

Understanding China's Business Cycle and Shocks: A Perspective from an Empirical DSGE Model

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Motivation

Status quo

- DSGE: *the* most popular macro research paradigm in China in the past decade
 - 200+ papers in top Chinese econ journals, with 70+ in *ERJ*
- Most papers focus on business cycle fluctuations
 - NK framework dominance with *housing* and *banking*
 - Modifications with *Chinese characteristics*

Questions

- ① Data: lack of standard macro dataset
 - More on Tao Zha's CMTS dataset below
- ② Shocks: lack of *quantitative* evaluations of *popular* shocks
 - Also related to *Chinese characteristics*

This lecture

Based on my paper published in *China Economic Review*

- “The Driving Forces of China’s Business Cycles: Evidence from an Estimated DSGE Model with Housing and Banking”
 - With Xinyu Ge of Soochow University, Xiao-Lin Li of Ocean University of China, Yong Li of Renmin University of China

In this lecture

- ❶ Construct a benchmark DSGE model with the most popular elements
 - NK nominal rigidity, monetary policy, housing, banking
 - In a nutshell: Gertler + Kiyotaki + Iacoviello
- ❷ Construct an aggregate quarterly macro dataset from 2000Q1
 - NAs mostly from CMTS
 - Labor in **hours**, by sector in construction and non-construction
 - Loans by sector in households and firms
- ❸ Confront the model with the data in a comprehensive way
 - Overall **structure**, but not necessarily steady state
 - Cyclical fluctuations
 - A battery of robustness analyses

Overall model: A standard NK model with

- Two types of households: patient (savers), impatient (borrowers)
- Three goods: housing, non-housing (consumption), capital
 - Non-housing: wholesale, retail
 - Wholesale Fs: labor from both HHs, capital
 - Capital: capital goods Fs with consumption goods as input
 - Housing: housing Fs with labor from both HHs, land from savers
 - Land: constant endowment
- Two (final) assets: firm financing (equity+loan), household debts (mortgages, etc.)
- Banking sector: intermediating funds from savers to Fs and borrowers
- Central bank: monetary policy rule

Patient households

- Population size 1 with preference:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_p^t A_{p,t} \left[\Gamma_p \ln(c_{p,t} - \tau_p c_{p,t-1}) + j_t \ln h_{p,t} - \frac{A_{n,t}}{1 + \eta_p} \left(l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p} \right)^{\frac{1+\eta_p}{1+\epsilon_p}} \right]$$

- Budget constraint:

$$c_{p,t} + q_t h_{p,t} + p_{x,t} x_t + d_t = w_{pc,t} l_{pc,t} + w_{ph,t} l_{ph,t} + q_t (1 - \delta_h) h_{p,t-1} + (p_{x,t} + R_t^x) x_{t-1} + \frac{R_t^d d_{t-1}}{\pi_t} + \Pi_t + T_t$$

- Land normalized to 1: $x_t \equiv 1$
- Demand** and **housing demand** shocks: $A_{p,t}$ and j_t , log AR(1)

Impatient households

- Population size 1 with preference:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t A_{p,t} \left[\Gamma_i \ln(c_{i,t} - \tau_i c_{i,t-1}) + j_t \ln h_{i,t} - \frac{A_{n,t}}{1 + \eta_i} \left(l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i} \right)^{\frac{1+\eta_i}{1+\epsilon_i}} \right]$$

- Budget constraint:

$$c_{i,t} + q_t h_{i,t} + \frac{R_t^b b_{t-1}}{\pi_t} = w_{ic,t} l_{ic,t} + w_{ih,t} l_{ih,t} + q_t (1 - \delta_h) h_{i,t-1} + b_t$$

Household borrowing

- Borrowing constraint:

$$b_t \leq m_t \mathbb{E}_t \left(\frac{q_{t+1} h_{i,t} \pi_{t+1}}{R_{t+1}^b} \right)$$

