Iacoviello (2005, *American Economic Review*)

ECON 70428: Advanced Macro: Financial Frictions

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Spring 2021

House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle

Iacoviello (2005) incorporates the Kiyotaki and Moore (1997, *JPE*) costly enforcement constraint into a monetary DSGE model

Base model:

- Households (consume housing and supply labor) and entrepreneurs (use housing and household labor as productive inputs to produce)
- Aggregate stock of housing fixed
- Entrepreneurs impatient relative to households
- Debt is nominal and not indexed to inflation
- Sticky prices via Calvo (1983) plus Taylor Rule for central bank
- Entrepreneurs subject to borrowing constraint based on value of their housing stock

Basic Story

In steady state of model, too little housing is allocated to entrepreneurs because of constraint

Contractionary monetary shock:

1. Directly tightens borrowing constraint because higher R_t
2. Tightens borrowing constraint further because of decline house price, q_t
3. Further tightens borrowing constraint because of decline in inflation, π_t (i.e. "debt-deflation")

Extended Model

Another impatient household, consumes housing and supplies labor, but more impatient than the patient household. Also subject to borrowing constraint

Entrepreneur accumulates physical capital

Adds adjustment costs to housing stock and physical capital

Additional stochastic shocks (productivity and preferences)

Subset of parameters are estimated

Basic conclusion: collateral constraint plus fixed debt **amplifies** effects of demand shocks but **dampens** responses to supply shocks

Base Model

Environment

Model has the following actors:

1. Patient households (denoted with $'$)
2. Entrepreneurs (like wholesale producers); subject to borrowing constraint
3. Retailers (sticky prices)
4. Final good
5. Government

Households get utility from housing; entrepreneurs use housing as a productive input

Total supply of housing is fixed

Patient Household Problem

Supply labor, consume goods and housing, and save via bonds

$$\max_{c'_t, h'_t, L'_t, B'_t} \ \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c'_t + j \ln h'_t - \frac{(L'_t)^\eta}{\eta} \right\}$$

s.t.

$$P_t c'_t + Q_t h'_t + R_{t-1} B'_{t-1} \leq B'_t + W_t L'_t + P_t F_t + Q_t h'_{t-1}$$

F_t is lump-sum profit from firms

Define $q_t = Q_t / P_t$, $w_t = W_t / P_t$, $b_t = B_t / P_t$, and $\pi_t = P_t / P_{t-1}$. Budget constraint in real terms:

$$c'_t + q_t h'_t + R_{t-1} b_{t-1} / \pi_t \leq b'_t + w_t L'_t + q_t h'_{t-1} + F_t$$

Patient Household FOC

$$q_t = j \frac{c'_t}{h'_t} + \beta \, \mathbb{E}_t \, \frac{c'_t}{c'_{t+1}} q_{t+1}$$

$$\left(L'_t\right)^{\eta - 1} = \frac{w_t}{c'_t}$$

$$1 = \beta \, \mathbb{E}_t \, \frac{c'_t}{c'_{t+1}} \frac{R_t}{\pi_{t+1}}$$

Entrepreneurs

Entrepreneurs produce an “intermediate” output that I’m going to call wholesale output using housing and labor from patient households:

$$Y_{w,t} = Ah_{t-1}^{\nu}L_t^{1-\nu}$$

This is sold to retailers at P_t^w

Discount future via $\gamma < \beta$ and do not work.

