices during the boom and bust derived from a speculative âbubbleâ and not from changes in standard determinants of housing values.
  - Boom is strongly correlated with the size of its later housing bust, this structural breaks are strongly correlated with house demand in the bust period

1st Stage

Deposits as proxy

$$RES_{k,t} = \sum_j \omega_{kj05} \Delta P_{jt}$$

- ΔP_{jt}: change in House Prices in county j
  - ω_{kj05} share of bank k deposits in county j in 2005

- Two major concerns:
  1. Weights are based on deposits rather than loans.
  2. Rise of mortgage-backed securities may have allowed banks to diversify away from their physical locations.

- Section 109 of the Riegle-Neal Interstate Banking and Branching Efficiency Act of 1994 prohibits a bank from establishing or acquiring branches outside of its home state primarily for the purpose of deposit production.
- Aguirregabiria et. al. (2016): evidence of a strong home bias for 1998-2010 period - local deposits are mostly used to fund local loans
- Chakraborty et. al. (2016):
  - when loans are sold, banks are likely to remain as servicers of the mortgage and maintain exposure to the local market.
  - MBS: often maintain a certain share of the security as a signal of its quality

Real Estate Shock - Summary Statistics

	Mean	SD	Median	Perc10	Perc90
RES					
2006-2009	-.0468	.0547	-.0445	-.1085	.0203
2006-2010	-.0458	.0502	-.0454	-.0999	.0049
Δ2006-2009	-.1267	.1007	-.1352	-.2197	.0019
Δ2006-2010	-.1573	.1024	-.1487	-.2708	-.0437
Δ House Prices - Unweighted					
2006-2009	-.0426	.0702	-.0468	-.1078	.0293
2006-2010	-.0482	.0704	-.0513	-.1239	.0222
Δ2006-2009	-.1182	.144	-.1142	-.2786	.0518
Δ2006-2010	-.173	.1557	-.1815	-.3554	.0003
Δ House Prices - Weighted					
2006-2009	-.0674	.0756	-.0603	-.1743	.0117
2006-2010	-.064	.0731	-.0554	-.1634	.0109
Δ_2006-2009	-.182	.1564	-.1751	-.396	-.0082
Δ_2006-2010	-.2228	.1684	-.2171	-.4865	-.0208

Source: Call Reports. Capital to Assets Ratio weighted by total assets in 2005

- The average Real Estate shock relevant for each bank is similar in size to the house price change in the US.
- Large variation across banks.

Instrument - Housing supply elasticity, Saiz (2010)

- Strong 1st Stage: Breaks in House Price evolution explains a large portion of the real estate shocks faced by the banks

	(1)	(2)	(3)	(4)
RES (HP break)	-0.307***	-0.308***	-0.254***	-0.254***
	(0.012)	(0.011)	(0.012)	(0.011)
Observations	7554	7554	7515	7515
Adjusted R^2	0.144	0.227	0.198	0.281
F	630.2	716.7	68.40	81.11
SD	robust	robust	robust	robust
Year FE	No	Yes	No	Yes

Empirical Strategy - Part II

- Estimate the impact of predicted changes in banks' capital ratio on Credit Supply

- **Change in mortgages originations at the county level (j)**

$$\Delta VolOrig_{j,t} = \beta_1 + \beta_2 \Delta \mathrm{Y}_{j,t} + \beta_3 \Delta H_{j,t} + \beta_4 X_{j,05} + \epsilon_{j,t}$$
$$\Delta \mathrm{Y}_{j,t} = \sum_k \alpha_{k,j} \Delta \widehat{K_{k,t,-j}}$$

  - $\Delta \widehat{Y_{k,t}}$ predicted change in Bank's Capital Ratio (regression part I)
  - $\Delta H_{j,t}$ change in House prices, Unemployment Rate and Income at county level
  - $X_{j,06}$ bank's controls at county level

