

## Macroprudential Policy in a Heterogeneous Agent Model

Bulent Guler <sup>1</sup>   Kyongchae Jung <sup>1</sup>   Hyunduk Suh <sup>2</sup>

<sup>1</sup>Indiana University

<sup>2</sup>Inha University

August 26, 2016

# Introduction

- Distributional effect from macroprudential policy: how does the policy affect agents with different age and wealth status?
- Tradeoff from macroprudential policy
  - During normal times, macroprudential policy restricts young and poor agents' chance to borrow against their future income.
  - However, the policy also protects them from foreclosure risk by containing the probability of financial crisis.
  - Meanwhile, old and wealthy agents are less constrained by LTV/DTI type of macroprudential policy.

- Macroprudential policy: why do we need it?
  - To reduce systemic risk and procyclicality of financial institutions
  - Pecuniary externality, fire sale risk, and excessive borrowing
  - Lorenzoni (2008), Jeanne and Korinek (2013) (excessive borrowing), and Brunnermeier and Sannikov (2014) (volatility paradox)
- Macroeconomic and welfare effect of macroprudential policy
  - Workhorse approach is to use financial friction DSGE models
  - Pariès et al. (2011), Kannan et al. (2012), Angeloni and Faia (2013), Gelain et al. (2013), Lambertini et al. (2013), Quint and Rabanal (2014), Rubio and Carrasco-Gallego (2014), Suh (2014), Bailliu et al. (2015), Brzoza-Brzezina et al. (2015).

- Limitation of the above approach: mostly rely on local approximation technique
  - Not enough to explain nonlinear nature of financial crisis
  - Macroprudential policy restrictions always bind in the equilibrium
  - Not much heterogeneity among agents
- Our approach: Non-linear heterogeneous agent OLG model with housing and household default
  - Gervais (2002), Arslan et al. (2015), Chatterjee and Eyigungor (2015), Corbae and Quintin (2015)
  - Macroprudential policy binds to only a few agents

- The model captures non-linearity, occasionally binding constraints, and fire-sale dynamics
- Based on this model, we analyze not only time series but also the cross-section effects of macroprudential policy
- The model also captures realistic features of housing markets, such as variable housing size, mortgage default, refinance, and the co-movement between housing price and supply

Model

- Agents enter the economy at the age of 21, as active renters
- They retire at 65, and enjoy terminal utility with their current wealth
- Individual income has deterministic and stochastic component
- They can optimally borrow mortgage loans, refinance, and default
- Defaulted (inactive) agents are restricted from the financial market
- Lenders are risk-neutral financial intermediaries whose required return is the risk-free rate plus a markup

- At the initial steady state (period 0), agents expect either a rise in the risk-free rate or the markup, but do not know when
- At period 1, one-time shock in the risk-free rate or the markup occurs
- Then the aggregate uncertainty vanishes and the economy converges towards the final steady state
- Housing supply is assumed to be increasing with the housing price
- There are suppliers of rental housing units

- Household utility function is given as

$$\mathbb{E}_0 \left[ \sum_{j=1}^{J_r} \beta^{j-1} u_k(c_j, h_j) + \beta^{J_r} W(w_{J_r}, y_{J_r}) \right]$$

subject to

$$y(j, z_j) \equiv \begin{cases} \exp(f(j) + z_j) & \text{if } j \leq J_r \\ 0 & \text{if } j = J_{r+1}. \end{cases}$$

- Inactive renters cannot borrow, and should remain as renters (whether active or inactive)

$$V^d(a, z, j) = \max_{c, a' \geq 0, h' \geq 0} \left\{ u_d(c, h') + \beta \mathbb{E}_{z'|z} \left[ \psi^d V^r(a', z', j+1) + (1 - \psi^d) V^d(a', z', j+1) \right] \right\}$$

subject to

$$c + qa' + p_r h' = y(j, z) + a,$$

- Active renters can access to mortgage loan to buy a house. If they remain to be renters, then

$$V^r(a, z, j) = \max_{c, a' \geq 0, h' \geq 0} \left\{ u_r(c, h') + \beta \mathbb{E}_{z'|z} V^r(a', z', j+1) \right\}$$

subject to

$$c + qa' + p_r h' = y(j, z) + a.$$

- If they choose to become homeowners,

$$V^{ro}(a, z, j) = \max_{c, (d, q_m) \in \Upsilon(\theta), h' \geq 0} \left\{ u_0(c, h') + \beta \mathbb{E}_{x', z' | z} V^o(h', x', a', q_m, z', j+1) \right\}$$

subject to

$$\begin{aligned} c + q_m a' + p_h h' (1 + \varphi_b) &= y(j, z) + a, \\ q_m a' &= -[d - m(a', q_m, j)], \\ d &\leq (1 - \lambda) p_h h' \quad \text{or} \quad m(a', q_m, j) \leq v y(j, z_j), \end{aligned}$$

$$V^r = \max \{ V^{rr}, V^{ro} \}.$$

- The first option for homeowners is to stay in their current house without refinancing

$$V^{oo}(h, x, a, q_m, z, j) = \max_{c, a' \geq \underline{a}} \left\{ u_o(c, h') + \beta \mathbb{E}_{x', z' | z} V^o(h', x', a', \tilde{q}_m, z', j + 1) \right\}$$

subject to

$$c + \tilde{q}_m a' + xp_h h = y(j, z) + a,$$

$$\underline{a} = \begin{cases} a + m(a, q_m, j) & \text{if } a < 0, \\ 0 & \text{if } a \geq 0, \end{cases}$$

$$\tilde{q}_m = \begin{cases} q_m & \text{if } a' < 0, \\ q & \text{if } a' \geq 0, \end{cases}$$

$$h' = h.$$

- The second option for homeowners is to increase or decrease the size of housing

$$V^{op}(h, x, a, q_m, z, j) = \max_{c, (d, q_m) \in \Upsilon(\theta), h' \geq 0} \left\{ u_o(c, h') + \beta \mathbb{E}_{x', z' | z} V^o(h', x', a', q'_m, z', j+1) \right\}$$

subject to

$$c + q'_m a' + p_h h' (1 + \varphi_b) + x p_h h = y(j, z) + a + p_h h (1 - \varphi_s)$$

$$q'_m a' = -[d - m(a', q'_m, j)],$$

$$d \leq (1 - \lambda) p_h h' \quad \text{or} \quad m(a', q'_m, j) \leq v y(j, z_j),$$