- **LTV** shock: m_t , log AR(1)
- **Labor supply** shock: $A_{n,t}$, log AR(1)
- Equilibrium borrowing: $\beta_i < \beta_p$

Consumption good sector: wholesale firms

- Profit maximization of wholesale firm i :

$$\max \frac{1}{X_t} Y_t(i) - w_{pc,t} l_{pc,t}(i) - w_{ic,t} l_{ic,t}(i) - Z_t k_t(i),$$

subject to

$$Y_t(i) = [A_{c,t} l_{pc,t}(i)^\alpha l_{ic,t}(i)^{1-\alpha}]^{1-\mu_c} k_t(i)^{\mu_c}$$

- Wholesale price: $1/X_t$, final consumption good as numeraire
- Capital return (dividend): Z_t
- **Supply shock**: $A_{c,t}$, log AR(1)

Consumption good sector: retail firms

- Aggregate demand:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{1}{1+\zeta_t}} di \right]^{1+\zeta_t}$$

- Retail firm i in monopolistic competition with demand curve

$$Y_t(i) = \left(\frac{p_{c,t}(i)}{p_{c,t}} \right)^{-\frac{1+\zeta_t}{\zeta_t}} Y_t$$

purchases $Y_t(i)$ from wholesale firm at price $1/X_t$

- Calvo pricing with partial indexation and cost-push shock ζ_t :

$$\ln \pi_t - \iota \ln \pi_{t-1} = \beta_p (\mathbb{E}_t \ln \pi_{t+1} - \iota \ln \pi_t) - \frac{(1-\lambda)(1-\beta_p \lambda)}{\lambda} \ln \frac{X_t}{X} + u_{cp,t},$$

Capital good sector

- 1-1 transformation of consumption good into capital good
- Profit maximization:

$$\max E_t \sum_{j=t}^{\infty} \Lambda_{t,j} \left\{ p_j I_{k,j} - \left[1 + \frac{\chi_k}{2} \left(\frac{I_{k,j}}{I_{k,j-1}} - 1 \right)^2 \right] I_{k,j} \right\}$$

- Capital good price: p_t

Housing good sector

- Profit maximization

$$\max q_t I_{h,t} - w_{ph,t} l_{ph,t} - w_{ih,t} l_{ih,t} - R_t^x x_{t-1}$$

subject to

$$I_{h,t} = [A_{h,t} l_{ph,t}^\alpha l_{ih,t}^{1-\alpha}]^{1-\mu_h} x_{t-1}^{\mu_h}$$

- House and land price: q_t and R_t^x
- **Housing supply** *shock*: $A_{h,t}$, log AR(1)

Banking sector

- Balance sheet:

$$p_t s_t + b_t = n_t + d_t$$

- Networth accumulation

$$n_t = [Z_t + (1 - \delta_k)p_t]\psi_t s_{t-1} + \frac{R_t^b b_{t-1}}{\pi_t} - \frac{R_t^d d_{t-1}}{\pi_t}$$

- **Capital quality** shock: ψ_t , log AR(1)
 - Close connection to investment specific shock, and investment wedge in business cycle accounting literature
- Incentive constraint:

$$V_t(s_t, b_t, d_t) \equiv \mathbb{E}_t \sum_{j=1}^{\infty} (1 - \sigma) \sigma^{j-1} \Lambda_{t,t+j} n_{t+j} \geq \theta(p_t s_t + b_t)$$

