Uncertainty, Sudden Stops and Macroprudential Policies

by

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Abstract

This paper studies how the government should alter macroprudential policy in response to a spike in uncertainty. I incorporate time-varying conditional variance and Epstein and Zin (1989) recursive utility in an otherwise standard model of debt deflation proposed by Bianchi (2011). Preliminary results show that the nature of uncertainty critically matters: While the government should strengthen macroprudential policies when households' incomes are temporarily more uncertain, strengthening macroprudential policies is not optimal if the whole balanced growth path of the economy is more uncertain. Quantitative results confirm that optimal macroprudential policy can effectively reduce the frequency and severity of crises.

Keywords: Financial Crisis, Macroprudential Policy, Sudden Stop

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Contents

1 Introduction

1.1 Research Question

Abrupt spikes in economic uncertainty present considerable economic and policy problems for emerging market economies. Amid the recent COVID crisis, monetary authorities in developing nations proactively employed foreign exchange reserves to maintain stability in their exchange rates when confronted with unexpected volatility surges; however, no notable increase in capital controls occurred (Bhargava et al., 2023). However, there are few papers study how theoretically government should motify modify their macroprudential approach in response to a spike in uncertainty. This paper aim to fill this research gap and potentially provide guidance on real policy design.

This paper incorporates time-varying conditional volatility and Epstein and Zin (1989) recursive utility into an otherwise standard model of debt deflation proposed by Bianchi (2011). In the model, pecuniary collateral externality causes over-accumulation of foreign debt, which rationalizes the macroprudential usage of capital controls modeled as a tax on external borrowing.

1.2 Preliminary Results

The preliminary results of this paper indicate that the optimal macroprudential tax is not necessarily higher when uncertainty is high, and the outcome critically depends on the nature of uncertainty: If a shock only increases the uncertainty of income under business cycle frequency (which I label as business-cycle uncertainty), then the government should increase the intensity of macroprudential policies. This result holds generally under reasonable combinations of intertemporal elasticity of substitution (IES, ψ) and relative risk aversion (RRA, γ).

However, if a shock makes the whole balanced growth path more uncertain (which I label as growth-trend uncertainty), then it is not optimal for the government to impose more intense macroprudential policies. In particular, under Epstein-Zin preferences with high RRA γ, the government should optimally impose more intense macroprudential policy when growth-trend uncertainty is low and business-cycle uncertainty is high. This indicates that different natures of uncertainty imply qualitatively different policy implications.

2 Literature Review

This paper is related to three series of literature. First, this paper contributes to research on financial crises with debt-deflation and their normative implications on macroprudential policy (Mendoza, 2002,0; Bianchi, 2011; Jeanne and Korinek, 2019). The model of this paper is an extension of Bianchi (2011), who demonstrate that financial constraints cause over-accumulation of foreign debt and macroprudential tax on borrowing can reduce the probability and severity of financial crises. This paper is also closely related to the normative analysis of Reyes-Heroles and Tenorio (2020), who show that a country should not, in general, increase capital controls when world interest rate volatility increases. My paper studies how policy should be designed when there is an increase in domestic uncertainty.

Second, this research is also related to the international finance literature with recursive preferences pioneered by Colacito and Croce (2011,0), and Colacito et al. (2018). In a recent work, Colacito et al. (2022) document that an increase in a country's output uncertainty is associated with drops in consumption and net exports, and they study the international volatility risk-sharing under a model with complete financial markets. While their work focuses on developed economies integrated into the world financial market, this paper targets small developing economies with limited external borrowing capacity.

Broadly speaking, this paper is related to a large booming literature on the macroeconomic implications of uncertainty shocks, modeled as time-varying second moments of economic variables (Bloom, 2009; Basu and Bundick, 2017; Fajgelbaum et al., 2017; Berger et al., 2020). This paper is closely related to Basu and Bundick (2017) who demonstrate that uncertainty shocks cause a demand collapse in a closed-economy New Keynesian model with aggregate demand externality. In their model, while uncertainty increases individuals' willingness to save, the rise in markups from nominal rigidities makes saving in general equilibrium fall instead, and they show that monetary policies are effective in addressing economic problems arising from uncertainty shocks. Different from their framework, this research studies the effect of uncertainty shocks under an open economy with pecuniary externality, which requires the government to use macroprudential policies rather than monetary policies to enhance social welfare.