- The third option for homeowners is to refinance their debt

$$V^{of}(h, x, a, q_m, z, j) = \max_{c, (d, q_m) \in \Upsilon(\theta)} \left\{ u_o(c, h') + \beta \mathbb{E}_{x', z' | z} V^o(h', x', a', q'_m, z', j+1) \right\}$$

subject to

$$\begin{aligned} c + q'_m a' - \zeta a' + x p_h h &= y(j, z) + a \\ q'_m a' &= -[d - m(a', q'_m, j)], \\ d &\leq (1 - \lambda) p_h h' \quad \text{or} \quad m(a', q'_m, j) \leq v y(j, z_j), \end{aligned}$$

- The fourth option for homeowners is to sell their houses and become renters

$$V^{or}(h, x, a, q_m, z, j) = \max_{c, a' \geq 0, h' \geq 0} \left\{ u_r(c, h') + \beta \mathbb{E}_{z'|z} V^r(a', z', j+1) \right\}$$

subject to

$$c + qa' + p_r h' + xp_h h = y(j, z) + p_h h(1 - \varphi_s) + a.$$

- The fifth option for homeowners is to default on their debts

$$V^{od}(h, x, a, z, j) = \max_{c, a' \geq 0, h' \geq 0} \left\{ u_d(c, h') + \beta \mathbb{E}_{z'|z} \left[ \psi^d V^r(a', z', j+1) + (1 - \psi^d) V^e(a', z', j+1) \right] \right\}$$

subject to

$$c + qa' + p_r h' = y(j, z) + \max[p_h h(1 - \varphi_l) + a, 0].$$

- Because of a moving shock, homeowners' value function can be represented by

$$V^o(h, x, a, q_m, z, j) = (1 - \psi^m) \max_{s'_o \in \{oo, op, of, or, od\}} V^{s'_o}(h, x, a, q_m, z, j) + \psi^m \max_{s'_m \in \{or, od\}} V^{s'_m}(h, x, a, q_m, z, j),$$

- The mortgage loan is designed to mature at the retirement age,

$$d = m \left( 1 + q_m + q_m^2 + \cdots + q_m^{J_r - j} \right),$$

$$m(d, r_m, j) = \frac{1 - q_m}{1 - q_m^{J_r - j + 1}} d.$$

$$V^l(h, x, a, r_m, z, j) = \begin{cases} -a + q_m a' + \frac{1}{1+r+\mu} \mathbb{E}_{x', z' | z} V^l(h', x', a', r_m, z', j+1) & \text{if hh stays,} \\ \min [p_h h(1 - \varphi_l), -a] & \text{if hh default,} \\ -a & \text{if hh sell/refinance.} \end{cases}$$

- Rental company's problem

$$V^{rc}(H_r) = \max_{x_r, H'_r} \left\{ (p_r - \phi)H'_r - p_h x_r + \frac{1}{1+r} \mathbb{E} V^{rc}(H'_r) \right\}$$

subject to  $H'_r = (1 - \delta_h)H_r + x_r$ .

- Goods production:  $\max_{N_c} Y_c - wN_c$  subject to  $Y = z_c N_c$ .
- Housing production:  $\max_N p_h l_h - wN_h$  subject to  $l_h = z_h N_h^{\alpha_h}$ .
- Yielding

$$w = p_h z_h \alpha_h N_h^{\alpha_h - 1}.$$

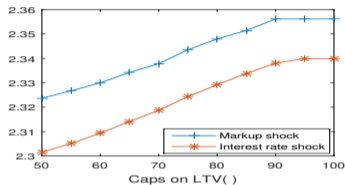
- 1 Labor market clears:  $N_h + N_c = 1$ ,
- 2 Housing market clears:  $H = H_r + \int h d\Gamma_{s=0}$  and  $l_h = z_h N_h^{\alpha_h}$  satisfies (20),
- 3 Rental market clears:  $H_r = \int h d\Gamma_{s=r}$
- 4 Goods market clears :  $Y = \int c d\Gamma + \nu$  where  $\nu$  represents the costs including housing transaction, refinancing and maintenance costs.

# Calibration

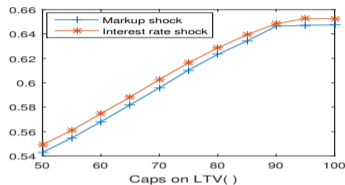
| Parameter         | Explanation                                      | Value  |
|-------------------|--------------------------------------------------|--------|
| $\sigma$          | Inverse elasticity of intertemporal substitution | 1.5    |
| $\eta$            | Consumption share in preference                  | 0.85   |
| $r$               | Risk-free interest rate - initial                | 0.03   |
| $\psi^d$          | prob. of being an active renter                  | 0.14   |
| $\rho$            | Persistence, income shock                        | 0.97   |
| $\sigma_\epsilon$ | Standard deviation, innovations in income shock  | 0.13   |
| $\varphi_h$       | Transaction cost in selling houses, households   | 0.07   |
| $\varphi_b$       | Transaction cost in buying houses, households    | 0.03   |
| $\delta_h$        | Aggregate Depreciation rate of housing           | 0.015  |
| $\gamma_o$        | Utility gain, homeowners                         | 0.1560 |
| $\beta$           | Household discount factor                        | 0.9204 |
| $\psi^m$          | Moving probability                               | 0.049  |
| $\zeta$           | Refinance cost, households                       | 0.01   |
| $x$               | Owner-occupied depreciation rate                 | 0.025  |