Monetary policy and additional setup

- Taylor rule:

$$R_t^d = [R_{t-1}^d]^{\alpha_r} \left[\pi_t^{\alpha_\pi} \left(\frac{GDP_t}{G\bar{D}P} \right)^{\alpha_y} \bar{R}^d \right]^{1-\alpha_r} u_{mp,t}$$

with iid **monetary policy shock** $u_{mp,t}$, and

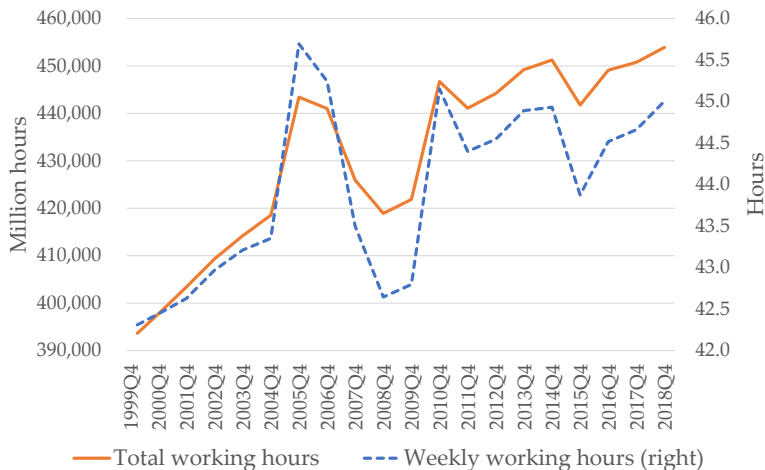
$$GDP_t = Y_t + q_t I_{h,t}$$

- Aggregate bank network: old + new
- Aggregate capital accumulation: $K_{t+1} = \psi_{t+1} [I_{k,t} + (1 - \delta_k) K_t]$
 - Capital shock works like an investment shock/wedge

Data: quarterly, 2000Q1–2018Q4

- NAs and inflation: CMTS by Tao Zha et al.
 - Consumption, non-residential investment, residential investment
 - Output: consumption + investment
- Aggregate labor: working population \times average working hours
 - Average hours: China Labor Statistical Yearbook, original for urban sector, adjusted for the difference between urban and rural sectors
 - Annual observation, interpolation
- Financial variables: PBC + micro data
 - Non-residential loan, residential loan, deposit
 - Post 2006: PBC statistics for sectoral financing
 - Pre 2006: interpolation from annual banking data
- Housing price: NBS
 - New housing sales in value / size, cf. Minetti et al. (2019)

Working hours: meaningful BC variations



Data: map into the model

- Seasonally adjusted
- Real values: adjusted for inflation
- Allocations: per capita measure
 - Divided by total population
- For “steady state” calibration: compute target ratios directly with per capita data series
 - Most important: average banking leverage 2.96, interest rate spread 3%, residential investment to GDP 12%, land value to annual GDP 3.7, housing wealth to annual GDP 3.1
- For Bayesian estimation: HP filter log series with parameter 1600
 - 33 papers in top macro journals use HP filtered data for estimation

