HOUSING MARKET CYCLES, PRODUCTIVITY GROWTH, AND HOUSEHOLD DEBT

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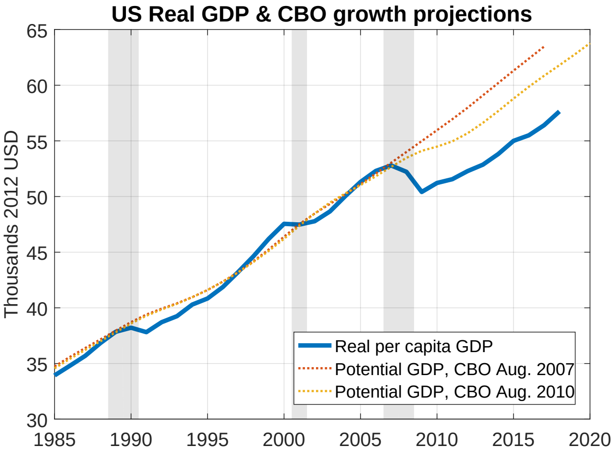
Moody's Analytics

Slow recoveries from financial crises



Recoveries from financial crises tend to be slow and incomplete

(Cerra and Saxena 2008; Reinhart and Rogoff 2009; Romer and Romer 2017)

Focus: the role of housing market cycles and home-equity borrowing

Empirical evidence and a general equilibrium model

Empirical evidence

Housing market boom-and-bust cycles predict lower future TFP growth

Unbalanced panel of 50 countries, 1950 - 2018:

- House price indexes
- Private debt
- Real economy indicators
- Constructed utilization-adjusted TFP

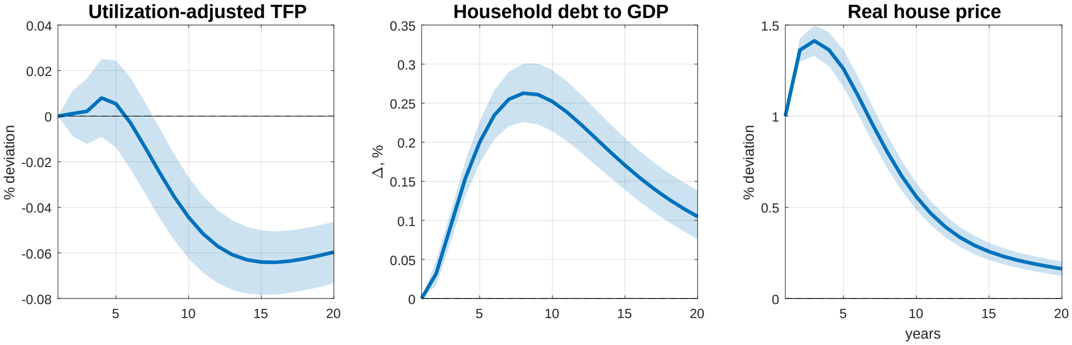
Imbs (1999) correction

Two experiments:

- House price shock in a panel VAR
- Event study of housing market crashes by local projections

House price shock in a panel VAR

Panel VAR in levels, Cholesky identification, house price ordered last:



A rise is house prices and household debt predict lower TFP growth in the medium run

Event study of housing market crashes

63 housing market boom-and-bust events List

Elasticities of macroeconomic variables to the house price decline during the crash:

$$\Delta_h y_{i,t+h} = \alpha_i^h + \alpha_t^h + \delta_i t + \boldsymbol{\beta}^h \Delta p_{i,t}^{\text{crash}} + X'_{i,t}\Gamma^h + \varepsilon_{it}^h$$

$\Delta_h y_{i,t+h} = \log(Y_{i,t+h}) - \log(Y_{i,t})$, country i

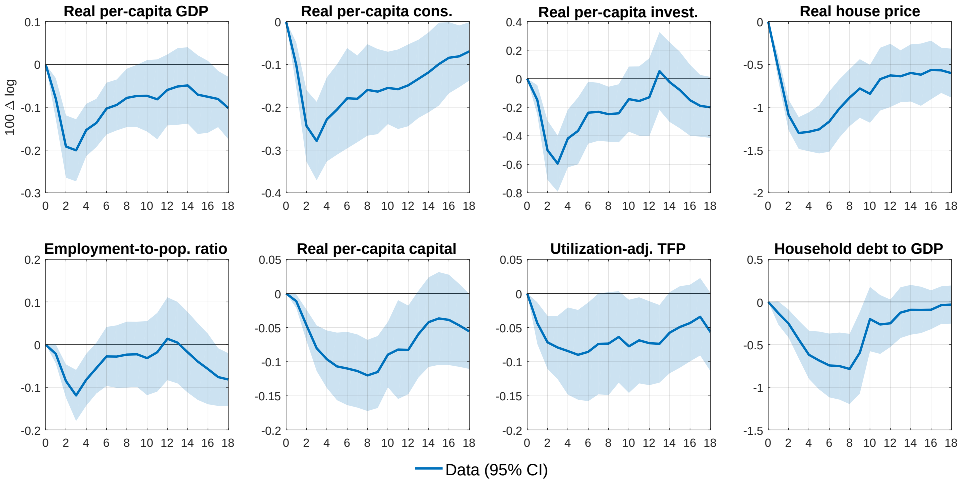
$\Delta p_{i,t}^{\text{crash}}$ – housing crash measure (3-year price decline from the peak)

α_i^h, α_t^h, $\delta_i t$ – country and year fixed effects, country trends

$X_{i,t}$ – vector of controls List

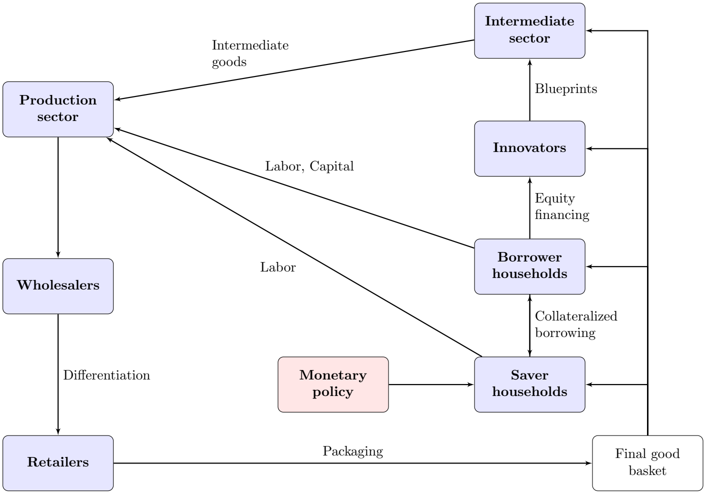
H-period response: $\{\boldsymbol{\beta}^h\}_{h=1:H}$

