Optimal Time-Consistent Macroprudential Policy

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Why study macroprudential policy?

- MPP has gained relevance as a tool aimed at hampering credit booms that precede financial crises (booms occur with 2.8% prob., but a third of them end in a crisis (Mendoza & Terrones (2012)))
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- MPP analysis needs a quantitative framework capable of:
  1. Matching crisis dynamics and capturing prudential mechanisms
  2. Evaluating effectiveness (frequency & magnitude of crises)
  3. Addressing inability to commit
What is in this paper?

1. A theoretical and quantitative analysis of optimal, time-consistent MPP in a Fisherian model of financial crises:

   - Occasionally-binding collateral constraint causes crises
   - Collateral valued at marked prices introduces pecuniary externality
   - Forward-looking asset pricing makes MPP time-inconsistent under commitment, so we solve for optimal policy without commitment
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   - Forward-looking asset pricing makes MPP time-inconsistent under commitment, so we solve for optimal policy without commitment

2. An analytical comparison of MPP with and without commitment

3. A quantitative evaluation of the effectiveness of optimal, time-consistent MPP v. simple policy rules
Main Theoretical Findings

1. Optimal MPP under commitment is time-inconsistent:
   - Via pricing kernel, future consumption affects current prices
   - When constraint binds, reducing future consumption raises current asset prices & borrowing capacity
   - If government re-optimizes ex post, it ignores the costs of current consumption over previous collateral values and borrowing capacity
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2. Constrained-efficient allocations (with or without commitment) are implementable with a state-contingent debt tax

3. Prudential component of the tax is strictly positive
Main Quantitative Findings

Optimal, time-consistent MPP is very effective:

- Probability of crises falls from 4% to 0.02%
- Asset Prices fall 39 ppts less (44% v. 5%)
- Equity Premium decreases by a factor of 6 (from 5% to 0.8%)
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1. Optimal, time-consistent MPP is very effective:
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2. Tax on debt averages 3.6%, with 0.7 corr. with leverage

3. Simple taxes are much less effective, and can be welfare-reducing if they are not set carefully
Related Literature


- **Quantitative Macro-Finance Models**:

Outline

1. Analytics of Pecuniary Externality and Time Inconsistency (in a simplified model for presentation)
   - Aggregate collateral, endowment economy

2. Model for Quantitative Analysis
   - Individual collateral, production, working capital

3. Quantitative Findings
Decentralized Equilibrium without Policy

Households solve:

\[
\max_{\{c_t, k_{t+1}, b_{t+1}\}_{t \geq 0}} \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t u(c_t)
\]

s.t.  
\[
c_t + q_t k_{t+1} + \frac{b_{t+1}}{R} = k_t(q_t + z_t) + b_t \quad (\lambda_t)
\]

\[
\frac{b_{t+1}}{R} \geq -\kappa q_t \quad (\mu_t)
\]

- \(z_t\) follows a Markov process
- Aggregate capital in unit fixed supply used as collateral
- One-period, non-state-contingent bonds, exog. interest rate \(R\)
Excess Returns and Asset Pricing

Binding constraint increases excess returns

\[ E_t[R_{t+1}^k] - R = \frac{\mu_t - \text{Cov}_t(\beta u'(c_{t+1}), R_{t+1}^k - R)}{\beta E_t u'(c_{t+1})} \]
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causing asset prices to fall

$$q_t = E_t \sum_{j=0}^{\infty} \frac{z_{t+j+1}}{\prod_{i=0}^{j} E_{t+i} R_{t+1+i}^k}$$

tightening further the constraint and feeding back to asset prices
Excess Returns and Asset Pricing