3 Theoretical Framework

3.1 Environment

Consider a small-open economy populated with a continuum of representative households indexed by $i \in [0,1]$. Households' preferences of consumption over time are characterized by Epstein and Zin (1989) recursive utility with IES ψ and RRA γ. Household's value function V_{it}:

$$V_{it} = \left\{ (1-\beta)(c_t)^{1-\frac{1}{\psi}} + \beta \left[E_t \left(V_{i,t+1}^{1-\gamma} \right) \right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}} \tag{1}$$

Households' consumption baskets are Armington aggregation of tradeable goods c_{it}^T and non-tradable goods c_{it}^N with elasticity of substitution $1/(1+\eta)$ and weight ω:

$$c_{it} = \left[\omega \left(c_{it}^T \right)^{-\eta} + (1-\omega) \left(c_{it}^N \right)^{-\eta} \right]^{-\frac{1}{\eta}} \tag{2}$$

In each period, representative households receive identical tradable and nontradable endowments $\{Y_t^T, Y_t^N\}$ fluctuating over time. The financial market is incomplete, and households can only trade one-period risk-free bonds with face value $b_{i,t+1}$ at world interest rate $1+r_t$. $\frac{b_{i,t+1}}{1+r_t}$ is therefore the current period saving, and $\frac{b_{i,t+1}}{1+r_t} < 0$ means households are net borrowers. I first consider the case where the interest rate is constant at $r_t = r$, and then extend the result to a stochastic rate. The household's budget constraint is:

$$b_{it} + Y_t^T + p_t^N Y_t^N \geq \frac{b_{i,t+1}}{1+r_t} + c_{it}^T + p_t^N c_{it}^N \tag{3}$$

Following and Mendoza (2002) and Bianchi (2011), I consider a debt-to-income borrowing constraint that each household's borrowing cannot exceed κ fraction of its income which is an increasing function of current nontradable good price p_T^N.

$$\frac{b_{i,t+1}}{1+r} \geq -\kappa \left(Y_{it}^T + p_t^N Y_{it}^N \right) \tag{4}$$

In the decentralized equilibirum, households maximize eq.(1) with consumption aggregator eq.(2) by choosing $\{c_{it}^T, c_{it}^N, b_{i,t+1}\}$ under budget constraint e.q.(3) and borrowing constraint e.q.(4).

3.2 Driving Forces

In the model, households trade a risk-free bond while facing stochastic tradable and non-tradable incomes $\{Y_t^T, Y_t^N\}$. I assume that both of them contain a growth-trend component Γ_t, whose growth rate G_t is stationary. In addition, the tradable income also include a transitory component [1]:

$$Y_t^N = \Gamma_t \tag{5}$$

$$Y_t^T = Z_t \Gamma_t \tag{6}$$

$$\frac{\Gamma_t}{\Gamma_{t-1}} = G_t \tag{7}$$

$$\log Z_t = \rho_Z \log Z_{t-1} + \epsilon_{Z,t} \quad \epsilon_{Z,t} \sim N\left(0, \sigma^2_{Z,t}\right) \tag{8}$$

$$\log G_t = (1-\rho_G)\mu_G + \rho_G \log G_{t-1} + \epsilon_{G,t} \quad \epsilon_{G,t} \sim N\left(0, \sigma^2_{G,t}\right) \tag{9}$$

I model uncertainty as the time-varying second moments of two processes and label them as business cycle uncertainty ($\sigma^2_{Z,t}$) and growth-trend uncertainty ($\sigma^2_{G,t}$). Either of them can follow an AR(1) process:

$$\log \sigma^2_{Z,t} = \left(1-\rho_{\sigma_Z}\right)\mu_{\sigma_Z} + \rho_{\sigma_Z} \log \sigma^2_{Z,t-1} + \epsilon_{\sigma_Z,t}, \quad \epsilon_{\sigma_Z,t} \sim N\left(0, \sigma^2_{\sigma_Z}\right) \tag{10}$$

$$\log \sigma^2_{G,t} = \left(1-\rho_{\sigma_G}\right)\mu_{\sigma_G} + \rho_{\sigma_G} \log \sigma^2_{G,t-1} + \epsilon_{\sigma_G,t}, \quad \epsilon_{\sigma_G,t} \sim N\left(0, \sigma^2_{\sigma_G}\right) \tag{11}$$

I include both business-cycle and growth-trend components because this specification distinguishes two different uncertainties, which have entirely different implications for macroprudential policies. On one hand, business-cycle uncertainty shock $\epsilon_{\sigma_Z,t}$ only makes the economy temporarily uncertain without affecting the balanced-growth path. This echoes the aggregate productivity uncertainty studied by Leduc and Liu (2016) and Bloom et al. (2018). On the other hand, a positive realization of $\epsilon^2_{\sigma_G}$ affects the distribution of the balanced-growth path, making the permanent income uncertain. This echoes the volatility shock of Bansal and Yaron (2004), Nakamura et al. (2017), and Colacito et al. (2022).