Event study of housing market crashes



Household deleveraging, persistent decrease in the TFP level

General equilibrium model



- Two-agent NK model (borrower-saver)
- Home equity-based borrowing
- Occasionally binding collateral constraint
- Endogenous growth through product creation (Romer 1990)

Experiment: a series of housing demand shocks to match the evidence

Appendix

Endogenous growth through innovation

Aggregate production function: $$Y_t = F\Big(\underbrace{K_t,\ L_t}_{\text{Rival factors}},\ \underbrace{\int_0^{N_t} x_t(\omega) d\omega}_{\text{Non-rival “ideas”}} \Big)$$

New “ideas” through innovation (S): $$\dot{N}_t = \phi_t S_t^{\rho}$$

Positive externality in innovation: $$\phi_t = \phi N_t$$

Monopolistic competition: $x_t(\omega)$ are imperfectly substitutable $\longrightarrow$ positive profit $\longrightarrow$ entry subject to a sunk cost

Connection to business cycles: Entry incentives depend on cyclical conditions

Housing as collateral

$$\max \quad \mathbb{E}_t \sum_{j=t}^{\infty} \beta^{j-t} [u(C_j, L_j) + \underbrace{\eta_j g(h_j^B)}_{\text{Utility from housing}}]$$

Budget constraint: $\quad C_t + P_t^h(h_t - h_{t-1}) + (1 + r_{t-1}) \frac{B_{t-1}}{P_t} = \frac{B_t}{P_t}$ + other terms

Occasionally binding collateral constraint: $\quad B_t \leq \underbrace{m P_t^h h_t}_{\text{Fraction of housing value}}$

$$\mathbb{E}_t \left(\beta \frac{u'_{c_{t+1}}}{u'_t} \frac{1+r_t}{\Pi_{t+1}} \right) = \underbrace{1 - \chi_t}_{\text{Intertemporal distortion}}$$

$\chi_t \geq 0 \equiv$ Lagrange multiplier w.r.t. the collateral constraint

IRF matching

Crisis experiment: a sequence of negative housing preference shocks to mimic the empirical housing price decline

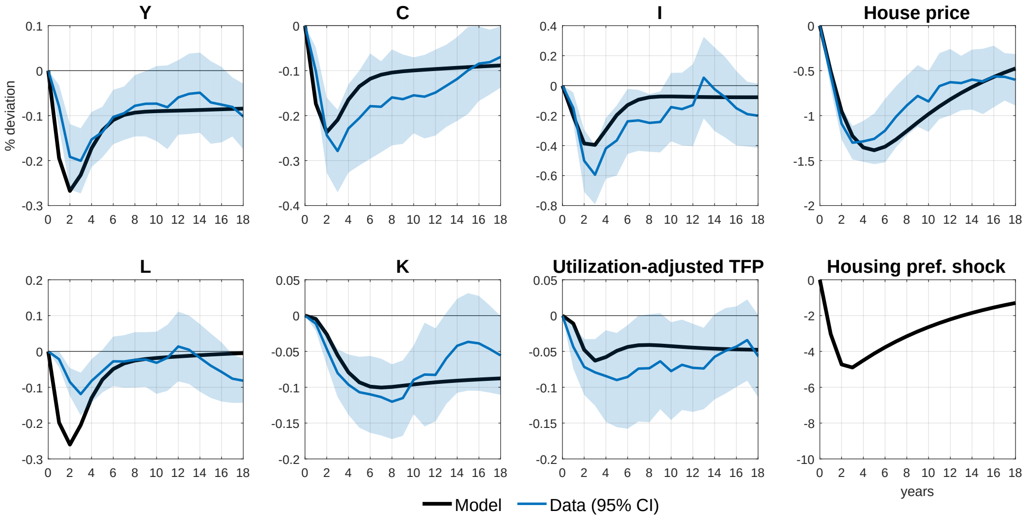
The resulting theoretical IRFs are used to estimate a set of quantitative parameters P

IRF matching estimator: choose P to minimize the weighted distance between empirical (Σ^{LP}) and theoretical (Σ^{DSGE}) impulse responses:

$$\min_{P} \ (\Sigma^{DSGE}(P) - \Sigma^{LP}) \ \Omega^{-1} \ (\Sigma^{DSGE}(P) - \Sigma^{LP})'$$

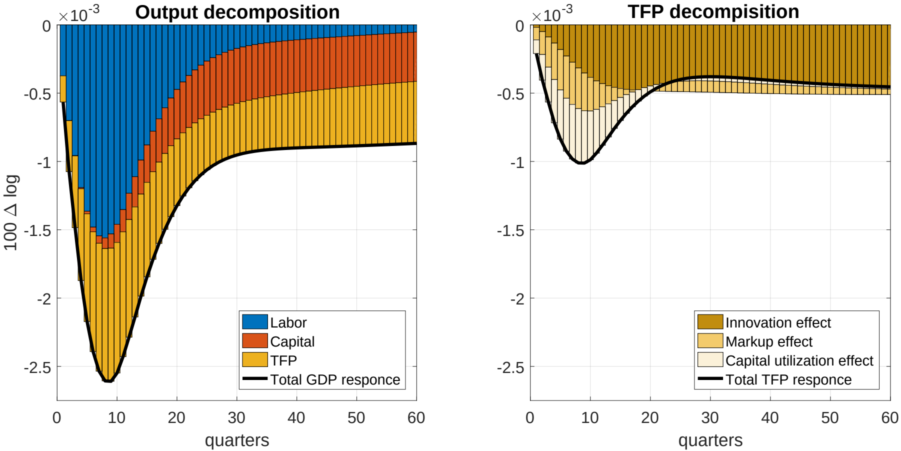
Quantitative parameters: Capital adjustment costs (ψ_K); R&D adjustment costs (ψ_N); Borrowing limit inertia (ρ_b); Labor disutility inertia (γ), Capital utilization parameter (c_2)