Binding constraint increases excess returns

$$\mathbb{E}_t[R^k_{t+1}] - R = \frac{\mu_t - \text{Cov}_t(\beta u'(c_{t+1}), R^k_{t+1} - R)}{\beta \mathbb{E}_t u'(c_{t+1})}$$

caus[ing asset prices to fall]

$$q_t = \mathbb{E}_t \sum_{j=0}^{\infty} \frac{z_{t+j+1}}{\prod_{i=0}^{j-1} \mathbb{E}_{t+i} R^k_{t+1+i}}$$

tightening further the constraint and feeding back to asset prices

.... but agents do not internalize effects of ex-ante borrowing decisions on $q_t$ ex post ⇒ pecuniary externality
Normative Analysis

- Constrained-efficient regulator (planner) chooses debt and transfers borrowed resources facing the same credit constraint
  - Households choose $c_{t+1}, k_{t+1}$ (asset market remains competitive)
  - Asset Euler eq. becomes implementability constraint:

$$q_t u'(c_t) = \beta E_t u'(c_{t+1}) (z_{t+1} + q_{t+1})$$
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- Without commitment, the regulator at date \( t \) takes into account how its decisions affect the regulator’s plans at \( t+1 \), and thereby \( c_{t+1}, q_{t+1} \) and thus \( q_t \)
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- Without commitment, the regulator at date $t$ takes into account how its decisions affect the regulator’s plans at $t+1$, and thereby $c_{t+1}, q_{t+1}$ and thus $q_t$

- Equivalent approach: Ramsey planner choosing debt taxes
Time-Consistent Regulator’s Problem

Taking as given future regulator’s $C$ and $Q$, the planner solves:

$$V(b, z) = \max_{c, b', q} \left[ u(c) + \beta \mathbb{E}_{z' | z} V(b', z') \right]$$

subject to

$$c + \frac{b'}{R} = b + z \quad (\lambda)$$

$$\frac{b'}{R} \geq -\kappa q \quad (\mu^*)$$

$$q = \frac{\beta \mathbb{E} u'(C(b', z'))(Q(b', z') + z')}{u'(c)} \quad (\xi)$$
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MPE requires $c(b, z) = \mathcal{C}(b, z), q(b, z) = \mathcal{Q}(b, z)$. 
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Pecuniary Externalities

Via $q_t$ (when $\mu^*_t > 0$):

$c_t : \quad \lambda_t = u'(c_t) - \kappa \mu^*_t q_t \frac{u''(c_t)}{u'(c_t)}$

Extra Benefits from $c_t$
Pecuniary Externalities

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Extra Benefits from $c_t$

$b_{t+1} : \lambda_t = \beta R \mathbb{E}_t \lambda_{t+1} + \xi_t \beta \mathbb{E}_t u''(c_{t+1}) C_b(t+1)(Q_{t+1}(t+1)) + z_{t+1} + Q_b(t+1)u'(c_{t+1}) + \mu_t$

Effects of Future Policies on Current Asset Prices
Pecuniary Externalities

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Extra Benefits from $c_t$

$$b_{t+1} : \quad \lambda_t = \beta R^t \lambda_{t+1} + \xi_t \beta^t E_t \left( u''(c_{t+1}) C_b(t+1)(Q_{t+1}(t+1)) + z_{t+1} \right) + Q_b(t+1) u'(c_{t+1}) + \mu^*_t$$

Effects of Future Policies on Current Asset Prices

Via $q_{t+1}$ (when $\mu^*_t = 0, E[\mu^*_{t+1}] > 0$):

$$u'(c_t) = \beta R^t \left( u'(c_{t+1}) - \frac{\kappa \mu^*_{t+1} q_{t+1} u''(c_{t+1})}{u'(c_{t+1})} \right)$$
Optimal Time-Consistent Debt Tax

Proposition: The regulator’s equilibrium can be decentralized with a state-contingent debt tax (i.e. bond prices become $1/[R(1 + \tau_t)]$) with its revenue rebated as a lump-sum transfer and a tax rate such that:

$$1 + \tau_t = \frac{1}{\mathbb{E}_t u'(t + 1) \mathbb{E}_t [u'(t + 1) - \xi_{t+1} u''(t + 1) Q_{t+1} + \xi_t \Omega_{t+1}]}$$

$$+ \frac{1}{\beta R \mathbb{E}_t u'(t + 1)} [\xi_t u''(t) q_t]$$
**Optimal Time-Consistent Debt Tax**