Second, including growth-trend shocks also helps to match important features of emerging markets, including excess volatility of consumption (Aguiar and Gopinath, 2007) and slow recovery from financial crises (Seoane and Yurdagul, 2019).

3.3 Decentralized Equilibrium

I conduct following detrend on variables to get bounded ergodic distributions:

$$\hat{X}_{it} = \frac{X_{it}}{\Gamma_{t-1}} \quad X_{it} \in \left\{V_{it}, c_{it}, c^T_{it}, c^N_{it}, b_{it}, B_{it}, Y^T_t, Y^N_t\right\} \tag{12}$$

[1] I can alternatively include both components in tradable and nontradable incomes. This implicitly assume that tradable and nontradable incomes are propositional to each other.

The households' problem, after detrending, can be written in the following recursive form. I use $\hat{b}$ and $\hat{B}$ to denote household and aggregate detrended bond holdings, and $\mathbf{S} = \{Z, \Gamma, \sigma_Z, \sigma_G\}$ is a vector of exogenous states. Variables with a prime are values of the next period.

$$\hat{V}_{de}\left(\hat{b}, \hat{B}, \mathbf{S}\right) = \max_{\hat{c}^T, \hat{c}^N, \hat{b}'} \left\{ (1-\beta)\left(\hat{c}\right)^{1-\frac{1}{\psi}} + \beta \left[E_{\mathbf{S}'|\mathbf{S}} \left(\hat{V}_{de}\left(\hat{b}', \hat{B}', \mathbf{S}'\right)^{1-\gamma} \right) \right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}} G^{1-\frac{1}{\psi}} \right\}^{\frac{1}{1-\frac{1}{\psi}}} \tag{13}$$

$$\text{where} \quad \hat{c} = \left[\omega \left(\hat{c}^T\right)^{-\eta} + (1-\omega)\left(\hat{c}^N\right)^{-\eta} \right]^{-\frac{1}{\eta}} \tag{14}$$

subject to

$$\hat{b} + \hat{Y}^T + p^N \hat{Y}^N \geq \frac{\hat{b}' G}{1+r} + \hat{c}^T + p^N \hat{c}^N \tag{15}$$

$$\frac{\hat{b}' G}{1+r} \geq -\kappa \left(\hat{Y}^T + p^N \hat{Y}^N \right) \tag{16}$$

$$\hat{B}' = \mathcal{B}(\hat{B}, \mathbf{S}) \tag{17}$$

Definition 1 (decentralized competitive equilibrium): The decentralized competitive equilibrium consists of: (1) decision rules $\hat{c}^T = \hat{c}^T(\hat{b}, \hat{B}, \mathbf{S}), \hat{c}^N = \hat{c}^N(\hat{b}, \hat{B}, \mathbf{S}), \hat{b}' = \hat{b}'(\hat{b}, \hat{B}, \mathbf{S})$, (2) value function $\hat{V}_{de}(\hat{b}, \hat{B}, \mathbf{S})$, (3) pricing function for non-tradable goods $p^N = p^N(\hat{B}, \mathbf{S})$, (4) perceived aggregate debt law of motion $\hat{B}' = \mathcal{B}(\hat{B}, \mathbf{S})$ such that (a) policy rules and value function solve the above laissez-faire optimization problem (b) pricing function for non-tradable goods clears nontradable market $\hat{c}^N = \hat{y}^N$ (b) perceived aggregate debt law of motion consist with debt decision rule $\mathcal{B}(\hat{B}, \mathbf{S}) = \hat{b}'(\hat{B}, \hat{B}, \mathbf{S})$

Solving the laissez-faire household problem yields equilibrium conditions in which $\hat{\lambda}_{de}$ and $\hat{\mu}_{de}$ are Lagrange multipliers associate with budget eq.(15) and borrowing constraint eq.(16):

$$\hat{V}_{de}^{\frac{1}{\psi}} (1-\beta) \left[\left(\hat{c}\right)^{-\frac{1}{\psi}} \omega \left(\frac{\hat{c}^T}{\hat{c}} \right)^{-\eta-1} \right] = \hat{\lambda}_{de} \tag{18}$$

$$p^N = \frac{1-\omega}{\omega} \left(\frac{\hat{c}^T}{\hat{c}^N} \right)^{\eta+1} \tag{19}$$