Housing market crash: model vs evidence



More IRFs

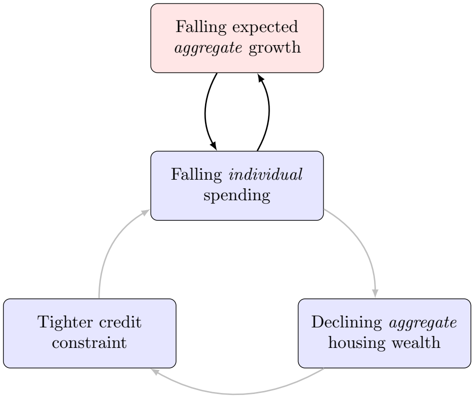
Model-based decomposition of output and TFP dynamics



$$\Delta \mathrm{GDP}_t = \Delta \mathrm{TFP}_t + \underbrace{\alpha \Delta K_t}_{\text{Capital}} + \underbrace{(1-\alpha)\Delta L_t}_{\text{Labor}}$$

$$\Delta \mathrm{TFP}_t = \underbrace{\Delta \Omega_t}_{\text{Markup}} + \underbrace{\alpha \Delta u_t}_{\text{Utilization}} + \underbrace{(1-\alpha)\Delta N_t}_{\text{Innovation}}$$

Negative housing demand shock: main channels



(1) **Aggregate demand channel** IRFs

Demand effects of deleveraging

(2) **Productivity growth channel** IRFs

Endogenous slowdown in TFP growth prolonging the crisis

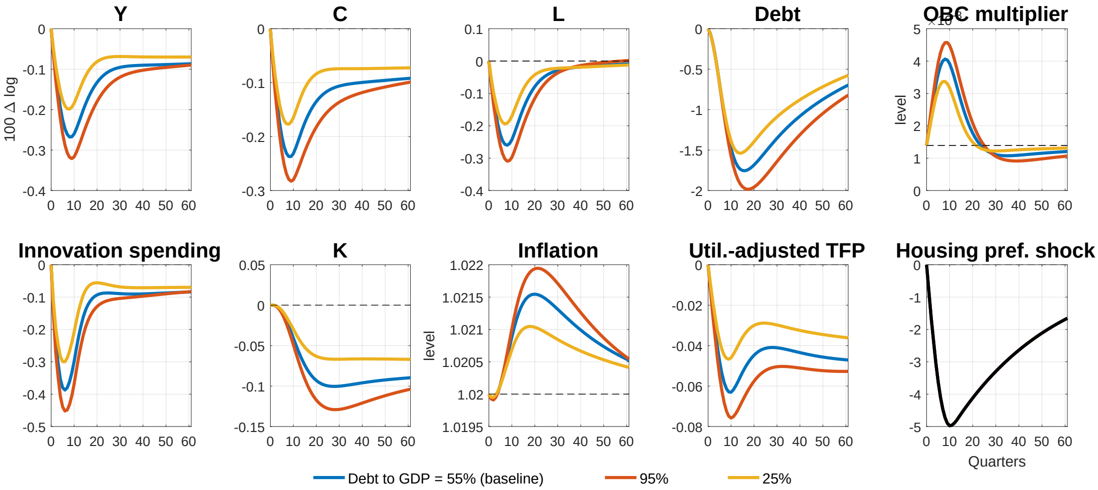
(3) **Fisherian debt deflation channel**

Negative feedback loop between deleveraging and the collateral price

(4) **Expected income growth channel**

Negative feedback loop between expected growth and consumption

State-dependent amplification: sensitivity to the debt-to-DGP ratio



Lessons for monetary policy

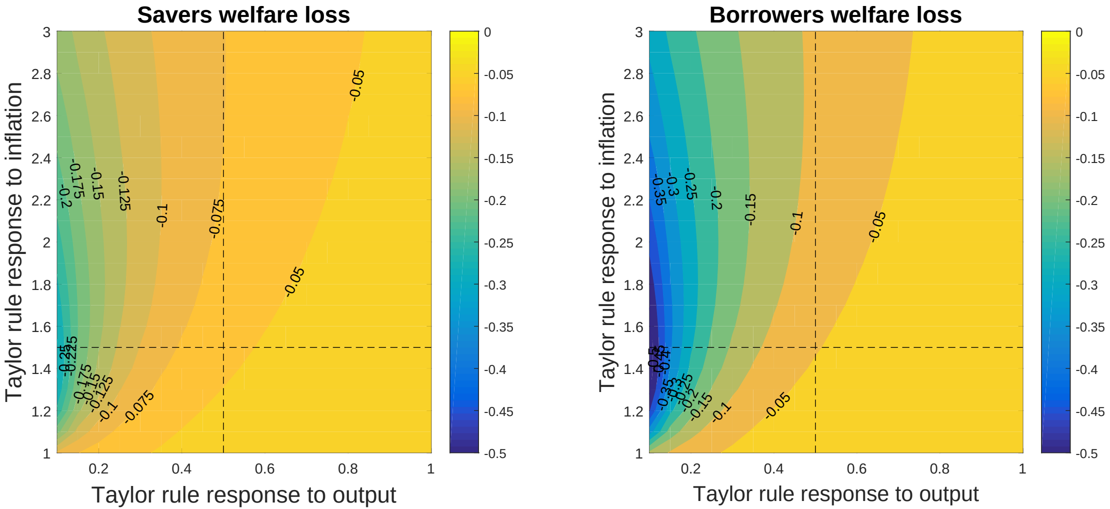
Counterfactual simulations under various parameters of the Taylor rule (ϕ_y, ϕ_π):

$$\frac{1+r_t}{1+r} = \left(\frac{1+r_{t-1}}{1+r}\right)^{\rho_r} \left(\left(\frac{Y_t}{Y_t^{BGP}}\right)^{\phi_y} \left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi}\right)^{1-\rho_r}$$

Criterion: welfare loss in % of the steady-state consumption

- Focus on output stabilization, as opposed to inflation stabilization, is welfare-improving...
- ...especially for borrowers and in the presence of endogenous growth mechanism

Monetary policy and the the welfare cost of the crisis



Conclusion

Housing market crashes are transitory events but they can leave long-lasting scars on economic activity...