# Steady State Analysis

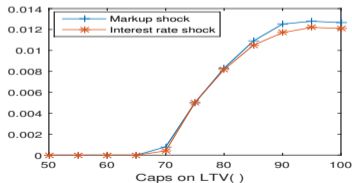
## The effects of LTV policy, key first moments



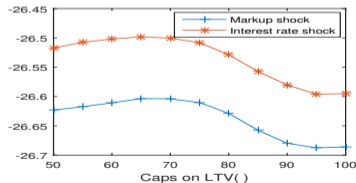
(a) Housing price



(b) Homeownership rate

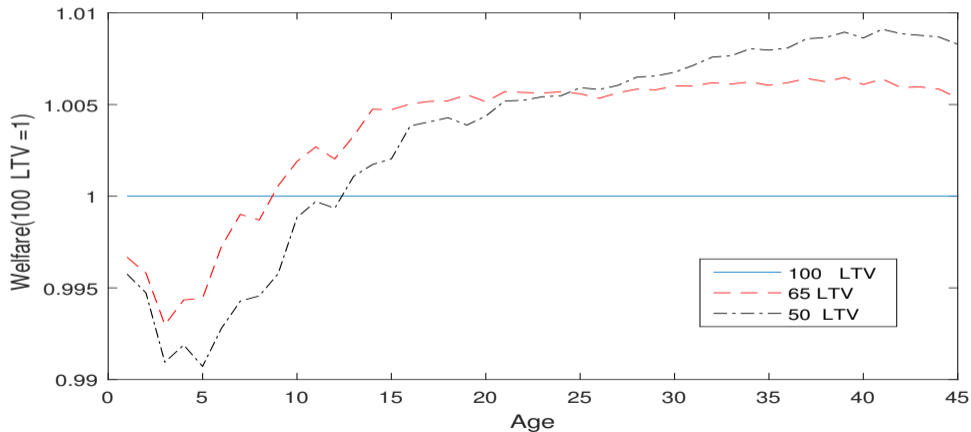


(c) Foreclosure rate

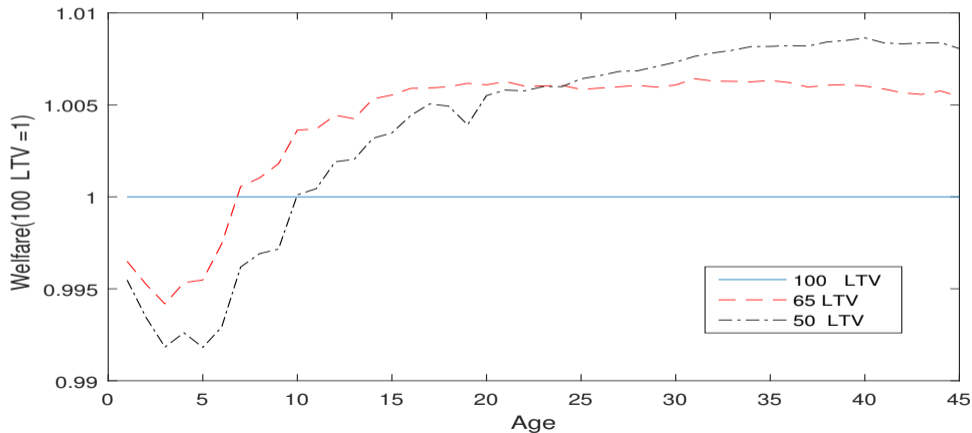


(d) Welfare

The effects of LTV policy, expecting a markup shock, welfare by age



The effects of LTV policy, expecting an interest rate shock, welfare by age

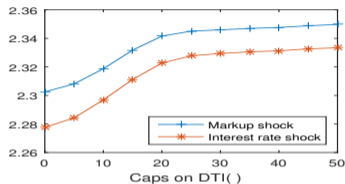


## Wealth distribution, LTV policy

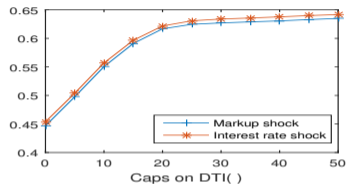
|                |         |       |       |       |       |      |      |              | (%) |
|----------------|---------|-------|-------|-------|-------|------|------|--------------|-----|
| Expected shock | LTV cap | 0-1.5 | 1.5-3 | 3-4.5 | 4.5-6 | 6-9  | 9-12 | More than 12 |     |
| Markup         | 100%    | 51.57 | 13.79 | 9.31  | 6.49  | 8.99 | 5.46 | 4.38         |     |
|                | 65%     | 50.10 | 14.70 | 9.54  | 6.62  | 9.05 | 5.54 | 4.44         |     |
|                | 50%     | 49.56 | 15.08 | 9.62  | 6.66  | 9.07 | 5.55 | 4.45         |     |
| Interest rate  | 100%    | 51.09 | 13.75 | 9.35  | 6.45  | 9.22 | 5.58 | 4.56         |     |
|                | 65%     | 49.55 | 14.67 | 9.61  | 6.54  | 9.35 | 5.65 | 4.64         |     |
|                | 50%     | 49.02 | 15.04 | 9.69  | 6.59  | 9.35 | 5.67 | 4.65         |     |

Note: Each number in the table is the relative frequency, that is, the number of agents in each wealth class divided by the total number of agents (900,000).