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$$+ \frac{1}{\beta R \mathbb{E}_t u'(t + 1)} [\xi_t u''(t) q_t]$$

**MP debt tax:** If $\mu_t^* = 0$ and $\mathbb{E}[\mu_{t+1}^*] > 0$, the tax reduces to:

$$\tau_t^{MP} = -\mathbb{E}_t \frac{\kappa \mu_{t+1}^*}{u'(C(b_{t+1}, z_{t+1}))} u''(C(b_{t+1}, z_{t+1})) \frac{Q(b_{t+1}, z_{t+1})}{\mathbb{E}_t u'(C(b_{t+1}, z_{t+1}))}$$
Equity Premia in the DE and SP

- Decentralized equilibrium

\[ R^e_p = \mu_t \frac{u'(t) E_t m_{t+1}}{E_t m_{t+1}} - \frac{E_t (\phi_{t+1} m_{t+1})}{E_t m_{t+1}} - \frac{cov_t(m_{t+1}, R^q_{t+1})}{E_t [m_{t+1}]} \]

\[ m_{t+1} \equiv \beta \frac{u'(c_{t+1})}{u'(c_t)}, \quad \phi_{t+1} \equiv \kappa \frac{\mu_{t+1} q_{t+1}}{u'(c_t) q_t}. \]
Equity Premia in the DE and SP

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\[ R_{t}^{ep} = \frac{\mu_{t}}{u'(t)E_{t}m_{t+1}} - \frac{E_{t}(\phi_{t+1}m_{t+1})}{E_{t}m_{t+1}} - \frac{cov_{t}(m_{t+1}, R_{t+1}^{q})}{E_{t}[m_{t+1}]} \]

Liquidity\[ \quad \text{Collateral} \quad \text{Risk} \]

\[ m_{t+1} \equiv \frac{\beta u'(c_{t+1})}{u'(c_{t})}, \quad \phi_{t+1} \equiv \kappa \frac{\mu_{t+1}}{u'(c_{t})} \frac{q_{t+1}}{q_{t}}. \]

- Social planner

\[ R_{t}^{ep} = \frac{\mu^{*}_{t} + \xi_{t}u''(t)q_{t} + \beta R E_{t} \xi_{t} \Omega_{t+1}}{u'(t)E_{t}m_{t+1}} - \frac{E_{t}(\phi^{*}_{t+1}m_{t+1})}{E_{t}m_{t+1}} \]

Liquidity\[ \quad \text{Collateral} \quad \text{Risk} \]

\[ - \frac{cov_{t}(m_{t+1}, R_{t+1}^{q})}{E_{t}m_{t+1}} - \frac{\beta R E_{t}(\xi_{t+1}u''(t+1)Q_{t+1})}{u'(t)E_{t}m_{t+1}} \]

Externality
Comparison with Commitment

\[ c_t : \quad \lambda_t = u'(c_t) - \xi_t q_t u''(c_t) + u''(c_t) \xi_{t-1} (q_t + z_t) \quad \forall t > 0 \]

\[ q_t :: \quad \xi_t = \xi_{t-1} + \frac{\mu^* \kappa}{u'(c_t)} \quad \forall t > 0 \]

\[ b_{t+1} :: \quad \lambda_t = \beta R_t \mathbb{E}_t \lambda_{t+1} + \mu^*_t \quad \forall t \geq 0 \]

Higher current consumption still raises current asset prices.
Comparison with Commitment

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But now lower current consumption raises previous asset prices
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\[ b_{t+1} :: \quad \lambda_t = \beta R_t E_t \lambda_{t+1} + \mu_t^* \quad \forall t \geq 0 \]