Borrow from households, B_t

Entrepreneur Problem

$$\max_{c_t, h_t, L_t, b_t} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \gamma^t \ln c_t$$

s.t.

$$P_t^w A h_{t-1}^{\nu} L_t^{1-\nu} - W_t L_t + B_t + Q_t h_{t-1} \geq P_t c_t + Q_t h_t + R_{t-1} B_{t-1}$$

$$B_t \leq m \, \mathbb{E}_t \left[\frac{Q_{t+1} h_t}{R_t} \right]$$

Borrowing constraint:

- $R_t B_t$ is what they have to pay back in $t+1$ from borrowing
- $Q_{t+1} h_t$ is the expected value of their housing in $t+1$
- Promised debt repayment, $R_t b_t$, can only be a fraction, $m \in [0, 1]$, of value of housing collateral

Constraints in Real Terms

$$\frac{Ah_{t-1}^{\nu} L_t^{1-\nu}}{X_t} - w_t L_t + b_t + q_t h_{t-1} \geq c_t + q_t h_t + R_{t-1} b_{t-1} / \pi_t$$

$$b_t \leq m \, \mathbb{E}_t \left[\frac{q_{t+1} h_t \pi_{t+1}}{R_t} \right]$$

Where $X_t = P_t / P_t^w$ is the retail markup (equivalently, $1/X_t$ is real marginal cost for the entrepreneur)

Because debt is nominal and not indexed to inflation, you get π_{t+1} showing up in the borrowing constraint

- Gives rise to a debt-deflation channel
- High inflation eases entrepreneur borrowing constraint, allowing them to borrow more. Deflation works in the opposite direction.

Entrepreneur FOC

$$(1-\nu) A h_{t-1}^{\nu} L_t^{-\nu} = X_t w_t$$

$$q_t = \mathbb{E}_t \left[\gamma \frac{c_t}{c_{t+1}} \left(\frac{\nu A h_t^{\nu-1} L_{t+1}^{1-\nu}}{X_{t+1}} + q_{t+1} \right) + m \lambda_t c_t q_{t+1} \pi_{t+1} \right]$$

$$1 = \gamma \, \mathbb{E}_t \, \frac{c_t}{c_{t+1}} \frac{R_t}{\pi_{t+1}} + c_t \lambda_t R_t$$

Here, $\lambda_t \geq 0$ is the multiplier on the borrowing constraint

Labor demand condition is standard; dynamic Euler equations are distorted via λ_t

Final Good and Retailers

Continuum of retailers $z \in [0, 1]$ produce $Y_t(z)$ using $Y_{w,t}$ as input (simply repackaging)

Retail output purchased at $P_{w,t}$ from entrepreneurs and sold at $P_t(z)$ to competitive firm, bundled into final output:

$$Y_t = \left(\int_0^1 Y_t(z)^{\frac{\epsilon-1}{\epsilon}} dz \right)^{\frac{\epsilon}{\epsilon-1}}$$

Profit maximization implies demand for retail output and price index:

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\epsilon} Y_t$$

$$P_t^{1-\epsilon} = \int_0^1 P_t(z)^{1-\epsilon} dz$$

Retailers

Retailers purchase entrepreneurial output at $P_{w,t}$ and costlessly transform into retail output:

$$Y_t(z) = Y_{w,t}(z)$$

Nominal profits plugging in the demand curve for their goods:

$$F_t(z)^n = P_t(z)^{1-\epsilon} P_t^{\epsilon-1} Y_t - P_t^w P_t(z)^{-\epsilon} P_t^{\epsilon} Y_t$$

Or, in real terms:

$$F_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{1-\epsilon} Y_t - X_t^{-1} \left(\frac{P_t(z)}{P_t}\right)^{-\epsilon} Y_t$$

Pricing Friction

Retailers subject to Calvo pricing friction: can only adjust price with probability $1 - \theta$

This makes problem dynamic – price chosen today will be in effect k periods into the future with probability θ^k

Discount real flow profits via patient household sdf, $\Lambda_{t,t+k} = \beta^k \frac{c'_t}{c'_{t+k}}$

Problem of updating retailer:

$$\max_{P_t(z)} \; \mathbb{E}_t \sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} \left\{ \left(\frac{P_t(z)}{P_{t+k}} \right)^{1-\epsilon} Y_{t+k} - X_{t+k}^{-1} \left(\frac{P_t(z)}{P_{t+k}} \right)^{-\epsilon} Y_{t+k} \right\}$$