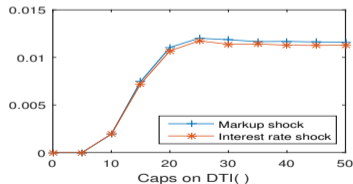
## The effects of DTI policy, key first moments



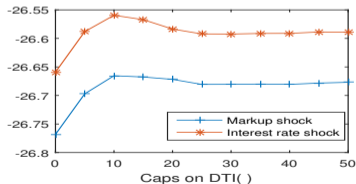
(a) Housing price



(b) Homeownership rate

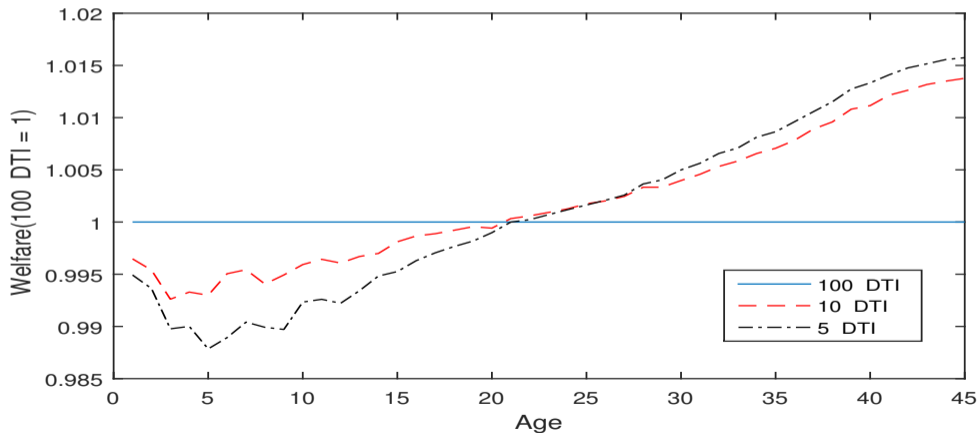


(c) Foreclosure rate

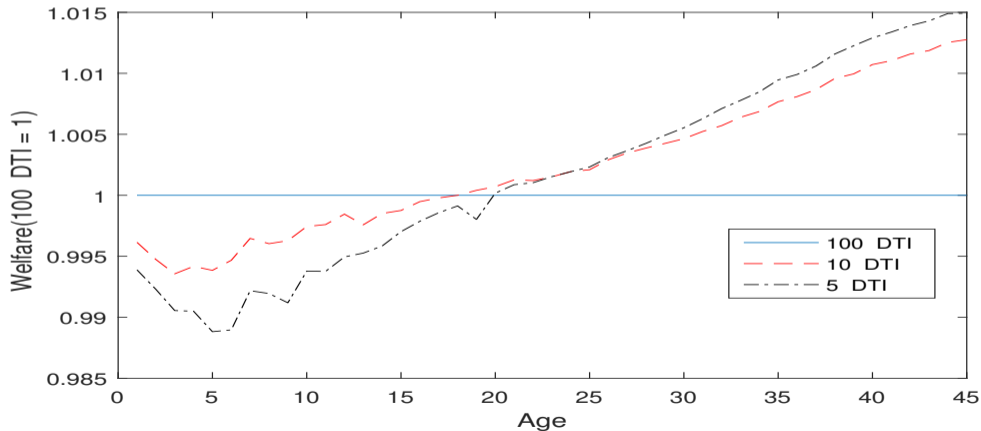


(d) Welfare

The effects of DTI policy, expecting a markup shock, welfare by age



The effects of DTI policy, expecting an interest rate shock, welfare by age



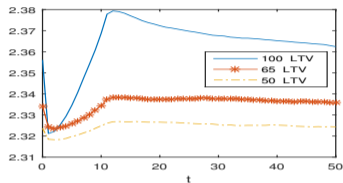
## Wealth distribution, DTI policy, markup shock

| Expected shock      | DTI cap  | (%)   |       |       |       |      |      |              |
|---------------------|----------|-------|-------|-------|-------|------|------|--------------|
|                     |          | 0-1.5 | 1.5-3 | 3-4.5 | 4.5-6 | 6-9  | 9-12 | More than 12 |
| Markup shock        | 100% DTI | 51.57 | 13.79 | 9.31  | 6.49  | 8.99 | 5.46 | 4.38         |
|                     | 10% DTI  | 51.09 | 13.45 | 9.70  | 6.68  | 9.09 | 5.54 | 4.45         |
|                     | 5% DTI   | 50.76 | 13.38 | 9.90  | 6.77  | 9.13 | 5.58 | 4.48         |
| Interest rate shock | 100% DTI | 51.09 | 13.75 | 9.35  | 6.45  | 9.22 | 5.58 | 4.56         |
|                     | 10% DTI  | 50.49 | 13.48 | 9.76  | 6.62  | 9.36 | 5.65 | 4.64         |
|                     | 5% DTI   | 50.14 | 13.43 | 9.98  | 6.71  | 9.39 | 5.69 | 4.66         |

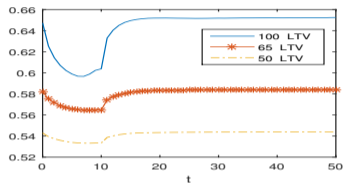
Note: Each number in the table is the relative frequency, that is, the number of agents in each wealth class divided by the total number of agents (900,000).