But now lower current consumption raises previous asset prices

→ A promise of low \( c_{t+1} \) at time \( t \) is time inconsistent
Optimal Macroprudential Debt Tax

Without commitment (Markov stationary):

\[ \tau_t^M = -\mathbb{E}_t \frac{\kappa \mu_{t+1}^*}{u'(c_{t+1})} u''(c_{t+1}) q_{t+1} \]

With commitment (Ramsey):

\[ \tau_t^R = -\mathbb{E}_t \frac{\kappa \mu_{t+1}^*}{u'(c_{t+1})} u''(c_{t+1}) q_{t+1} + \xi_{t-1} (\mathbb{E}_t u''(c_{t+1}) z_{t+1} - z_t u''(c_t)) \]

- Taxes differ if a collateral constraint was binding in the past
- \( \tau_t^R \geq \tau_t^M \) if output is high relative to the future
- Quantitatively, asset prices are higher (lower) with (without) commitment than without regulation
Decentralized Eq. v. MPP with Commitment

Value Function

Consumption

Asset Prices

Bond Policy Function

- Ramsey
- DE
Quantitative Analysis

- Introduce firms, labor supply, intermediate goods
- Add working capital for purchases of intermediate goods
- Assume capital has individual value as collateral
- Introduce TFP, interest-rate and financial shocks
Representative Firm-Household Problem

Maximize:

\[ \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t u(c_t - G(n_t)) \right] \]

subject to:

\[ q_t k_{t+1} + c_t + \frac{b_{t+1}}{R_t} = q_t k_t + b_t + [z_t F(k_t, v_t, n_t) - p_v v_t] \]

\[-\frac{b_{t+1}}{R} + \theta p_v v_t \leq \kappa_t q_t k_t \]
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\[ - \frac{b_{t+1}}{R} + \theta p_v v_t \leq \kappa_t q_t k_t \]

with functional forms:
\[ u(c - G(h)) = \left( \frac{c - \chi h^{1+\omega}}{1+\omega} \right)^{1-\sigma} - 1 \quad \omega > 0, \sigma > 1 \]
\[ F(k, h, v) = e^z k^{\alpha_k} v^{\alpha_v} h^{\alpha_h}, \quad \alpha_k, \alpha_v, \alpha_h \geq 0 \quad \alpha_k + \alpha_v + \alpha_v \leq 1 \]
## Calibration to OECD & U.S. Data

<table>
<thead>
<tr>
<th>Parameters set independently</th>
<th>Value</th>
<th>Source/Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk aversion</td>
<td>$\sigma = 1.$</td>
<td>Standard value</td>
</tr>
<tr>
<td>Share of inputs in gross output</td>
<td>$\alpha_v = 0.45$</td>
<td>Cross country average OECD</td>
</tr>
<tr>
<td>Share of labor in gross output</td>
<td>$\alpha_h = 0.352$</td>
<td>OECD GDP Labor share = 0.64</td>
</tr>
<tr>
<td>Labor disutility coefficient</td>
<td>$\chi = 0.352$</td>
<td>Normalization (mean $h = 1$)</td>
</tr>
<tr>
<td>Frisch elasticity</td>
<td>$1/\omega = 2$</td>
<td>Keane and Rogerson (2012)</td>
</tr>
<tr>
<td>Working capital coefficient</td>
<td>$\theta = 0.16$</td>
<td>U.S. WK/GDP ratio=0.133</td>
</tr>
<tr>
<td>Tight credit regime</td>
<td>$\kappa^L = 0.75$</td>
<td>U.S. post-crisis LTV ratios</td>
</tr>
<tr>
<td>Normal credit regime</td>
<td>$\kappa^H = 0.90$</td>
<td>U.S. pre-crisis LTV ratios</td>
</tr>
<tr>
<td>Interest rate</td>
<td>$\bar{R} = 1.1%, \rho_R = 0.68$</td>
<td>U.S. 90-day T-Bills</td>
</tr>
<tr>
<td></td>
<td>$\sigma_R = 1.86%$</td>
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<table>
<thead>
<tr>
<th>Parameters set by simulation</th>
<th>Value</th>
<th>Target</th>
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</thead>
<tbody>
<tr>
<td>TFP shock</td>
<td>$\rho_z = 0.78, \sigma_z = 0.01$</td>
<td>GDP sd. &amp; autoc. (OECD average)</td>
</tr>
<tr>
<td>Share of assets in gross output</td>
<td>$\alpha_k = 0.008$</td>
<td>Value of collateral matches total credit</td>
</tr>
<tr>
<td>Discount factor</td>
<td>$\beta = 0.95$</td>
<td>Private NFA = −25 percent</td>
</tr>
<tr>
<td>Transition prob. $\kappa^H$ to $\kappa^L$</td>
<td>$P_{H,L} = 0.1$</td>
<td>4 crises every 100 years (Appendix E2)</td>
</tr>
<tr>
<td>Transition prob. $\kappa^L$ to $\kappa^L$</td>
<td>$P_{L,L} = 0.$</td>
<td>1 year duration of crises (Appendix E2)</td>
</tr>
</tbody>
</table>
Comparing DE and SP Decision Rules