Optimal Price-Setting

$$P_t^* = \frac{\epsilon}{\epsilon - 1} \frac{\mathbb{E}_t \sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} X_{t+k}^{-1} P_{t+k}^{\epsilon} Y_{t+k}}{\mathbb{E}_t \sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} P_{t+k}^{\epsilon-1} Y_{t+k}}$$

Recursively in stationarized terms ($\pi_t^* = P_t^* / P_t$):

$$\pi_t^* = \frac{\epsilon}{\epsilon - 1} \frac{z_{1,t}}{z_{2,t}}$$

$$z_{1,t} = X_t^{-1} Y_t + \theta \, \mathbb{E}_t \, \Lambda_{t,t+1} \pi_{t+1}^{\epsilon} z_{1,t+1}$$

$$z_{2,t} = Y_t + \theta \, \mathbb{E}_t \, \Lambda_{t,t+1} \pi_{t+1}^{\epsilon-1} z_{2,t+1}$$

Monetary Policy and Aggregation

Taylor rule:

$$R_t = (\bar{r}r)^{1-r_R} (R_{t-1})^{r_R} \left(\pi_{t-1}^{1+r_\pi} (Y_{t-1}/Y)^{r_Y} \right)^{1-r_R} \exp(e_{R,t})$$

Price evolution:

$$1 = \theta \pi_t^{\epsilon-1} + (1-\theta)(\pi_t^*)^{1-\epsilon}$$

Production:

$$Y_t v_t^p = A h_{t-1}^{\nu} L_t^{1-\nu}$$

$$v_t^p = (1-\theta)(\pi_t^*)^{-\epsilon} + \theta \pi_t^{\epsilon} v_{t-1}^p$$

Resource:

$$c_t' + c_t = Y_t$$

Housing:

$$h_t' + h_t = H$$

Linearization and Calibration

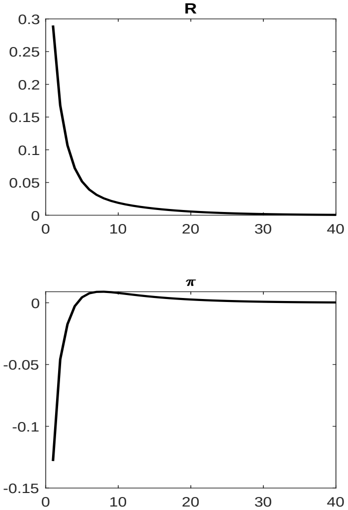
The system can be linearized by hand (or have the computer do it for you – much easier!)

Normalize steady state $Y = 1$

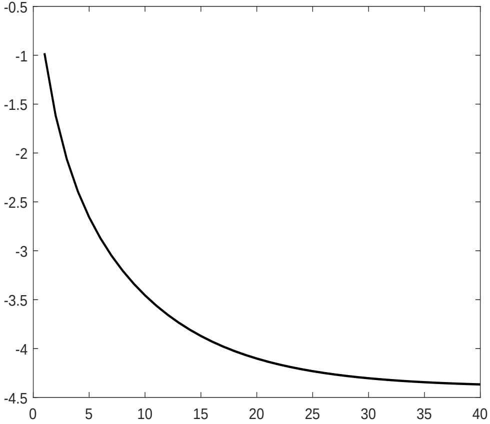
Set $\beta = 0.99$, $\gamma = 0.98$, $\nu = 0.03$, $j = 0.1$, and $m = 0.89$.