# Transition Analysis

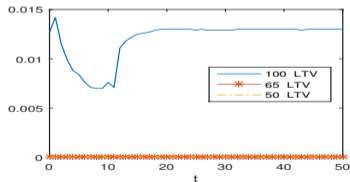
## The effects of LTV policy, key first moments



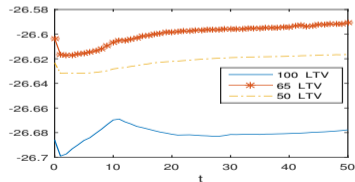
(a) Housing price, markup shock



(b) Home ownership rate, markup shock

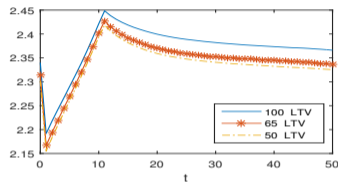


(c) Foreclosure rate, markup shock

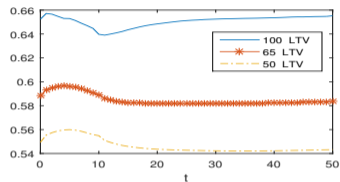


(d) Welfare, markup shock

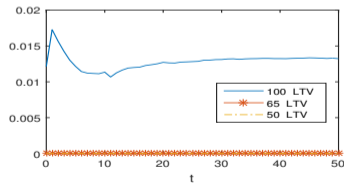
## The effects of LTV policy, key first moments



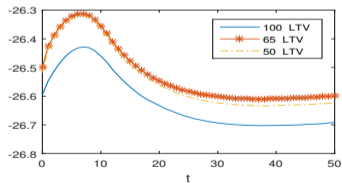
(a) Housing price, interest rate shock



(b) Home ownership rate, interest rate shock

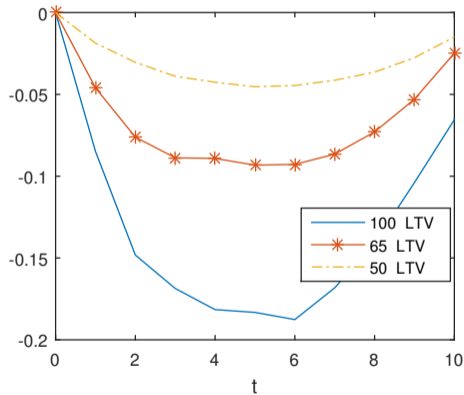


(c) Foreclosure rate, interest rate shock

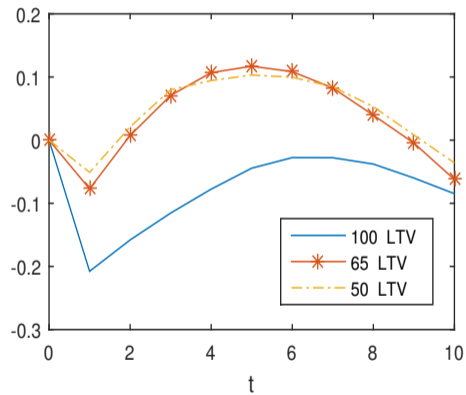


(d) Welfare, interest rate shock

The effects of LTV policy, welfare change during the crisis, young agents

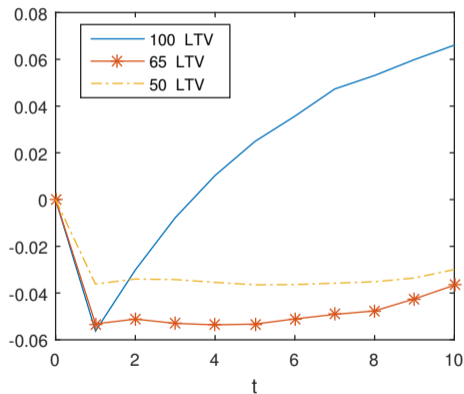


(a) Markup shock

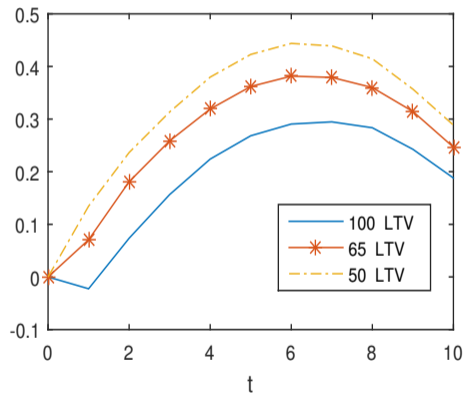


(b) Interest rate shock

The effects of LTV policy, welfare change during the crisis, middle-aged agents

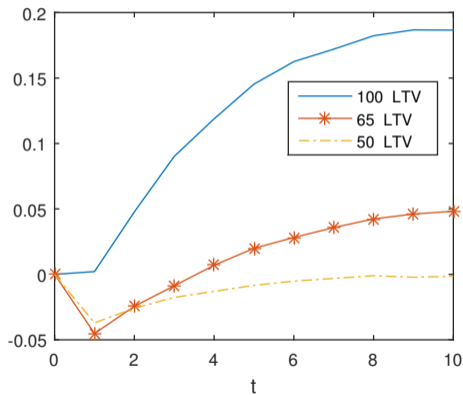


(a) Markup shock

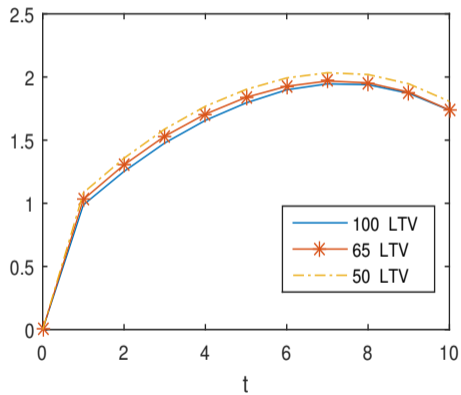


(b) Interest rate shock

The effects of LTV policy, welfare change during the crisis, old agents



(a) Markup shock



(b) Interest rate shock

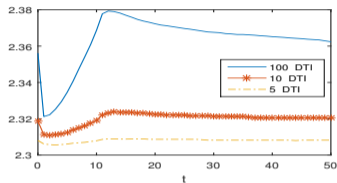
## Wealth distribution, LTV policy, markup shock