Current Bond Holdings ($B$)

Next-Period Bond Holdings ($\tilde{B}$)

-0.25 -0.2 -0.15 -0.1

Positive Crisis Probability Region

Constrained Credit Region

Stable Credit Region

$B^{SP}(B, s)$

$B^{DE}(B, s)$

$\tilde{B}^{SP}(B, s)$

$\tilde{B}^{DE}(B, s)$
Financial Amplification in DE

Stationary bond choice at $t$ with “good” shock
Financial Amplification in DE Cont.

Response to a bad shock at $t + 1$
SP’s bond choice at $t$ for same initial condition
Financial Amplification for the Planner Cont.

SP’s response to SAME bad shock at $t + 1$
Effectiveness of MPP: Summary Statistics

<table>
<thead>
<tr>
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<th>DE</th>
<th>SP</th>
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<tbody>
<tr>
<td><strong>Crisis Statistics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probability of crisis</td>
<td>4.0</td>
<td>0.02</td>
</tr>
<tr>
<td>Asset Price Drop</td>
<td>-43.7</td>
<td>-5.4</td>
</tr>
<tr>
<td>Equity Premium</td>
<td>4.8</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Mean tax and welfare gains</strong></td>
<td></td>
<td></td>
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<tr>
<td>Macroprudential Debt Tax</td>
<td>3.6</td>
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<tr>
<td>Welfare Gains</td>
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<td>0.30</td>
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</tbody>
</table>
Financial Crises with and without Policy

(a) Credit
(b) Asset Price
(c) Output
(d) Consumption

Decentralized Equilibrium
Social Planner
Optimal MP Taxes around Financial Crises
Distributions of Asset Returns

-45 -35 -25 -15 -5 5 15

0

0.2

0.4

0.6

0.8

1

Asset Returns (in percentage)

Probability

Social Planner

Decentralized Equilibrium

Social Planner

Decentralized Equilibrium
Asset Pricing in Good Times

(d) Volatility Asset Return

(e) Risk Premium

(a) Expected Return on Assets

Asset Price (b)

Decentralized Equilibrium Social Planner
Simple Macroprudential Policy Rules

1. Fixed debt tax across time and states

2. Financial Taylor Rule: \( \tau = \max[0, \tau_0(b_{t+1}/\bar{b})^{\eta_b} - 1] \)

Both are set to maximize average welfare gain \( \int \gamma(b, s) d\pi_0(b, s) \), where \( \pi_0(b, s) \) is DE’s cum. ergodic distribution and \( \gamma(b, s) \) is the welfare gain at state \((b, s)\) defined as:

\[
\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t^{DE} (1 + \gamma) - G(h_t^{DE})) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t^{SP} - G(h_t^{SP}))
\]
## Comparing Optimal TC-MPP with Simple Rules