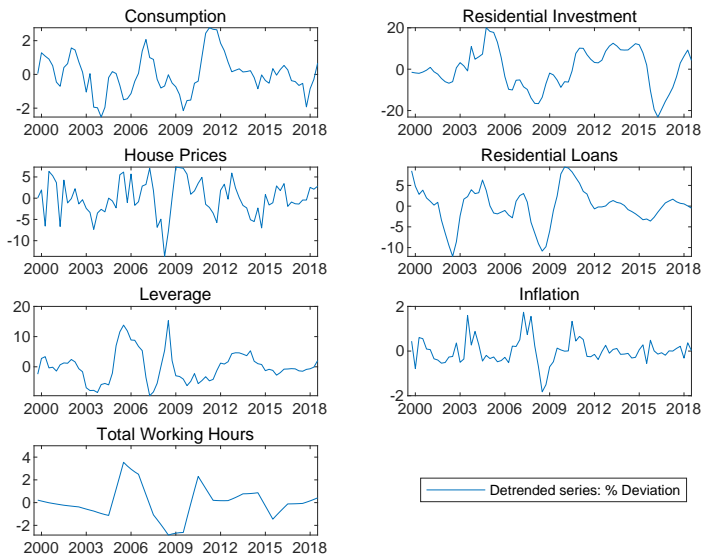
Parameter values: direct calibration

Parameters	Description	Value
β_p	Discount factor for savers	0.9975
β_i	Discount factor for borrowers	0.965
δ_k	Depreciation rate of capital	0.03
δ_h	Depreciation rate of houses	0.0097
μ_c	Share of capital	0.30
μ_h	Share of land	0.3097
θ	Fraction of assets diverted by banks	0.5961
ξ	Fraction of funds transferred to new banks	0.0089
j	Housing preference weight	0.2502
m	Steady state loan-to-value ratio	0.70
σ	Survival rate of banks	0.95
α	Labor income share of patient households	0.64
X	Steady state gross markup	1.15

Bayesian estimation

- 9 shocks: non-housing demand/supply, housing demand/supply, labor supply, LTV, capital quality, cost-push, monetary policy
 - iid for the last two
 - AR(1) for the rest
- 7 observables: consumption, aggregate labor, residential investment, house prices, residential loans, bank leverage ratio, inflation rate

Detrended data



Posterior means

Parameters	Mean	Parameters	Mean
χ_k	2.6554	ρ_c	0.9176
ι	0.1969	ρ_h	0.8939
λ	0.6659	ρ_k	0.9648
α_r	0.7899	ρ_j	0.9928
α_π	1.5323	ρ_p	0.8979
α_y	0.0033	ρ_m	0.7050
τ_p	0.2882	σ_c	0.0164
τ_i	0.2954	σ_h	0.0474
η_p	0.4814	σ_k	0.0018
η_i	0.3815	σ_j	0.0728
ϵ_p	1.0519	σ_p	0.0159
ϵ_i	1.0210	σ_m	0.0384
ρ_n	0.7818	σ_n	0.0237

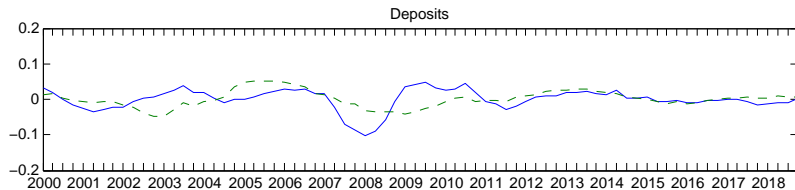
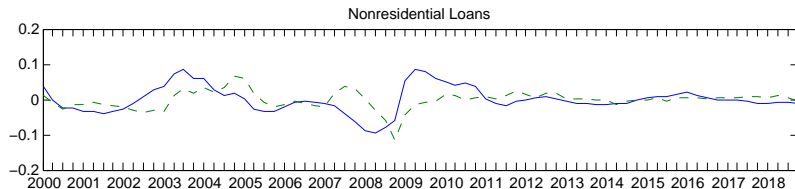
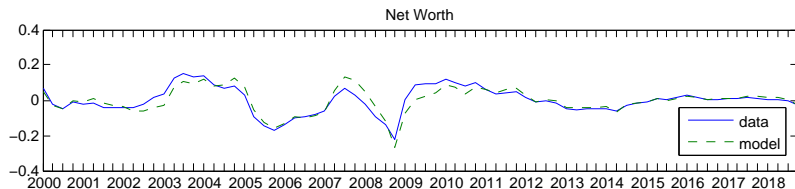
SD and relative SD: model vs. data

Variables	Data	Model mean	2.5% pct	97.5% pct
GDP	1.48	1.86	1.28	2.61
Consumption	0.78	0.75	0.52	1.06
Invest., capital	2.12	2.92	1.68	4.60
Invest., housing	6.49	3.66	2.42	5.30
House prices	2.83	2.78	1.80	4.10
Net worth	4.95	4.34	2.80	6.46
Loans, non-res.	2.46	1.80	1.17	2.67
Loans, res.	3.03	8.79	5.81	12.78
Deposits	1.96	2.12	1.45	3.01
Bank leverage	3.48	3.78	2.41	5.63
Inflation	0.39	0.38	0.23	0.58
Labor, total	0.91	1.22	0.84	1.72