$$\beta (1+r) \hat{V}_{de}^{\frac{1}{\psi}} \left\{ E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}_{de}' \right)^{1-\gamma} \right] \right\}^{\frac{\gamma-\frac{1}{\psi}}{1-\gamma}} E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}_{de}' \right)^{-\gamma} \hat{\lambda}_{de}' \right] + \hat{\mu}_{de} = \hat{\lambda}_{de} \tag{20}$$

$$\hat{\mu}_{de} \geq 0 \tag{21}$$

3.4 Pecuniary Externality and Optimal Policy

Bianchi (2011) shows that the laissez-faire competitive equilibrium is inefficient due to collateral constraints. Since each household is infinitesimal compared to the whole economy and the price of non-tradable goods is pinned down by aggregate debt, each individual does not internalize their effect on the price of nontradable goods and therefore the borrowing limit. This pecuniary externality causes debt holdings to deviate from the socially optimal level in good times.

Collateral constraints can also lead to a vicious circle during a crisis. When a large negative shock hits the economy, the drop in the nontradable price makes the borrowing constraint bind. This forces the households to deleverage by cutting tradable consumption, further amplifying the decrease in the nontradable price. This 'Fisherian debt deflation' mechanism leads to a 'sudden stop' of financial flow and a huge drop in consumption and net foreign assets. Calibrated to Argentina, Bianchi (2011) demonstrates that the pecuniary collateral externality leads to overborrowing in good times, making the economy vulnerable to a crisis.

Following Bianchi (2011), I study the optimal policy by assuming that a constrained social planner can choose the debt levels but let the goods market clear. The key difference is that the social planner internalizes the effect of borrowing on the non-tradable price. The social planner problem is stated as below [2]:

$$V_{sp}\left(\hat{B},\mathbf{S}\right)=\max_{\hat{c}^T,\hat{B}'}\left\{(1-\beta)\left(\hat{c}\right)^{1-\frac{1}{\psi}}+\beta\left[E_{\mathbf{S}'|\mathbf{S}}\left(V_{sp}\left(\hat{B}',\mathbf{S}'\right)^{1-\gamma}\right)\right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}}G^{1-\frac{1}{\psi}}\right\}^{\frac{1}{1-\frac{1}{\psi}}} \tag{22}$$

$$\text{where}\quad \hat{c}=\left[\omega\left(\hat{c}^T\right)^{-\eta}+(1-\omega)\left(\hat{Y}^N\right)^{-\eta}\right]^{-\frac{1}{\eta}} \tag{23}$$

subject to

$$\hat{B}+\hat{Y}^T\geq\frac{\hat{B}'G}{1+r}+\hat{c}^T \tag{24}$$

$$\frac{\hat{B}'G}{1+r}\geq-\kappa\left(\hat{Y}^T+\frac{1-\omega}{\omega}\left(\frac{\hat{c}^T}{\hat{Y}^N}\right)^{\eta+1}\hat{Y}^N\right) \tag{25}$$

The first order conditions with respect of c^t becomes:

$$\underbrace{\hat{V}_{sp}^{\frac{1}{\psi}}(1-\beta)\left[(\hat{c})^{-\frac{1}{\psi}}\,\omega\left(\frac{\hat{c}^T}{\hat{c}}\right)^{-\eta-1}\right]}_{\text{Decentralized Marginal Utility (MU)}}+\underbrace{\hat{\mu}_{sp}\overbrace{\left[\kappa\frac{1-\omega}{\omega}(\eta+1)\left(\frac{\hat{c}^T}{\hat{Y}^N}\right)^{\eta}\right]}^{\text{def.}\equiv\hat{\Psi}}}_{\text{Pecuniary Externality}}=\underbrace{\hat{\lambda}_{sp}}_{\text{Total MU}} \tag{26}$$

[2] As established by Schmitt-Grohé and Uribe (2017), this problem is equivalent to a Ramsey problem in which the government chooses a macroprudential policy τ to optimize social welfare.

Comparing eq.(18) with eq.(26), the social planner's marginal utility of income $\hat{\lambda}^{sp}$ is strictly higher than that of decentralized households in a crisis when the collateral constraint binds $\hat{\mu}^{sp} > 0$. The gap reflects the pecuniary externality, proportional to two ingredients: $\hat{\mu}_{sp}$, the shadow price of the borrowing constraint which reflects the **severity of the crisis**, and $\hat{\Psi} = \kappa {p'}^N(c^T)\hat{Y}^N = \left[\kappa \frac{1-\omega}{\omega}(\eta+1)\left(\frac{\hat{c}^T}{\hat{Y}^N}\right)^{\eta}\right]$, reflecting the **borrowing limit's sensitivity to additional income**. Since the social planner prefers higher consumption in a crisis, the planner will choose a lower level of external debt if the borrowing constraint has a positive probability of binding in the next period. This can be achieved by taxing borrowing [3]. I define the optimal macroprudential policy in the following way:

Definition 2 (optimal macro-prudential policy): Macroprudential policy is a proportional tax $\frac{\tau}{1+\tau}$ decentralized household need to pay on each unit of borrowing that push effective rate up to $(1+r)(1+\tau)$. Social planner then conduct lump-sum transfer to balance the government budget in each period. A macroprudential policy is said to be optimal if it implement the $\{\hat{c}^T, \hat{c}^N, \hat{B}'\}$ given by the social planner problem.

The following proposition characterize the optimal macroprudential policy:

Proposition 1 (optimal macroprudential policy): Suppose that in equilibrium $\hat{\Psi} < 1$ for all state $\{B, \mathbf{S}\}$[4] . When the borrowing constraint binds ($\mu^{sp} > 0$), the optimal macroprudential policy is indeterminate no larger than a positive upper-bound $\bar{\tau}$. When the borrowing constraint is slack $\mu^{sp} = 0$, the optimal macroprudential policy is given by

$$\tau = \frac{E_{\mathbf{S}'|\mathbf{S}}\left[\left(\hat{V}'_{sp}\right)^{-\gamma}\left(\hat{\mu}'_{sp}\hat{\Psi}'\right)\right]}{E_{\mathbf{S}'|\mathbf{S}}\left[\left(\hat{V}'_{sp}\right)^{-\gamma}\lambda'_{de}\right]} \tag{27}$$

in which $\hat{\mu}'_{sp}\hat{\Psi}'$ is next period's pecuniary externality and λ'_{de} is decentralized household's marginal utility of tradable consumption.

Proof. See Appendix B.

[3] Notice that a borrowing tax is not the only way to implement the social planner allocation. Since literature has established that the borrowing tax is equivalent to many practical policy instruments such as a reserve requirement (Bianchi, 2011) and foreign exchange intervention (Arce et al., 2019), I argue that the tax ratio is a measure of the intensity of these practical macroprudential policies

[4] This condition guarantees the uniqueness of equilibrium. If $\hat{\Psi} \geq 1$ in some $\{B, \mathbf{S}\}$, we can see from eq.(25) that additional one unit of borrowing for tradable consumption release the borrowing limit more than one unit. Schmitt-Grohé and Uribe (2021) shows that this may make the economy prone to self-fulfilling financial crises. This condition holds true under the benchmark calibration of this paper.

4 Quantitative Analysis

4.1 Calibration and Model Solution

The primary goal of the quantitative analysis is to study how uncertainty shocks affect the policy design under otherwise standard parameters from the literature. Therefore, I set $\{r, \beta, \kappa, \omega, \eta\}$ to the standard values from Bianchi et al. (2016), which calibrate to Argentina in annual frequency. Then, I use IES $\psi = 0.5$ and RRA $\gamma = 2$ for the benchmark. Notice that in this case, the utility function reduces to the standard constant relative risk aversion (CRRA) studied by Bianchi (2011). I then gradually increase RRA to $\gamma = 8$, following the literature on uncertainty shocks (Basu and Bundick, 2017; Colacito et al., 2022).

For the stochastic process, I adopt the persistence $\rho_z = 0.7501$ for transitory shock, $\rho_g = 0.5499$ for growth-trend shock, and I calibrate the unconditional standard deviation $E(\sigma_{Z,t}) = 0.0532$ for transitory shock and $E(\sigma_{G,t}) = 0.0353$ for growth-trend shock. These values come from the Bayesian estimation of Seoane and Yurdagul (2019) using Argentina data from 1876 to 2004.

For the evolution of uncertainty, I adopt the persistence $\rho_\sigma = 0.9^4$ and $\sigma_\sigma = 0.15 * 2$ on both transitory and trend[5]. These numbers are comparable to the estimation from Colacito et al. (2022), who estimate using OECD economies.

Table 1 summarizes the calibration of the model:

[Table 1 here]

I solve the model globally using the FiPIt algorithm proposed by Mendoza and Villalvazo (2020). To reduce the dimensions of the state space, I approximate the evolution of the stochastic process using a Markov chain with $5 \times 3 \times 5 \times 3$ states to approximate the evolution of $\{Z_t, \sigma_{Zt}, G_t, \sigma_{Gt}\}$ by matching exact conditional moments following Farmer and Toda (2017).