<table>
<thead>
<tr>
<th></th>
<th>Decentralized Equilibrium</th>
<th>Optimal Policy</th>
<th>Best Taylor</th>
<th>Best Fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welfare Gains (%)</td>
<td>–</td>
<td>0.30</td>
<td>0.09</td>
<td>0.03</td>
</tr>
<tr>
<td>Crisis Probability (%)</td>
<td>4.0</td>
<td>0.02</td>
<td>2.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Drop in Asset Prices (%)</td>
<td>−43.7</td>
<td>−5.4</td>
<td>−36.3</td>
<td>−41.3</td>
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<tr>
<td>Equity Premium (%)</td>
<td>4.8</td>
<td>0.77</td>
<td>3.9</td>
<td>4.3</td>
</tr>
</tbody>
</table>

**Tax Statistics**

<table>
<thead>
<tr>
<th></th>
<th>Decentralized Equilibrium</th>
<th>Optimal Policy</th>
<th>Best Taylor</th>
<th>Best Fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>–</td>
<td>3.6</td>
<td>1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Std relative to GDP</td>
<td>–</td>
<td>0.5</td>
<td>0.2</td>
<td>–</td>
</tr>
<tr>
<td>Correlation with Leverage</td>
<td>–</td>
<td>0.7</td>
<td>0.3</td>
<td>–</td>
</tr>
</tbody>
</table>
Fixed Taxes, Crisis Probability & Welfare

(a) Crisis Probability

(b) Welfare Gains

max
average
min
Fixed Taxes, Crisis Probability & Welfare

(a) Crisis Probability

(b) Welfare Gains

Percentage

Percentage Points

Tax (%)
Effects of Simple Policies on Crises

(a) Credit/GDP

(b) Asset Price

Decentralized Equilibrium  Optimal Tax  Simple Rule  Fixed Tax
Conclusions

1. Optimal MPP under commitment is not credible

2. Optimal, time-consistent MPP is very effective at reducing frequency & severity of crises, and increasing welfare

3. Simple rules reduce frequency of crises but are otherwise much less effective and can reduce welfare

4. MPP faces other serious hurdles: adapting to financial innovation and imperfect information (Bianchi, Boz & Mendoza, 2012), coordination with monetary policy, debtor heterogeneity, etc.

5. Ongoing agenda: MPP with heterogeneous agents and nominal rigidities, value of commitment in MPP
Commitment: Recursive Problem

Time $t > 0$ problem

$$V(b, J, z) = \max_{b', J'(z'), c} u(c) + \beta \mathbb{E} V(b', J'(z'), z')$$

$$\frac{b'}{R} + c = b + z$$

$$b' \leq \kappa q$$

$$q = \frac{\beta \mathbb{E}_z J'(z')}{u'(c)}$$

$$J = u'(c)z + \beta \mathbb{E}_z J'(z')$$
Commitment: Recursive Problem

Time $t = 0$ problem:

$$V_0(b, J, z) = \max_{b', J'(z'), c} u(c) + \beta \mathbb{E}V(b', J'(z'), z')$$

$$\frac{b'}{R} + c = b + z$$

$$b' \leq \kappa q$$

$$q = \frac{\beta \mathbb{E}_z J'(z')}{u'(c)}$$
Recursive Competitive Equilibrium

A RCE is defined by a pricing function \( q(B, z) \), a law of motion \( \mathcal{B} \), and policy functions with associated value function such that:

1. \( \{ V, \hat{b}', \hat{k}', \hat{c} \} \) solve:

\[
V(b, k, B, z) = \max_{b', k', c} u(c) + \beta \mathbb{E}_{z'}|z' V(b', k', B', z')
\]

s.t. \( q(B, z)k' + c + \frac{b'}{R} = k(q(B, z) + z) + b \)

\[
- \frac{b'}{R} \leq \kappa q(B, z)
\]

with \( B' = \mathcal{B}(B, z) \)