Correlations: model vs. data

Variables	Data	Model mean	2.5% pct	97.5% pct
Consumption	0.38	0.66	0.32	0.87
Invest., capital	0.49	0.41	-0.07	0.76
Invest., housing	0.57	0.58	0.23	0.82
House prices	0.13	0.54	0.15	0.80
Net worth	0.24	0.13	-0.23	0.46
Loans, non-res.	0.25	0.17	-0.18	0.49
Loans, res.	0.38	0.39	0.03	0.67
Deposits	0.29	0.48	0.16	0.72
Bank leverage	-0.12	0.08	-0.27	0.41
Inflation	0.01	-0.03	-0.34	0.27
Labor, total	0.20	0.55	0.21	0.79

Non-target variables: data (blue) vs. model (green)



Variance decomposition of shocks

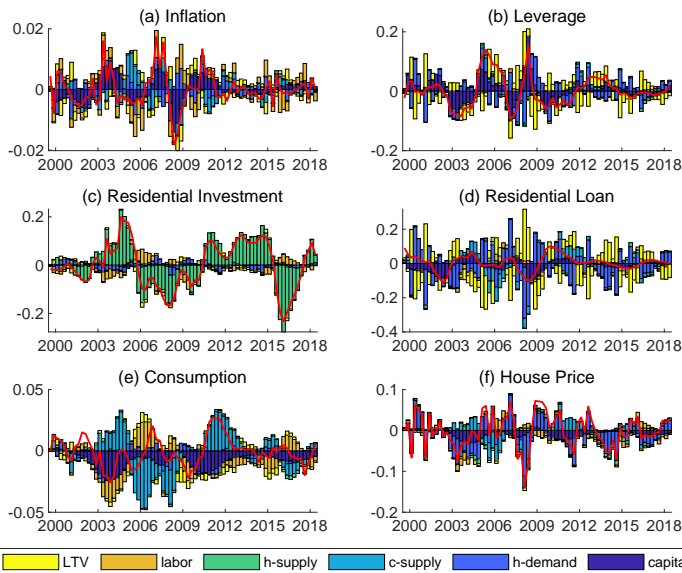
Var.	ψ	A_c	A_h	j	A_p	m	A_n	u_{mp}	u_{cp}
GDP	2.22	39.76	12.92	12.72	2.01	2.54	27.75	0.07	0.02
C	9.15	44.79	0.23	6.54	10.62	5.33	23.18	0.11	0.04
I_c	26.73	21.09	0.14	15.48	10.95	17.70	7.87	0.04	0.00
I_h	0.12	0.06	80.00	11.95	1.13	0.99	5.74	0.00	0.00
q	1.58	3.91	0.25	87.79	3.87	0.25	2.32	0.02	0.01
N	30.67	2.35	0.13	32.28	0.54	32.53	1.09	0.40	0.01
pS	20.26	6.80	0.11	34.81	3.57	28.09	6.20	0.14	0.02
B	3.31	2.20	0.10	60.81	1.92	30.91	0.59	0.16	0.01
D	7.16	8.49	0.12	42.50	10.22	25.22	6.21	0.06	0.02
ϕ	20.45	0.43	0.17	40.08	1.38	36.91	0.35	0.23	0.00
π	24.80	13.57	0.17	13.64	17.92	6.34	21.85	1.56	0.15
L	2.70	6.53	13.28	15.02	1.14	15.06	46.22	0.03	0.02