4.2 Optimal Policy Under Stochastic Uncertainty

Figure 1 plots the optimal macroprudential tax that implements the social planner's allocation under different preferences and uncertainty states. The x-axis indicates the bond holding, and the y-axis is the tax ratio τ. When the borrowing constraint binds, I set the macroprudential

[5] I can alternatively consider two models with either stochastic second-moment on cycle or trend shock. I leave serious estimation of the evolution of uncertainty for my future work.

policy to 0, which is optimal for the social planner according to Proposition 1. Therefore, the jumps in the figures indicate the states $\{B, \mathbf{S}\}$ where eq. (25) binds with equality.

[Figure 1 here]

The four subfigures above plot the optimal macroprudential policy under different business-cycle uncertainties σ_{Zt} and preference parameter settings. Each subfigure represents a combination of RRA γ and IES ψ. The blue (red) line indicates the state with high (low) business-cycle uncertainty. It can be noticed that the blue line is above the red line for all utility function settings. This reflects the fact that social planners should strengthen macroprudential policies in times of increased economic uncertainty.

The four subplots below, on the other hand, reflect rather different results for growth-trend uncertainty σ_{Gt}. Under Bianchi (2011) calibration with RRA $\gamma = 2$ and IES $\psi = 0.5$, the blue and red lines are close together, so the social planner should not change macroprudential policy according to growth-trend uncertainty if other states are the same. This pattern holds true if I change IES up to $\psi = 1.5$, despite the overall downward movement of the red and blue lines, indicating a lower intensity of macroprudential policy on average. However, increasing RRA to $\gamma = 8$ moves the red line up. In this utility function setting, optimal macroprudential policy should instead be higher with low growth uncertainty. This reflects the fact that uncertainties of different natures have diametrically opposed implications on macroprudential policy design.

4.3 Mechanism Analysis (Preliminary)

In order to understand why uncertainties of different natures have different implications for optimal macroprudential policy, I draw the numerator and denominator parts of eq. (27) separately for business-cycle uncertainty (Figure 2) and growth-trend uncertainty (Figure 3). In eq. (27), the numerator is the expected value of next period's pecuniary externality, and the denominator is the expected marginal utility of additional consumption for the decentralized household.

[Figure 2 here]

[Figure 3 here]

From Figure 2, we can see that business-cycle uncertainty affects macroprudential policy through the numerator: The spike in business-cycle uncertainty increases the probability of a binding borrowing constraint and also the severity of the crisis. This is different from Figure 3, which shows that growth-trend uncertainty does not strongly affect the numerator. The reasons for this need further study. Additionally, under Epstein-Zin preferences with high RRA γ, the denominator changes significantly under different growth-trend uncertainties. This implies that a strong desire for precautionary savings reduces an individual's marginal utility of consumption.

4.4 Long-run and Crisis Moments

Table 2 reports the moments of the model under different preferences. Each column of the table presents a combination of IES ψ and RRA γ, as reported in the first section of the table.

[Table 2 here]

The second section of Table 2 reports the long-run moments of the model. First, it can be seen that the economy accumulates more than 20% of external debt over current income on average. Although the social planner's debt-to-income ratio is lower than that of the decentralized household, the gap is small because sudden stop models following Mendoza (2002) and Bianchi (2011) feature strong impatience: With a time preference smaller than the inverse of the growth interest rate $\beta < \frac{1}{1+r}$, it is optimal to borrow and consume. This helps to match the high level of external borrowing before the emerging market crisis. However, although the social planner only slightly decreases the debt-to-income ratio, the macroprudential policy changes the distribution of external borrowing by shrinking the left tail of the ergodic borrowing distribution. Figure 4 plots the ergodic distribution of the social planner and decentralized households under different preference parameters.

[Figure 4 here]

Second, increasing the RRA or decreasing the IES reduces an economy's external borrowing as a percentage of current income. The reduction reflects the precautionary saving effect. High RRA and low IES push the ergodic distribution of bond holding to the right, farther away from the binding region. In Table 2, we can see that this leads to a lower probability of sudden stops and a lower level of macroprudential tax.

The third part of Table 2 reports the sudden-stop-crisis moments. In this paper, I define a sudden stop as a period with a binding borrowing constraint and at least a two standard deviation current account reversal. Following Bianchi et al. (2016), I further define a financial amplification parameter, Omega (Ω), as the changes in variables during the crisis compared to normal times.

We can see that the consumption drops and real exchange rate depreciation for the social planner are lower than those for the decentralized household, indicating that macroprudential policies can effectively decrease the severity of sudden-stop crises. We can also see that consumption drops in the high RRA or low IES models are smaller, reflecting the lower severity of sudden stops due to high precautionary saving.