| Expected shock | LTV cap  | (% , pp) |         |         |        |         |         |              |
|----------------|----------|----------|---------|---------|--------|---------|---------|--------------|
|                |          | 0-1.5    | 1.5-3   | 3-4.5   | 4.5-6  | 6-9     | 9-12    | More than 12 |
| t=0            | 100% LTV | 51.57    | 13.79   | 9.31    | 6.49   | 8.99    | 5.46    | 4.38         |
|                | 65% LTV  | 50.10    | 14.70   | 9.54    | 6.62   | 9.05    | 5.54    | 4.44         |
|                | 50% LTV  | 49.56    | 15.08   | 9.62    | 6.66   | 9.07    | 5.55    | 4.45         |
| t= 1           | 100% LTV | 51.90    | 13.72   | 9.22    | 6.50   | 8.96    | 5.40    | 4.30         |
|                |          | (0.33)   | (-0.07) | (-0.08) | (0.01) | (-0.04) | (-0.06) | (-0.09)      |
|                | 65% LTV  | 50.21    | 14.67   | 9.52    | 6.62   | 9.04    | 5.53    | 4.41         |
|                |          | (0.11)   | (-0.03) | (-0.03) | (0.00) | (-0.01) | (-0.01) | (-0.03)      |
|                | 50% LTV  | 49.62    | 15.06   | 9.61    | 6.67   | 9.06    | 5.55    | 4.44         |
|                |          | (0.06)   | (-0.02) | (-0.01) | (0.00) | (-0.01) | (-0.01) | (-0.01)      |
| t= 10          | 100% LTV | 51.23    | 13.97   | 9.37    | 6.57   | 8.96    | 5.50    | 4.41         |
|                |          | (-0.35)  | (0.17)  | (0.06)  | (0.08) | (-0.04) | (0.03)  | (0.03)       |
|                | 65% LTV  | 50.09    | 14.67   | 9.58    | 6.63   | 9.04    | 5.54    | 4.44         |
|                |          | (-0.01)  | (-0.04) | (0.04)  | (0.02) | (-0.01) | (0.01)  | (0.00)       |
|                | 50% LTV  | 49.68    | 14.93   | 9.65    | 6.67   | 9.06    | 5.56    | 4.46         |
|                |          | (0.12)   | (-0.15) | (0.02)  | (0.00) | (-0.01) | (0.01)  | (0.00)       |

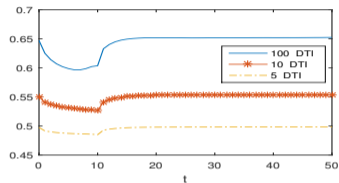
## Wealth distribution, LTV policy, interest rate shock

|                |          | (% , pp) |         |         |         |         |         |              |
|----------------|----------|----------|---------|---------|---------|---------|---------|--------------|
| Expected shock | LTV cap  | 0-1.5    | 1.5-3   | 3-4.5   | 4.5-6   | 6-9     | 9-12    | More than 12 |
| t=0            | 100% LTV | 51.09    | 13.75   | 9.35    | 6.45    | 9.22    | 5.58    | 4.56         |
|                | 65% LTV  | 49.55    | 14.67   | 9.61    | 6.54    | 9.35    | 5.65    | 4.64         |
|                | 50% LTV  | 49.02    | 15.04   | 9.69    | 6.59    | 9.35    | 5.67    | 4.65         |
| t= 1           | 100% LTV | 52.41    | 13.34   | 8.97    | 6.32    | 9.20    | 5.36    | 4.39         |
|                |          | (1.33)   | (-0.41) | (-0.38) | (-0.12) | (-0.02) | (-0.22) | (-0.17)      |
|                | 65% LTV  | 51.03    | 14.14   | 9.20    | 6.48    | 9.25    | 5.43    | 4.46         |
|                |          | (1.49)   | (-0.53) | (-0.40) | (-0.06) | (-0.10) | (-0.22) | (-0.17)      |
|                | 50% LTV  | 50.45    | 14.55   | 9.30    | 6.55    | 9.22    | 5.45    | 4.48         |
|                |          | (1.43)   | (-0.49) | (-0.39) | (-0.04) | (-0.13) | (-0.21) | (-0.17)      |
| t= 10          | 100% LTV | 49.65    | 13.45   | 9.10    | 6.35    | 9.26    | 5.88    | 6.31         |
|                |          | (-1.44)  | (-0.30) | (-0.24) | (-0.10) | (0.04)  | (0.30)  | (1.75)       |
|                | 65% LTV  | 47.89    | 14.42   | 9.40    | 6.52    | 9.40    | 5.95    | 6.42         |
|                |          | (-1.66)  | (-0.25) | (-0.20) | (-0.03) | (0.05)  | (0.30)  | (1.78)       |
|                | 50% LTV  | 47.23    | 14.80   | 9.55    | 6.56    | 9.45    | 5.97    | 6.45         |
|                |          | (-1.79)  | (-0.24) | (-0.14) | (-0.03) | (0.10)  | (0.30)  | (1.80)       |

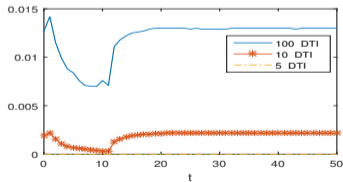
## The effects of DTI policy, key first moments