Taylor rule parameters based on OLS estimation of interest rate rule

Response to Monetary Policy Shock



Cumulative Output Response to Shock: Compare to Figure 2 in Paper



Amplification

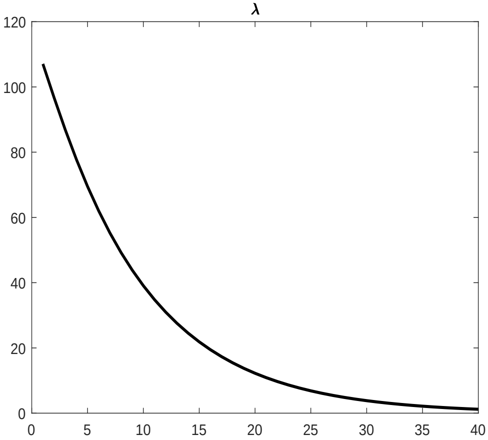
Borrowing constraint amplifies the effect of the policy shock

Distinct channels all work in same direction:

1. Higher R_t reduces amount entrepreneurs can pay back, tightens constraint
2. Higher R_t lowers future house price, q_{t+1}. This also tightens constraint
3. Higher R_t lowers π_{t+1}, also tightening constraint. This is "debt deflation" channel

Can see this in response of λ_t to the policy shock – it goes up (borrowing constraint is tighter)

Multiplier Response to Shock



Extended Model

Extended Model

The extended model adds an additional type of agent:

- Impatient household, denoted by $''$
- Like patient household, they consume housing and supply labor to entrepreneurs
- But $\beta'' < \beta$, and like entrepreneur, they are subject to a borrowing constraint based on value of housing

Entrepreneurs can now also accumulate physical capital (subject to convex adjustment cost)

In addition, allow for convex housing adjustment costs

Also allows for additional shocks – stochastic productivity, A_t, and housing preference, j_t

Entrepreneurs

Production function now:

$$Y_{w,t} = A_t K_t^{\mu} h_{t-1}^{\nu} \left(L_t'\right)^{\alpha(1-\mu-\nu)} \left(L_t''\right)^{(1-\alpha)(1-\mu-\nu)}$$

Capital accumulation:

$$K_t = I_t + (1-\delta)K_{t-1}$$

Adjustment costs (show up as resource costs):

$$\xi_{k,t} = \psi \left(\frac{I_t}{K_{t-1}} - \delta\right)^2 \frac{K_{t-1}}{2\delta}$$

$$\xi_{e,t} = \phi_e \left(\frac{h_t - h_{t-1}}{h_{t-1}}\right)^2 \frac{q_t h_{t-1}}{2}$$

FOC

Capital:

$$v_t = \gamma\,\mathbb{E}_t\,\frac{1}{c_{t+1}}\left[\frac{\psi}{\delta}\left(\frac{I_{t+1}}{K_t}-\delta\right)\frac{I_{t+1}}{K_t}-\frac{\psi}{2\delta}\left(\frac{I_{t+1}}{K_t}-\delta\right)^2\right]+$$
$$\gamma\,\mathbb{E}_t\left[\frac{\mu Y_{t+1}}{c_{t+1}K_tX_{t+1}}+(1-\delta)v_{t+1}\right]$$

Where $v_t = \frac{1}{c_t}\left(1+\frac{\psi}{\delta}\left(\frac{I_t}{K_{t-1}}-\delta\right)\right)$

Housing:

$$\frac{q_t}{c_t}\left(1+\phi_e\left(\frac{h_t-h_{t-1}}{h_{t-1}}\right)\right)=$$
$$\gamma\,\mathbb{E}_t\,\frac{1}{c_{t+1}}\left[\frac{\nu Y_{t+1}}{h_tX_{t+1}}+q_{t+1}-\frac{\phi_e q_{t+1}}{2}\left(\frac{h_{t+1}-h_t}{h_t}\right)^2+\phi_e\left(\frac{h_{t+1}-h_t}{h_t}\right)\frac{q_{t+1}h_{t+1}}{h_t}\right]+$$
$$m\lambda_t\,\mathbb{E}_t\,q_{t+1}\pi_{t+1}$$

Impatient and Patient Households

Just like patient households, but $\beta'' < \beta$ and subject to same borrowing constraint entrepreneur faces:

$$b_t'' \leq m'' \, \mathbb{E}_t \, \frac{q_{t+1} h_t'' \pi_{t+1}}{R_t}$$

FOC are similar, but allow for housing adjustment cost function (looks just like one for entrepreneur, but with parameter ϕ_h