4.5 Crisis Dynamics

Figure 5 plots the exogenous state around the sudden-stop crisis of the model with IES $\psi = 0.5$ and RRA $\gamma = 0.5$ (Models with other preference parameters share similar patterns). We can see from the graph that crises are mainly associated with large negative realizations of the endowment shock in both trend and cycle, and there are no systematic changes in uncertainty. Notice that this is not the case if I consider mechanisms where the uncertainty shock may be correlated with the constraint parameter κ or the world interest rate r. I discuss these potential mechanisms in the next chapter.

[Figure 5 here]

Figure 6 shows the adjustment of the endogenous variables. It is clear that optimal macroprudential policies can effectively reduce the price and real variable adjustments associated with financial crises.

[Figure 6 here]

5 Work Schedule

5.1 Research Plan

The study is still in its preliminary stages. My research plan is as follows. In the first stage, I need to understand more clearly the mechanisms by which uncertainty shocks of different natures work in my current theoretical framework. I plan to carry out the following two tasks: First, I plan to decompose the optimal macroprudential policy equation (27) into different components and see how it changes with different uncertainty states. Second, I plan to study a three-period model in the fashion of Erten et al. (2021) or an infinite-horizon model with uncertainty resolved in one period following Bianchi and Lorenzoni (2022) to illustrate the mechanism. This stage of research may last for no longer than one month. In the second stage, I plan to carefully bring the model to the data. I will familiarize myself with the relevant empirical techniques and estimate the optimal macroprudential policy implied by this model. I plan to finish this stage of research by the end of this year. In the final stage, I may consider different extensions of my current model. I discuss some directions for extension in the next subsection.

5.2 Potential Extensions

Nature of Uncertainty Shock: There are two potential extensions related to the specification of exogenous shocks. First, the uncertainty studied in this paper is country-specific and independent from the external borrowing rate r. If I alternatively consider global uncertainty, it means that high uncertainty may be correlated with low borrowing costs. Studying how the government should alter its macroprudential policy under global uncertainty is a nontrivial extension. Second, I specify the endowment level and uncertainty shocks as two uncorrelated random variables. Crises mostly arise from low realizations of the endowment level rather than shifts in uncertainty. Alternatively, high uncertainty may be correlated with low aggregate output, which may help to better fit the model with crisis dynamics.

Production Economy: In my current model, households' incomes come from the stochastic evolution of endowments that is exogenously governed by a stochastic process. While this assumption helps me limit the effects of uncertainty shocks to the household sector and purify the mechanism analysis, understanding how uncertainty shocks distort production and how this is related to emerging market crises is a meaningful further question. I can follow the theoretical frameworks of Benigno et al. (2013), Arce et al. (2023), and Drechsel and Kim (2024), who study macroprudential policies in a production economy without considering time-varying uncertainty.

Nature of Borrowing Constraint: Another important extension is to consider alternative natures of borrowing constraints. In this paper, I follow Bianchi (2011) and model borrowing backed by real income, where the current relative price of nontradable goods determines the time-varying borrowing capacity. Alternatively, I can consider a loan-to-capital constraint in a production economy, as in Mendoza (2010). In this environment, a volatility shock will not only change the total volume of investment but also the composition of investment in bonds and capital due to changes in the risk premium. This will make the analysis of macroprudential policies more complex. Additionally, I can consider value-at-risk (VaR) types of borrowing constraints. With VaR constraints, high uncertainty will directly lower the external borrowing capacity of the economy.

Different Types of Capital Flow: My current theoretical framework features strong financial market incompleteness, with households able to borrow only through one-period risk-free foreign currency bonds. In reality, developing countries may have different types of capital flows with different externalities. Korinek (2018) studies the externality of different types of international capital flows in a model framework where households have access to a complete set of state-contingent claims. Ma and Wei (2020) also considers how low financial development alters the portfolio of capital flows toward non-state-contingent financial claims. Both theoretical frameworks can potentially be extended to a stochastic uncertainty setting.