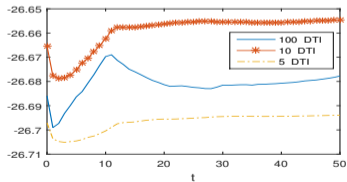
(a) Housing price, markup shock



(b) Home ownership rate, markup shock

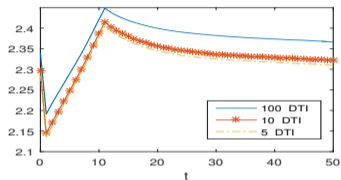


(c) Foreclosure rate, markup shock

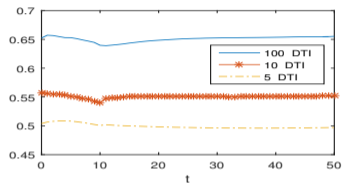


(d) Welfare, markup shock

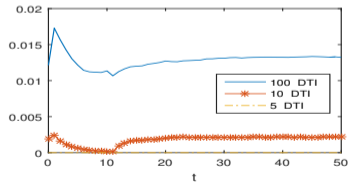
## The effects of DTI policy, key first moments



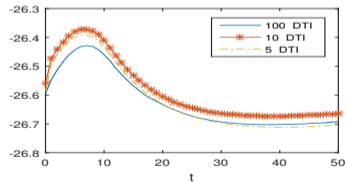
(a) Housing price, interest rate



(b) Home ownership rate, interest rate shock

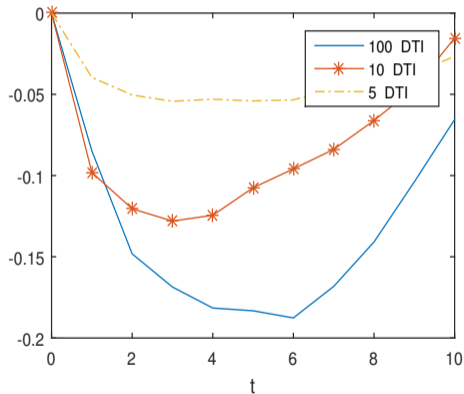


(c) Foreclosure rate, interest rate shock

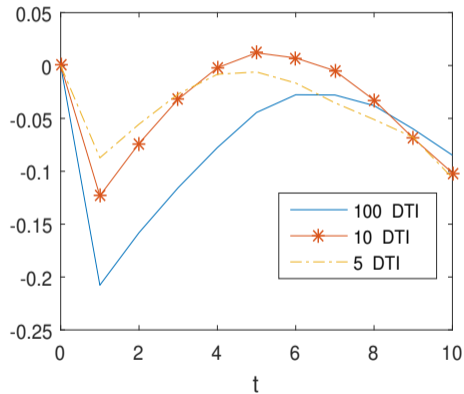


(d) Welfare, interest rate shock

The effects of DTI policy, welfare change during the crisis, young agents

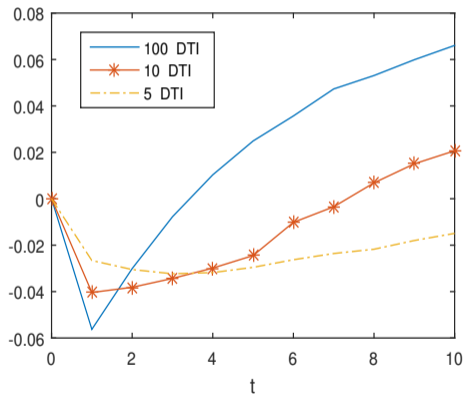


(a) Markup shock

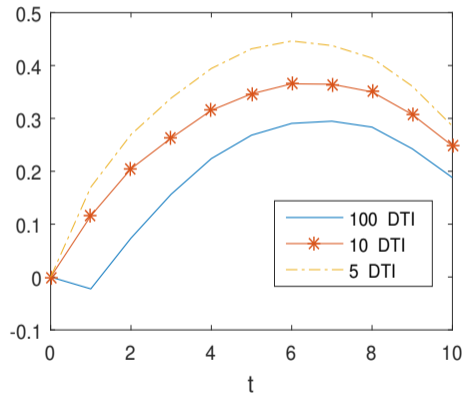


(b) Interest rate shock

The effects of DTI policy, welfare change during the crisis, middle-aged agents

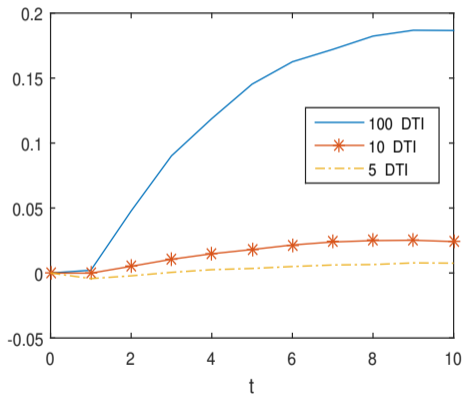


(a) Markup shock

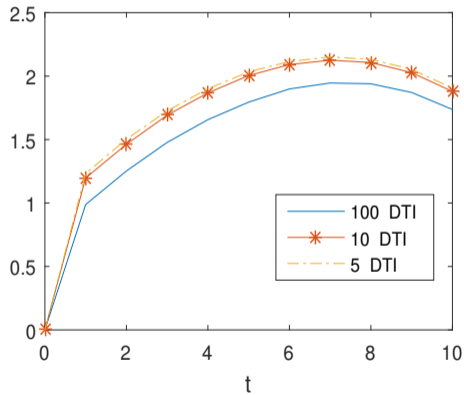


(b) Interest rate shock

The effects of DTI policy, welfare change during the crisis, old agents



(a) Markup shock



(b) Interest rate shock

## Wealth distribution, DTI policy, markup shock

| Expected shock | DTI cap  | (% , pp) |         |         |        |         |         |              |
|----------------|----------|----------|---------|---------|--------|---------|---------|--------------|
|                |          | 0-1.5    | 1.5-3   | 3-4.5   | 4.5-6  | 6-9     | 9-12    | More than 12 |
| t=0            | 100% DTI | 51.57    | 13.79   | 9.31    | 6.49   | 8.99    | 5.46    | 4.38         |
|                | 10% DTI  | 51.09    | 13.45   | 9.70    | 6.68   | 9.09    | 5.54    | 4.45         |
|                | 5% DTI   | 50.76    | 13.38   | 9.90    | 6.77   | 9.13    | 5.58    | 4.48         |
| t= 1           | 100% DTI | 51.90    | 13.72   | 9.22    | 6.50   | 8.96    | 5.40    | 4.30         |
|                |          | (0.33)   | (-0.07) | (-0.08) | (0.01) | (-0.04) | (-0.06) | (-0.09)      |
|                | 10% DTI  | 51.14    | 13.45   | 9.68    | 6.68   | 9.08    | 5.53    | 4.43         |
|                |          | (0.05)   | (0.00)  | (-0.02) | (0.00) | (-0.01) | (-0.02) | (-0.02)      |
|                | 5% DTI   | 50.77    | 13.39   | 9.89    | 6.77   | 9.13    | 5.57    | 4.47         |
|                |          | (0.01)   | (0.01)  | (-0.01) | (0.00) | (0.00)  | (0.00)  | (-0.01)      |
| t= 10          | 100% DTI | 51.23    | 13.97   | 9.37    | 6.57   | 8.96    | 5.50    | 4.41         |
|                |          | (-0.35)  | (0.17)  | (0.06)  | (0.08) | (-0.04) | (0.03)  | (0.03)       |
|                | 10% DTI  | 50.93    | 13.48   | 9.78    | 6.73   | 9.09    | 5.55    | 4.45         |
|                |          | (-0.16)  | (0.03)  | (0.08)  | (0.04) | (0.00)  | (0.01)  | (0.00)       |
|                | 5% DTI   | 50.77    | 13.29   | 9.96    | 6.78   | 9.14    | 5.58    | 4.48         |
|                |          | (0.01)   | (-0.09) | (0.06)  | (0.01) | (0.01)  | (0.00)  | (0.00)       |