- ...especially when they happen in a highly indebted economy
- ...especially when monetary policy prioritizes inflation stabilization too strongly relative to output stabilization or is constrained by the zero lower bound

Properly designed — and timely — fiscal policy response may offset a large share of the negative effect

APPENDIX

Utilization-adjusted TFP

Utilization adjustment approach of Imbs (1999) based on a partial-equilibrium version of a model from Burnside and Eichenbaum (1996)

Firms problem:

$$\max_{K_t, u_t, e_t} \left[Z_t (u_t K_t)^{\alpha} (e_t L_t)^{1-\alpha} - w(e_t) L_t - (r_t + \delta u_t^{\phi}) K_t \right]$$

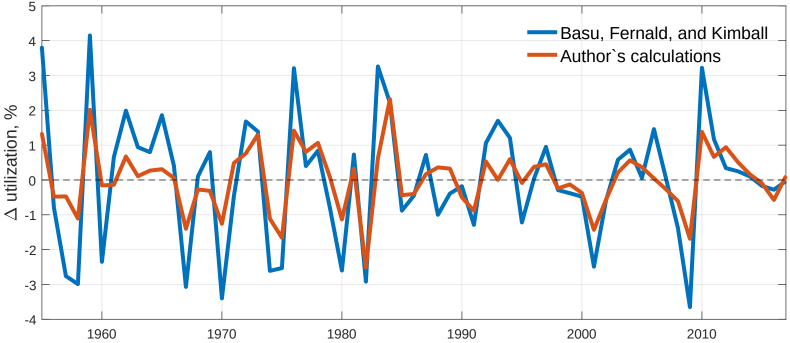
Households problem:

$$\max_{\{C_{t+j}, L_{t+j}, e_{t+j}\}_{j=0}^{\infty}} \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(\ln(C_t) - \frac{L_t^{1+\epsilon}}{1+\epsilon} - \frac{e_t^{1+\psi}}{1+\psi} \right) \quad \text{s.t. } C_t \leq w(e_t) L_t$$

Capital utilization: $u_t = \left(\frac{Y_t/K_t}{Y/K} \right)^{\frac{\delta}{r+\delta}}$ **Labor effort:** $e_t = \left(\frac{Y_t/C_t}{Y/C} \right)^{\frac{1}{1+\psi}}$

Back

US factor utilization



Back

Event study: sample of housing market crashes

	Peak	Trough	3 years	Total		Peak	Trough	3 years	Total		Peak	Trough	3 years	Total
BEL	1979	1985	-26%	-38%	GBR	1973	1977	-24%	-29%	NLD	1978	1985	-34%	-48%
BGR	1996	2002	-40%	-52%	GBR	1989	1996	-22%	-30%	NLD	2008	2013	-11%	-26%
BGR	2008	2013	-39%	-44%	GBR	2007	2012	-16%	-23%	NOR	1987	1992	-29%	-43%
BRA	2014	2017	-16%	-16%	GRC	2007	2017	-15%	-45%	NZL	1974	1980	-18%	-36%
CAN	1981	1985	-26%	-30%	HKG	1981	1984	-47%	-47%	NZL	2007	2009	-11%	-11%
CHE	1973	1976	-20%	-20%	HKG	1997	2003	-42%	-57%	PER	1999	2003	-15%	-29%
CHE	1990	2000	-20%	-33%	HRV	1999	2002	-14%	-14%	PHL	1996	2004	-36%	-53%
CHE	1959	1961	-12%	-12%	HRV	2009	2015	-19%	-24%	POL	2010	2013	-16%	-16%
COL	1989	1992	-13%	-13%	HUN	2006	2013	-17%	-37%	PRT	1992	1996	-11%	-12%
COL	1995	2003	-14%	-35%	IRL	2006	2012	-30%	-46%	RUS	2008	2011	-33%	-33%
CZE	2008	2013	-15%	-19%	ISL	2007	2010	-32%	-32%	SGP	1983	1986	-31%	-31%
DEU	1981	1987	-11%	-14%	ITA	1981	1986	-21%	-31%	SGP	1996	1998	-32%	-34%
DNK	1979	1982	-34%	-34%	ITA	1992	1997	-14%	-26%	SRB	2010	2013	-29%	-29%
DNK	1986	1993	-18%	-31%	JPN	1974	1977	-23%	-23%	SVK	2008	2012	-21%	-26%
DNK	2007	2012	-19%	-28%	JPN	1991	2012	-13%	-51%	SVN	2011	2014	-21%	-21%
ESP	1991	1996	-13%	-15%	KOR	1991	1998	-25%	-43%	SWE	1979	1985	-26%	-35%
ESP	2007	2014	-15%	-36%	LTU	2007	2010	-43%	-43%	SWE	1990	1993	-30%	-30%
EST	2007	2009	-51%	-52%	LUX	1980	1984	-22%	-23%	THA	2006	2009	-30%	-30%
FIN	1974	1979	-25%	-31%	LVA	2007	2010	-47%	-47%	USA	2006	2012	-14%	-26%
FIN	1989	1993	-42%	-47%	MYS	1997	1999	-15%	-18%	ZAF	1984	1987	-39%	-39%
FRA	1980	1985	-11%	-16%	NLD	1964	1966	-27%	-29%	ZAF	2007	2012	-16%	-19%

- 63 events in total, 39 before 2006,
- Median duration: 5 years peak to though, -30.6% price decline

Back

Local projections, control variables

Value at the peak and one lag:

- Growth rate of the response variable
- Real per-capita investment growth
- GDP-deflator inflation rate
- Real house price growth rate
- Net exports to GDP

Value at the peak:

- Investment to GDP
- Exchange rate regime indicator (Ilzetzki et al. 2019)
- Systematic banking & currency crises indicator (Laeven and Valencia 2012)

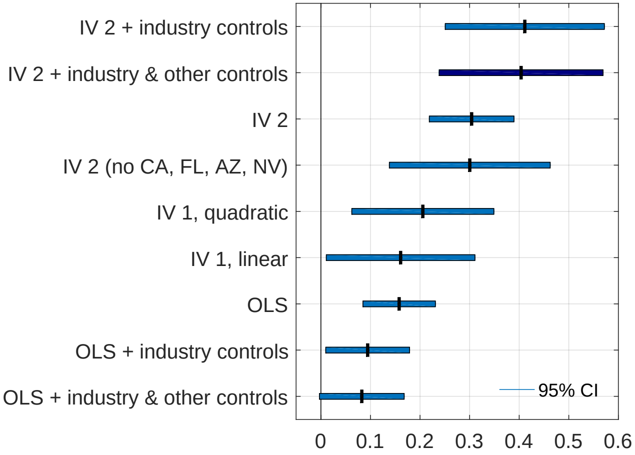
Back

Housing market crash and productivity growth across US MSAs

Higher exposure to the crash, slower post-crisis labor productivity growth

Housing market crash and productivity growth across US MSAs

$$\Delta_{2017}^{2007} \log (Y/L)_i = \alpha + \eta \widehat{\Delta_{2010}^{2007} \log P_i^H} + X_i'\Gamma + \varepsilon_i$$



Higher exposure to the crash, slower productivity growth

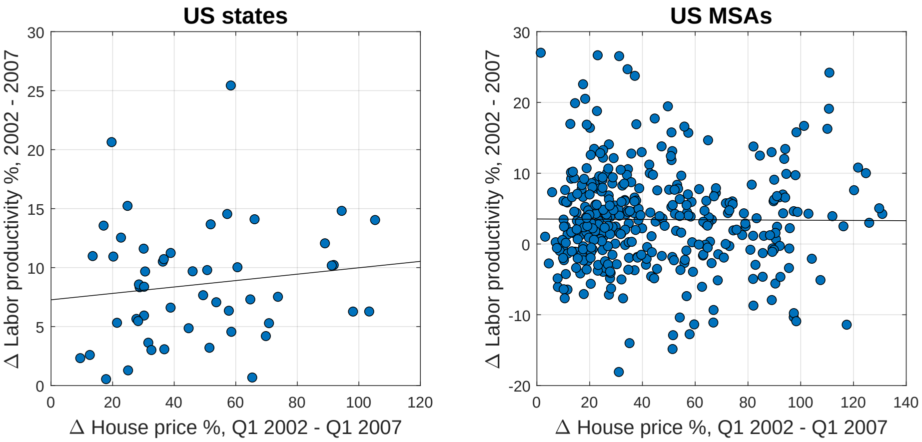
Can explain up to 50% of the GDP gap relative to the pre-crisis trend

Identification

IV 1: housing supply elasticity

IV 2: regional sensitivity

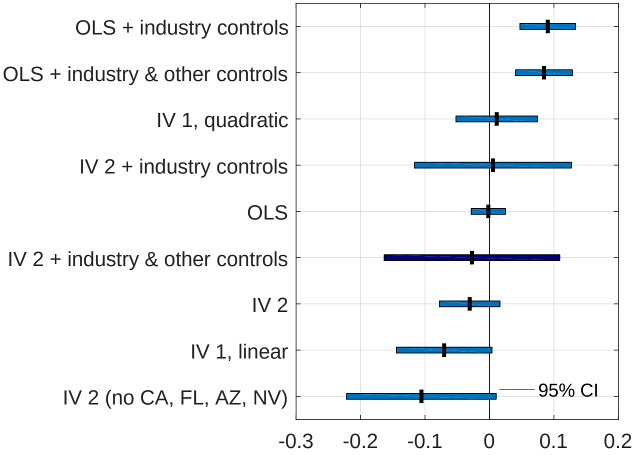
Housing market boom and productivity growth across US MSAs



No relation between the house price growth and productivity growth during the boom

Housing market boom and productivity growth across US MSAs

$$\Delta_{\substack{2002\\2007}} \log(Y/L)_i = \alpha + \boldsymbol{\eta} \widehat{\Delta_{\substack{2002\\2007}} \log P_i^H} + X_i'\Gamma + \varepsilon_i$$



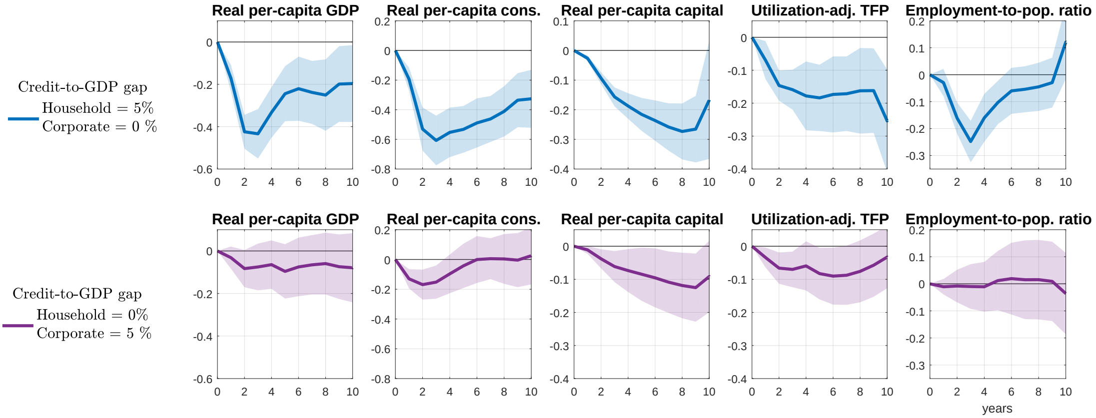
No strong relation between the house price growth and productivity growth during the boom

Identification

IV 1: housing supply elasticity

IV 2: regional sensitivity

Relative role of household and corporate debt



Significant interaction between the initial household — but not firm — debt-to-GDP gap and the house price decline