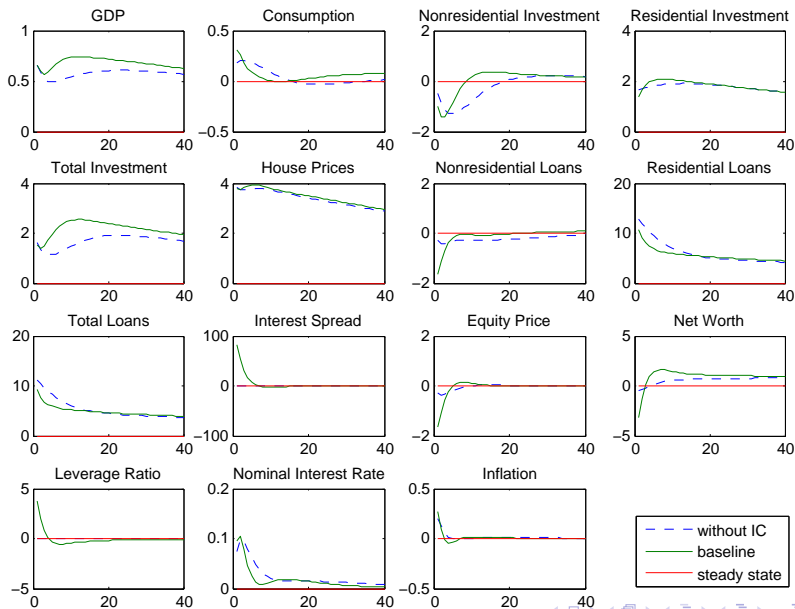
Important shocks

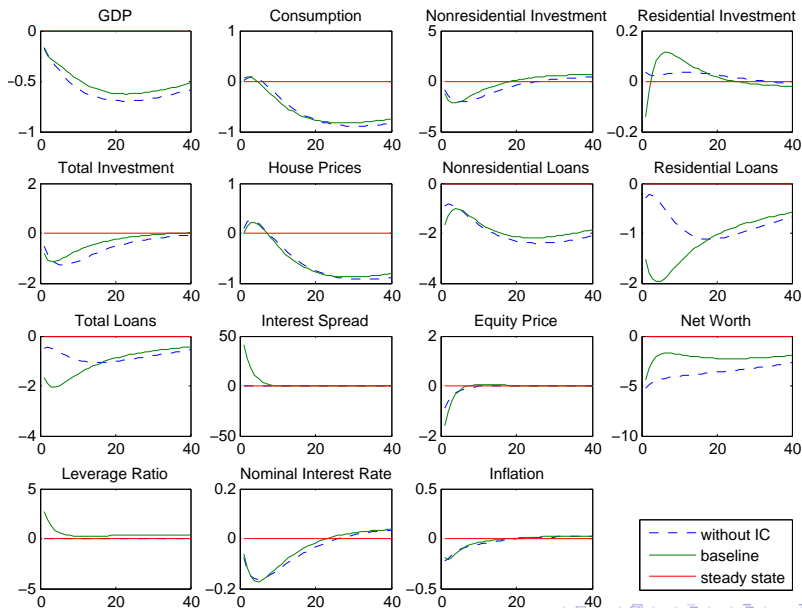
According to variance decomposition of 27 variables:

- Of 9 shocks, cost-push and monetary policy shock are not *important*
 - Monetary policy shock here is to the policy rate
 - Quantity shocks likely to be more *powerful*
- For the rest, importance high to low: housing demand, LTV, capital quality, supply, labor supply, housing supply, demand

Historical shock decomposition



Housing demand shock: **baseline** vs. **no financial friction**

Capital quality shock: **baseline** vs. **no financial friction**

Takeaways and remarks

- “Real” shocks are *real*: housing related, financial (capital) related, supply side (non-residential + labor)
- “Nominal” shocks are *nominal*: cost-push, monetary policy
- Crucial **interactions** between the housing and banking sectors in driving the BC fluctuations
- Overall conclusions consistent with the business cycle accounting literature on emerging market economies
 - Chari, Kehoe, and McGranttan (2007, ECTA)
 - Brinca, Chari, Kehoe, and McGranttan (2016, Handbook chapter)

CAVEAT past two decades, upto 1st order, misspecification risk

- **what's behind the shocks?** — more researches using micro data