## Wealth distribution, DTI policy, interest rate shock

|                |          | (%, pp) |         |         |         |         |         |              |
|----------------|----------|---------|---------|---------|---------|---------|---------|--------------|
| Expected shock | DTI cap  | 0-1.5   | 1.5-3   | 3-4.5   | 4.5-6   | 6-9     | 9-12    | More than 12 |
| t=0            | 100% DTI | 51.09   | 13.75   | 9.35    | 6.45    | 9.22    | 5.58    | 4.56         |
|                | 10% DTI  | 50.49   | 13.48   | 9.76    | 6.62    | 9.36    | 5.65    | 4.64         |
|                | 5% DTI   | 50.14   | 13.43   | 9.98    | 6.71    | 9.39    | 5.69    | 4.66         |
| t= 1           | 100% DTI | 52.41   | 13.34   | 8.97    | 6.32    | 9.20    | 5.36    | 4.39         |
|                |          | (1.33)  | (-0.41) | (-0.38) | (-0.12) | (-0.02) | (-0.22) | (-0.17)      |
|                | 10% DTI  | 51.42   | 13.53   | 9.35    | 6.58    | 9.24    | 5.42    | 4.46         |
|                |          | (0.94)  | (0.05)  | (-0.41) | (-0.05) | (-0.13) | (-0.23) | (-0.18)      |
|                | 5% DTI   | 50.82   | 13.77   | 9.53    | 6.68    | 9.25    | 5.46    | 4.50         |
|                |          | (0.68)  | (0.33)  | (-0.45) | (-0.02) | (-0.14) | (-0.23) | (-0.17)      |
| t= 10          | 100% DTI | 49.65   | 13.45   | 9.10    | 6.35    | 9.26    | 5.88    | 6.31         |
|                |          | (-1.44) | (-0.30) | (-0.24) | (-0.10) | (0.04)  | (0.30)  | (1.75)       |
|                | 10% DTI  | 48.70   | 13.18   | 9.65    | 6.62    | 9.45    | 5.96    | 6.44         |
|                |          | (-1.78) | (-0.29) | (-0.11) | (-0.01) | (0.09)  | (0.31)  | (1.80)       |
|                | 5% DTI   | 48.41   | 12.94   | 9.90    | 6.72    | 9.56    | 6.00    | 6.48         |
|                |          | (-1.73) | (-0.50) | (-0.08) | (0.01)  | (0.17)  | (0.31)  | (1.82)       |

## Conclusion

- Macroprudential policy is effective in mitigating housing crisis given a markup shock
- Not as effective given a rise in the interest rate.
- The initial steady state welfare analysis
  - Welfare analysis has interior solutions at 65% LTV or 10% DTI limits
  - Macroprudential policy corrects pecuniary externality in a competitive economy
  - However, age-by-age welfare analysis shows that tighter LTV or DTI policy lowers the welfare of younger agents, by restricting their borrowing limits.
  - Tighter LTV or DTI limits also reduces the proportion of wealth-poor agents

- Transition analysis
  - Macroprudential policy mitigates the decrease in housing price and home ownership rate, and the increase in foreclosure.
  - However, its effect is less drastic if the shock is the rise in the interest rate.
  - Ironically, transition analysis shows that macroprudential policy protects those young agents the most once shocks occur, as it reduces the degree of the housing market and foreclosure crisis.

- Optimal policy: alternative approach
- Countercyclical LTV & DTI policy
- The relationship between monetary policy and macroprudential policy