Production sector, full problem

Production function: $F_t = Z_t \left(\tilde{K}_t^{\alpha} L_t^{1-\alpha}\right)^{1-\xi} \left(\int_0^{N_t} x_t(\omega)^{\frac{1}{\nu}} d\omega\right)^{\nu\xi}$

$$\max_{\{x_{t+j}(\omega), L_{t+j}, K_{t+j}\}_{j=0}^{\infty}} \quad \mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j}^{B} \left[p_t^F F_{t+j} - R_{t+j}^K \tilde{K}_{t+j} - W_{t+j} L_{t+j} - \int_0^{N_t} p_{t+j}^x(\omega) x_{t+j}(\omega) d\omega \right]$$

Labor demand: $W_t = p_t^F (1-\alpha)(1-\xi) \dfrac{F_t}{L_t}$

Capital demand: $R_t^K = p_t^F \alpha (1-\xi) \dfrac{F_t}{\tilde{K}_t}$

Intermediate-good demand: $p_t^x(\omega) = p_t^F \xi \dfrac{F_t}{X_t} x_t(\omega)^{\frac{1-\nu}{\nu}}$

Intermediate sector, full problem

$$\max_{p_t^x(\omega)} \quad \left[(p_t^x(\omega) - A^{-1})x_t(\omega)\right] \text{ s.t.} \qquad p_t^x(\omega) = p_t^F \xi \frac{F_t}{X_t} x_t(\omega)^{\frac{1-\nu}{\nu}}$$

Optimal relative price: $\quad p_t^x = \nu \; A^{-1}$

Optimal quantity: $\quad x_t = \left(\frac{A\xi}{\nu}\right)^{\frac{1}{1-\xi}} (p_t^F Z_t)^{\frac{1}{1-\xi}} N_t^{\frac{\nu\xi-1}{1-\xi}} \tilde{K}_t^{\alpha} L_t^{1-\alpha}$

Real profit: $\quad d_t = \frac{\nu - 1}{\nu} p_t^x x_t = \frac{\nu - 1}{A} x_t$

Innovators, full problem

Individual production function: $N_{et}^{i} = \phi_t^i S_t^i$ Aggregate productivity: $\phi_t = \phi \frac{N_t}{N_t^{\rho} S_t^{1-\rho}}$

$$\max_{\{S_{t+j}^i\}_{j=0}^{\infty}} \quad \mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j}^{B} \left(p_{t+j}^{i,b} \phi_{t+j}^{i} S_{t+j}^{i} - (1 + AC_{S,t+j}) S_{t+j}^{i} \right)$$

Optimal blueprint price: $p_t^{i,b} = \frac{1}{\phi_t^i} \left(1 + AC_{S,t} + AC'_{S,t} S_t^i - \mathbb{E}_t \left(\Lambda_{t,t+1}^{B} AC'_{S,t+1} S_{t+1}^{i} \right) \right)$

Downstream sectors: retailers and wholesalers, full problem

$$\max_{\{P(j)_{t+k}\}_{k=0}^{\infty}} \quad \mathbb{E}_t \sum_{k=0}^{\infty} \Lambda_{t,t+k} \left[\frac{P_{t+k}(j)}{P_t} Y_{t+k}(j) - \frac{P^F_{t+k}}{P_t} F_{t+k}(j) - AC_{p,k}(j) - \Gamma \right], \qquad \text{s.t}$$

Production fucntion: $\quad Y_t(j) = F_t(j)$

Retailers demand: $\quad Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\eta} Y_t$

Price adjustment cost: $\quad AC_{p,t}(j) = \frac{\psi_p}{2} \left(\frac{P_t(j)}{P_{t-1}(j)\Pi} - 1 \right)^2 Y_t$

$$P_t(j) = \mu_t P^F_t \qquad \mu_t = \frac{\eta}{(\eta - 1) + \psi_p \frac{\Pi_t}{\Pi} \left(\frac{\Pi_t}{\Pi} - 1 \right) - \psi_p \mathbb{E}_t \Lambda_{t,t+1} \left(\frac{\Pi_{t+1}}{\Pi} - 1 \right) \frac{\Pi_{t+1}}{\Pi} \frac{Y_{t+1}}{Y_t}}$$

Households: savers

$$\max_{\{C_j^S, L_j^S, h_j^S, B_{j+1}^S\}_{j=t}^{\infty}} \quad \mathbb{E}_t \sum_{j=t}^{\infty} \beta_S^{j-t} \left(u(C_j^S, L_j^S) + g(h_j^S) \right) \quad \text{s. t.}$$

Budget constraint: $$C_t^S + P_t^h \Delta h_t^S + (1 + r_{t-1}) \frac{B_t^S}{P_t} = W_t L_t^S + \frac{B_{t+1}^S}{P_t}$$

Households: borrowers

$$\max_{\{C_j^B, L_j^B, h_j^B, B_{j+1}^B, I_j, K_{j+1}, \iota_{j+1}, u_j\}_{j=t}^{\infty}} \quad \mathbb{E}_t \sum_{j=t}^{\infty} \beta_B^{j-t} \left(u(C_j^B, L_j^B) + g(h_j^B) \right) \quad \text{s. t.}$$

Budget constraint: $$C_t^B + I_t + P_t^h \Delta h_t^B + (1 + r_{t-1}) \frac{B_t^B}{P_t} + \iota_{t+1} v_t (N_t + N_{et}) =$$

$$= \iota_t (v_t + d_t) N_t + W_t L_t^B + R_t^K K_t + \frac{B_{t+1}^B}{P_t}$$

Capital accumulation: $$K_{t+1} = (I_t - AC_{I,t}) + (1 - \delta_K(u_t)) K_t$$

Collateral constraint: $$B_t^B \leq \rho_B \frac{B_{t-1}^B}{\Pi_t} + (1 - \rho_B) m P_t^h h_t^B$$

Capital utilization: $$\delta_K(u_t) = \delta_K + c_1 (u_t - 1) + (c_2/2)(u_t - 1)^2$$