Banking Sector

- $Q_t M_t$ can be seen as "representative" mortgage.
- **Principal Evolution:**
$$\tilde{M}_{t+1} = (1 - \mathbf{d}_{t+1} - \mathbf{s}_{t+1})(1-\mu) M_t$$
  - $\mathbf{d}_{t+1} M_t = \int \mathbf{1}_{\{\mathbf{d_{it+1}=1}\}} m_{it} di, \quad \mathbf{s}_{t+1} M_t = \int \mathbf{1}_{\{\mathbf{s_{it+1}=1}\}} m_{it} di$
- **Earnings:**
$$\Pi_{t+1} = \underbrace{Z_{t+1} M_t + \left(\tilde{Q}_{t+1} \tilde{M}_{t+1} - Q_t M_t\right)}_{r^m_{t+1} Q_t M_t} - rB_t - \Phi\left(\frac{Q_t M_t}{N_t}\right)$$
$$Z_{t+1} M_t = (1 - \mathbf{d}_{kt+1} - \mathbf{s}_{kt+1})(\mu + x) M_t + \mathbf{d}_{t+1} x^d_{t+1} M_t + \mathbf{s}_{t+1}(1+x) M_t$$
$$r^m_{t+1} = \frac{Z_{t+1} + \tilde{Q}_{t+1}(1 - \mathbf{d}_{t+1} - \mathbf{s}_{t+1})(1-\mu)}{Q_t} - 1$$

Bank's Problem

Banking Sector

$$V_{t-1}\left(M_{t-1}, N_{t-1}\right) = max_{\{M_{t+\tau}, B_{t+\tau}\}} E_t \sum_{\tau=0}^{\infty} \beta_b^{\tau+1} \omega \left[N_{t-1+\tau} + \Pi_{t+\tau}\right]$$
$$= max_{\{M_t, B_t\}} E_t \left[\omega \left[N_{t-1} + \Pi_t\right] + V_t\left(M_t, N_t\right)\right]$$

s.t.

$$Q_t M_t = B_t + N_t$$

$$N_{t+1} = (1-\omega)\left[N_t + \Pi_{t+1}\right]$$

$$\Pi_t = r_t^m Q_{t-1} M_{t-1} - r B_{t-1} - \Phi\left(\frac{Q_{t-1} M_{t-1}}{N_{t-1}}\right)$$

$$r_t^m = \frac{Z_t + \tilde{Q}_t\left(1 - \mathbf{d}_t - \mathbf{s}_t\right)(1-\mu)}{Q_{t-1}} - 1$$

$$Z_t = \left(1 - \mathbf{d}_{kt} - \mathbf{s}_{kt}\right)(\mu + x) + \mathbf{d}_t x_t^d + \mathbf{s}_t (1+x)$$

Bank's Problem

Banking Sector

$$N = (1-\omega)\left[(1+r)N + (r^m - r - \Phi(L))QM\right]$$

$$r^m - r - \Phi(L) - \Phi'(L)L = 0$$

- Then

$$1 = (1-\omega)\left[1 + r + \Phi'(L)L^2\right]$$

- If $(1-\omega)(1+r) = 1$

$$L \leq \tilde{L} \qquad r^m - r = 0$$

- If $(1-\omega)(1+r) > 1$

$$L > \tilde{L} \qquad r^m - r > 0$$

Bank's Problem

Equilibrium

Given the **initial** distributions $\Gamma_H(\Lambda_h, 0)$, $\Gamma_M(\Lambda_r, 0)$ and $\Gamma_{NM}(\Lambda_r, 0)$ over $\Lambda_h = (y, a, h, m, \delta_h)$ and $\Lambda_r = (y, a)$; net worth N_0 and asset composition $Q_0 M_0$; initial stock of own-occupied H_O and rental H_R houses and an exogenous r, the equilibrium is defined as

- sequence of house prices $\{p_t^h\}$, rents $\{p_t^r\}$, mortgage price function $\{q_t(y, a', m', h')\}$ and funding cost of banks $\{r_t^c\}$ for $t \geq 1$
- sequence of decision rules and distributions of homeowners $\Gamma_H(\Lambda_h, t)$, renters $\Gamma_j(\Lambda_r, t), j \in \{M, NM\}\}$ for $t \geq 1$
- Evolution of N_t and asset composition $Q_t M_t$ for $t \geq 1$

such that:

- Decision rules are optimal given prices sequences
- Rents satisfy zero profit condition
- Cost of funding and individual mortgage prices satisfy the bank's problem
- Demand for owner-occupied house equals supply
- Distributions are implied by the sequence of optimal decision rules and initial distributions

Individual Mortgage