2. Rational Expectations: \( \mathcal{B}(B, z) = \hat{b}(B, 1, B, z) \).

3. Asset market clears \( \hat{k}'(B, 1, B, z) = 1 \)
Microfoundation for Collateral Constraint

- Households enter period with outstanding debt, repay and then issue new debt
- Opportunity to default on new issuances at the end of the period
- Upon default:

  HH loses \( (1 - \kappa) \) of value of assets, but can immediately raise new debt

  HH makes take it or leave it offer to creditors accepted if

  \(- \frac{b'}{R} \leq \kappa qk\)
Value of Default

\[ V^d(\tilde{d}, b, k, X) = \max_{b', k', c} u(c) + \beta \mathbb{E}_{s'|s} V(b', k', B', z') \]

s.t. \[ q(B, z)k' + c + \frac{b'}{R} = \tilde{d} + q(B, z)k(1 - \kappa) + b + zk \]

\[ -\frac{b'}{R} \leq \kappa q(B, z)k \]

Household defaults if \(-\frac{b'}{R} \leq \kappa qk\)
## Asset Pricing Statistics

<table>
<thead>
<tr>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Return</td>
<td>Risk-free Plus Tax Premium</td>
<td>Equity Premium</td>
<td>Liquidity Premium</td>
<td>Collateral Effect</td>
<td>Risk Premium of Risk $\sigma_t(R^q_{t+1})$</td>
<td>Price $SR_t$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Decentralized Equilibrium

<table>
<thead>
<tr>
<th>Condition</th>
<th>Expected Return</th>
<th>Risk-free Plus Tax Premium</th>
<th>Equity Premium</th>
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<th>Collateral Effect</th>
<th>Risk Premium of Risk</th>
<th>Price $SR_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconditional</td>
<td>6.0</td>
<td>1.2</td>
<td>4.8</td>
<td>4.7</td>
<td>1.4</td>
<td>1.5</td>
<td>14.6</td>
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<tr>
<td>Constrained</td>
<td>85.6</td>
<td>1.2</td>
<td>84.4</td>
<td>84.1</td>
<td>0.0</td>
<td>0.2</td>
<td>4.1</td>
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<tr>
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<td>1.2</td>
<td>0.1</td>
<td>0.0</td>
<td>1.5</td>
<td>1.6</td>
<td>15.3</td>
</tr>
</tbody>
</table>

### Social Planner

<table>
<thead>
<tr>
<th>Condition</th>
<th>Expected Return</th>
<th>Risk-free Plus Tax Premium</th>
<th>Equity Premium</th>
<th>Liquidity Premium</th>
<th>Collateral Effect</th>
<th>Risk Premium of Risk</th>
<th>Price $SR_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconditional</td>
<td>4.1</td>
<td>3.3</td>
<td>0.8</td>
<td>1.8</td>
<td>1.2</td>
<td>0.2</td>
<td>5.2</td>
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<tr>
<td>Constrained</td>
<td>6.9</td>
<td>-21.8</td>
<td>28.7</td>
<td>28.5</td>
<td>0.0</td>
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<td>5.1</td>
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<tr>
<td>Unconstrained</td>
<td>3.9</td>
<td>5.0</td>
<td>-1.2</td>
<td>0.0</td>
<td>1.3</td>
<td>0.2</td>
<td>5.2</td>
</tr>
</tbody>
</table>
Calibration Strategy

  - Preferences and production parameters set independently to match standard targets
  - TFP and interest rates estimated as a VAR(1)
  - Financial shocks are assumed to be independent and follow a two-state Markov chain \( \{ \kappa^L, \kappa^H \} \) with transition matrix \( P \)
  - \( P \) calibrated to match frequency and duration of financial crises (crisis defined as a fall in credit of more than 2SD)

back calibration