Households, equilibrium conditions

	Savers	Borrowers
Bonds	$\mathbb{E}_t\left(\Lambda^S_{t,t+1}\frac{1+r_t}{\Pi_{t+1}}\right)=1$	$\mathbb{E}_t\left(\Lambda^B_{t,t+1}\frac{1+r_t-\rho_B\chi_{t+1}}{\Pi_{t+1}}\right)=1-\chi_t$
Housing demand	$P^h_t=\mathbb{E}_t\left(\Lambda^S_{t,t+1}P^h_{t+1}\right)+(g'_{h^S_t}/u'_{C^S_t})$	$P^h_t=\mathbb{E}_t\left(\Lambda^B_{t,t+1}P^h_{t+1}\right)+(g'_{h^B_t}/u'_{C^B_t})+\chi_t m P^h_t$
Labor supply	$W_t=u'_{L^S_t}/u'_{C^S_t}$	$W_t=u'_{L^B_t}/u'_{C^B_t}$
Capital supply	-	$q_t=\mathbb{E}_t\left(\Lambda^B_{t,t+1}((1-\delta_K(u_t))q_{t+1}+R^K_{t+1})\right)$
Tobin's q	-	$q_t=1+q_t AC'_{I,t}+\mathbb{E}_t\Lambda^B_{t,t+1}q_{t+1}AC'_{I,t+1}$
Equity demand	-	$v_t=(1-\delta_N)\mathbb{E}_t\left(\Lambda^B_{t,t+1}(d_{t+1}+v_{t+1})\right)$
Capital utilization	-	$\delta'_K(u_t)=R^K_t$

Model summary

Market clearing & budget constr.	$y_t^{GDP} = y_t - \frac{x_t}{A} = c_t^S + c_t^B + i_t + p_t^b n_{e,t} + AC_t^\Sigma$	$c_t^S + p_t^h(h_t^S - h_{t-1}^S) - \frac{1+r_{t-1}}{\Pi_t}\frac{b_t}{g_t} = w_t L_t^S - b_{t+1}$
Euler equations	$\mathbb{E}_t\left(\Lambda_{t,t+1}^S \frac{1+r_t}{\Pi_{t+1}}\right) = 1$	$\mathbb{E}_t\left(\Lambda_{t,t+1}^B \frac{1+r_t-\rho_B\chi_{t+1}}{\Pi_{t+1}}\right) = 1 - \chi_t$
Collateral constraint	$(b_{t+1} - \rho_B \frac{b_t}{\Pi_t g_t} - (1-\rho_B) m p_t^h h_t^l)\chi_t = 0$	$\chi_t \geq 0$
Labor market	$w_t = \upsilon_t (L_t^H)^\epsilon, \quad H \in \{S, B\}$	$w_t = \frac{1}{\mu_t}(1-\alpha)(1-\xi)\frac{y_t}{L_t^S + L_t^B}$
Capital market	$q_t = \mathbb{E}_t\left(\Lambda_{t,t+1}^B((1-\delta_{K,t})q_{t+1} + R_{t+1}^K)\right)$	$R_t^K = \frac{1}{\mu_t}\alpha(1-\xi)\frac{y_t}{\tilde{k}_t}$
Housing market	$p_t^h = \mathbb{E}_t\left(\Lambda_{t,t+1}^S p_{t+1}^h g_{t+1}\right) + \kappa\vartheta_t \frac{(h_t^S)^{\epsilon h}}{\lambda_t^S}$	$p_t^h = \mathbb{E}_t\left(\Lambda_{t,t+1}^P p_{t+1}^h g_{t+1}\right) + \kappa\vartheta_t \frac{(1-h_t^S)^{\epsilon h}}{\lambda_t^P} + \chi_t m p_t^h$
Equity market	$v_t = (1-\delta_N)\mathbb{E}_t\left(\Lambda_{t,t+1}^B(d_{t+1} + v_{t+1})\right)$n	$\phi_t v_t = 1 + AC_{S,t} + AC'_{S,t} S_t^i - \mathbb{E}_t\left(\Lambda_{t,t+1}^B AC'_{S,t+1} S_{t+1}^i\right)$
K and N accumulation	$k_{t+1} g_{t+1} = (1-\delta_{K,t})k_t + (1 - AC_{I,t})i_t$	$g_{t+1} = (1-\delta_N)\left(1 + \phi s_t^\rho\right)$
Taylor rule	$1 + r_t = \max\left(0; (1+r_{t-1})^{\rho r}\left((1+r)\left(y_t^{GDP}/y^{GDP}\right)^{\phi Y}(\pi_t/\pi)^{\phi\pi}\right)^{1-\rho r} u_t\right)$	

Calibration summary

	Calibrated parameters	Value	Source / target
β_S	Savers discount factor	0.9968	4% annual real interest rate
β_B	Borrowers discount factor	0.9963	$\beta_B = \beta_S - 0.0005$
σ	Relative risk aversion	2	Conventional
$1/\epsilon_L$	Elasticity of labor supply	1	Conventional
$\nu/(\nu-1)$	Intermediate-good elasticity of subst.	1.1852	BGP requirement $\xi(\nu-1)/(1-\xi) = 1-\alpha$
η	Retail-good elasticity of subst.	11	10% steady-state markup
$1/A$	Intermediate sector marginal cost	1	Normalization
ρ	R&D output elasticity	0.8	Comin and Gerlter (2006)
δ_N	Intermediate sector exit rate	0.025	Bilbiie et al. (2012)
ϕ_y ; ϕ_π; ρ_r	Taylor rule: output; inflation: inertia	0.25; 1.5; 0.7	Conventional
$\bar{Z}$	Final sector productivity	0.574	Normalization, $Y^{GDP} = 1$
ψ_p	Price adjustment cost	120	4-quarter average Calvo price ridigity equivalent
$1/\epsilon_h$	Elasticity of housing demand	0.2	Hanushek and Quigley (1980)
m	Max leverage	0.7	Warnock and Warnock (2008)
α	Capital share	0.4	Data median, PWT 9.1
δ_K	Steady state capital depreciation	0.0134	$\frac{I}{K} = 0.0167$, (data median, PWT 9.1)
ϕ	R&D productivity	0.268	Annual per-capita TFP growth = 0.8% (data median, PWT 9.1)
κ	Share of housing in utility	0.006	Mortgage debt to GDP = 0.55
ξ	Intermediate good share	0.1	R&D spending to GDP = 6.5%