Patient household problem same as base model, but with addition of adjustment cost (same parameter as for impatient households, ϕ_h)

Both types subject to same housing preference shock, j_t

Aggregation

The aggregate resource constraint works out to:

$$Y_t = \underbrace{c'_t + c''_t + c_t}_{C_t} + I_t + \xi_{e,t} + \xi_{k,t} + \xi'_{h,t} + \xi''_{h,t}$$

All the adjustment costs show up as resource costs

But all are zero in steady state and therefore do not appear in linearized resource constraint

Parameterization/Estimation

Iacoviello calibrates some parameters and estimates another subset

Does estimation by impulse response matching relative to a VAR

1. Estimate four variable VAR (interest rate, inflation, housing price, and output) using this recursive ordering
2. Collect IRFs to the these four orthongalized shocks
3. Add a fourth shock to model – "inflation" shock in linearized Phillips Curve
4. Form reduced form VAR and compute IRFs to orthogonalized shocks based on the model solution

VAR vs. Model

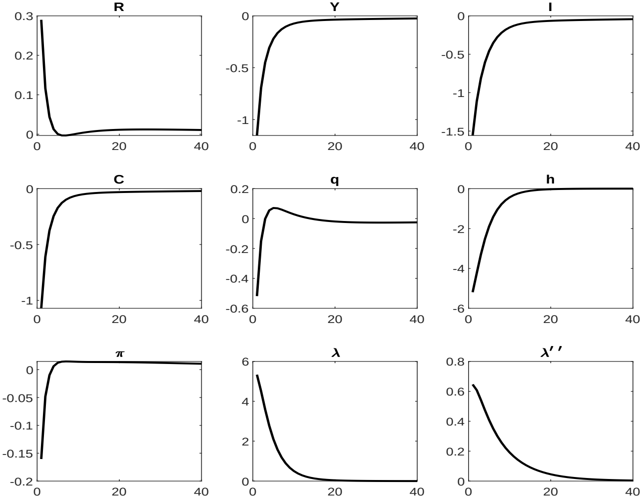
The linearized solution of the model permits a VAR representation

But the orthogonalization used empirically is **not** consistent with the model, except for the monetary policy shock

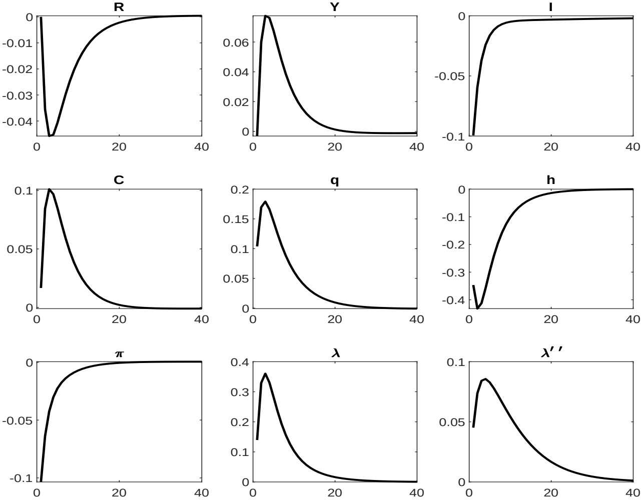
- In model, interest rate reacts to other shocks with a lag
- So ordering it first makes sense
- But all other shocks affect all variables contemporaneously
- So the Choleski ordering doesn't make sense from perspective of identifying IRFs to shocks in the model, excepting the policy shock

The estimation exercise is nevertheless well-specified – think of orthogonalized VAR IRFs as interesting moments you'd like model to match

Impulse Responses to Policy Shock



Impulse Responses to Productivity Shock ($\rho_A = 0.8$)



Impulse Responses to Housing Preference Shock