Utility function

GHH preference: $$u(C_t^H, L_t^H) = \left(\left(C_t^H - \Upsilon_t (L_t^H)^{1+\epsilon_L}/(1+\epsilon_L)\right)^{1-\sigma} - 1\right)/(1-\sigma)$$

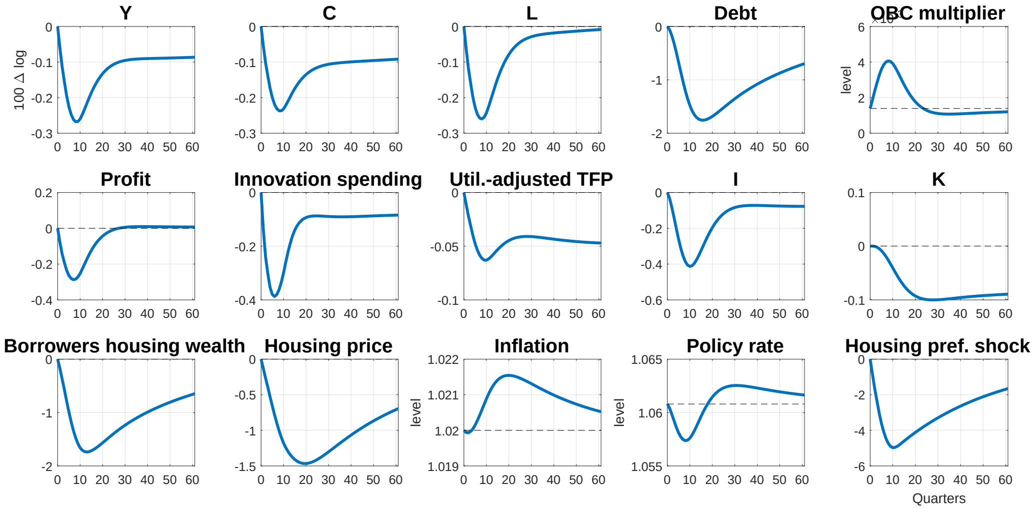
Housing utility: $$g(h_t^H) = (h_t^H)^{1-\epsilon_h}/(1-\epsilon_h)$$

Labor supply: $$W_t = \Upsilon_t (L_t^H)^{\epsilon_L} \qquad \Upsilon_t = \Upsilon_{t-1}^{\gamma} N_t^{1-\gamma}$$

Time-varying disutility of labor (Queralto 2019; Jaimovich and Rebelo 2009)

BGP with constant hours exists but the short-run effect of growth on labor supply is limited

Baseline simulation, extended set of impulse responses



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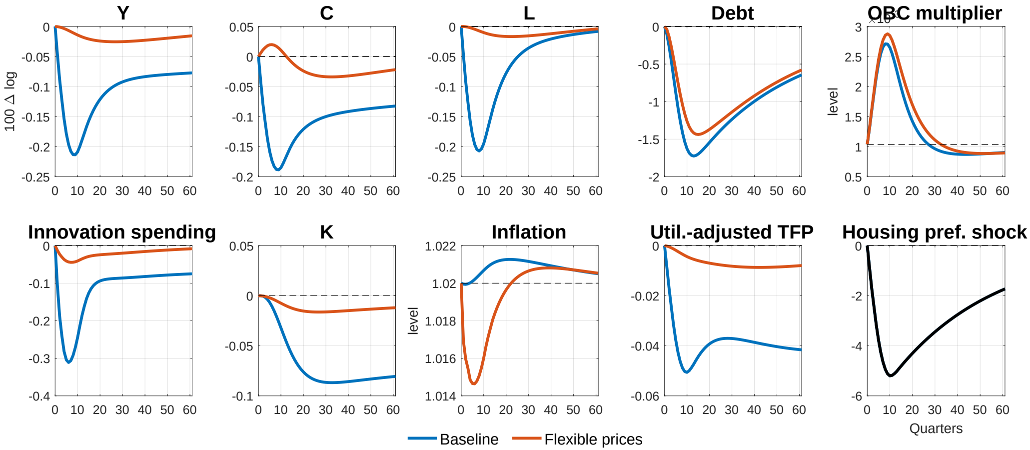
Aggregate demand channel: baseline vs flexible price economy



Nominal frictions matter

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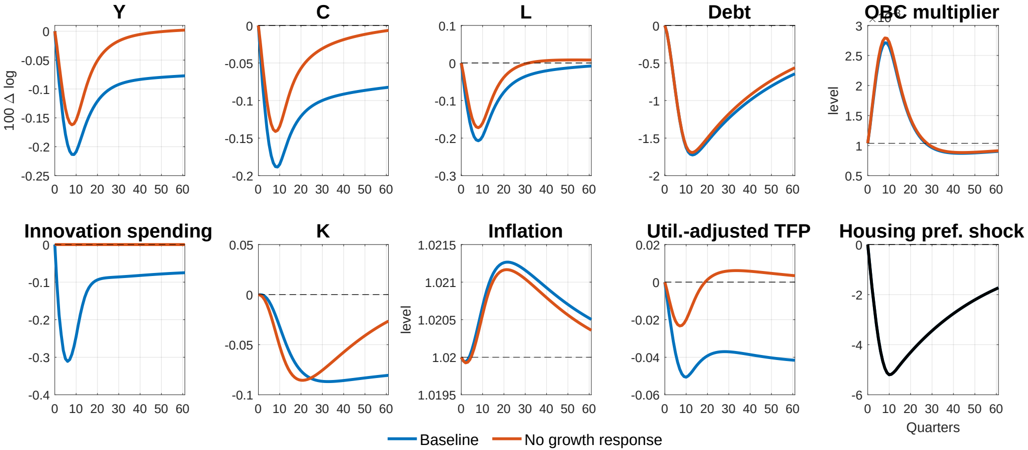
Productivity growth channel: baseline vs no growth response



Endogenous productivity growth is key for generating the persistent response of TFP, consumption, and output

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