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A Tables and Figures

Table 1: Calibration

Model Parameters (Bianchi et al., 2016)	Variable	Value
Discount factor	β	0.91
Interest rate	r	0.04
Credit coefficient	κ	0.32
Share of non-tradables	ω	0.32
Elasticity of Substitution	$1/(1+\eta)$	0.83

Evolution of States: Level (Seoane and Yurdagul, 2019)	Variable	Value
Persistence of business cycle: Level	ρ_Z	0.7501
Persistence of Growth Trend: Level	ρ_G	0.5499
Uncond. Std. of business cycle shock	$E(\sigma_{Zt})$	0.0532
Uncond. Std. of gorwth trend shock	$E(\sigma_{Gt})$	0.0353

Evolution of States: Uncertainty (Colacito et al., 2022)	Variable	Value
Persistence of business cycle: Uncertainty	ρ_{σ_Z}	0.9^4
Persistence of Growth Trend: Uncertainty	ρ_{σ_G}	0.9^4
Std. of business cycle uncertainty shock	$\sigma_{\sigma Z}$	$0.15 * 2$
Std. of gorwth trend uncertainty shock	$\sigma_{\sigma G}$	$0.15 * 2$

Figure 1: Optimal Macroprudential Tax Across Volatility State

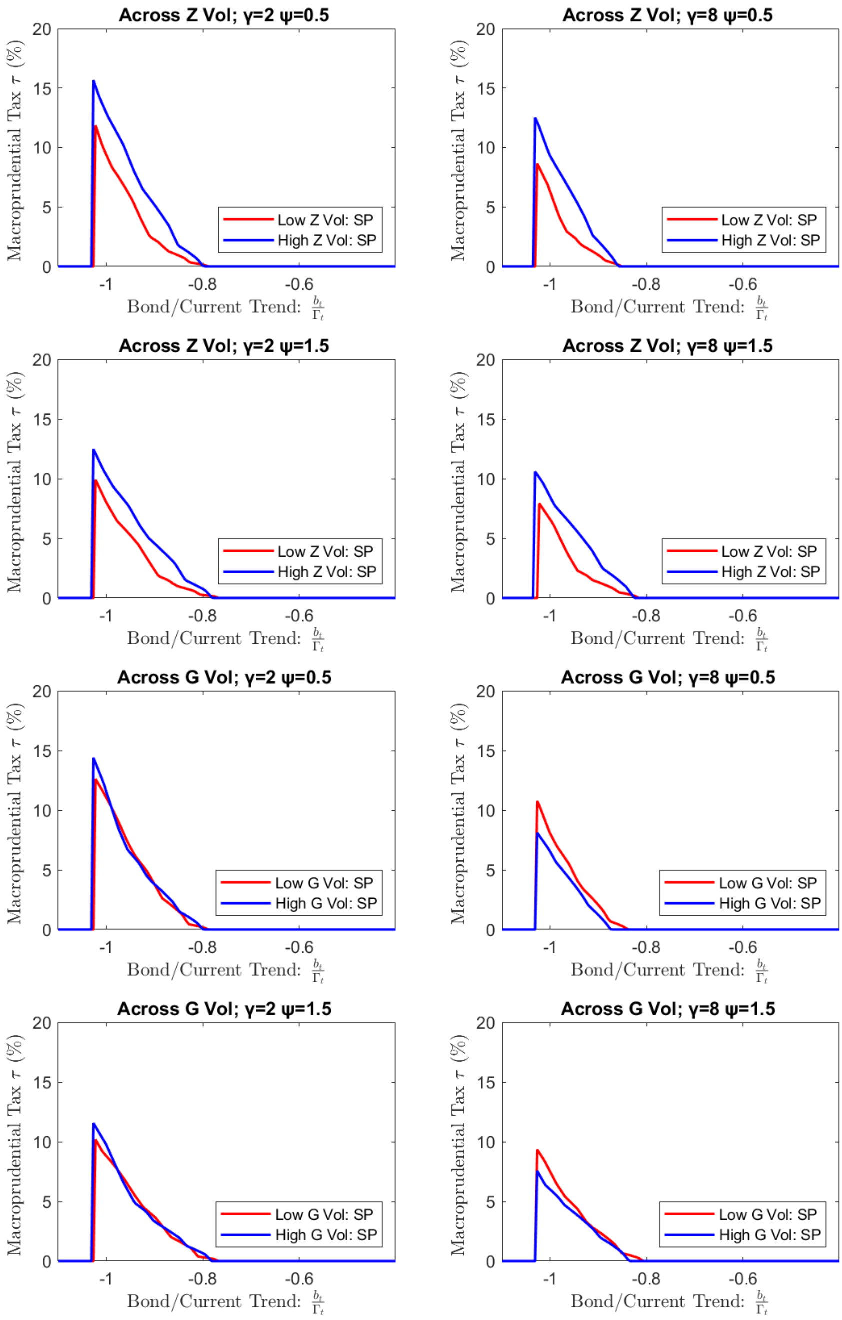


Figure 2: Macroprudential Tax Decompose: Business-Cycle Uncertainty

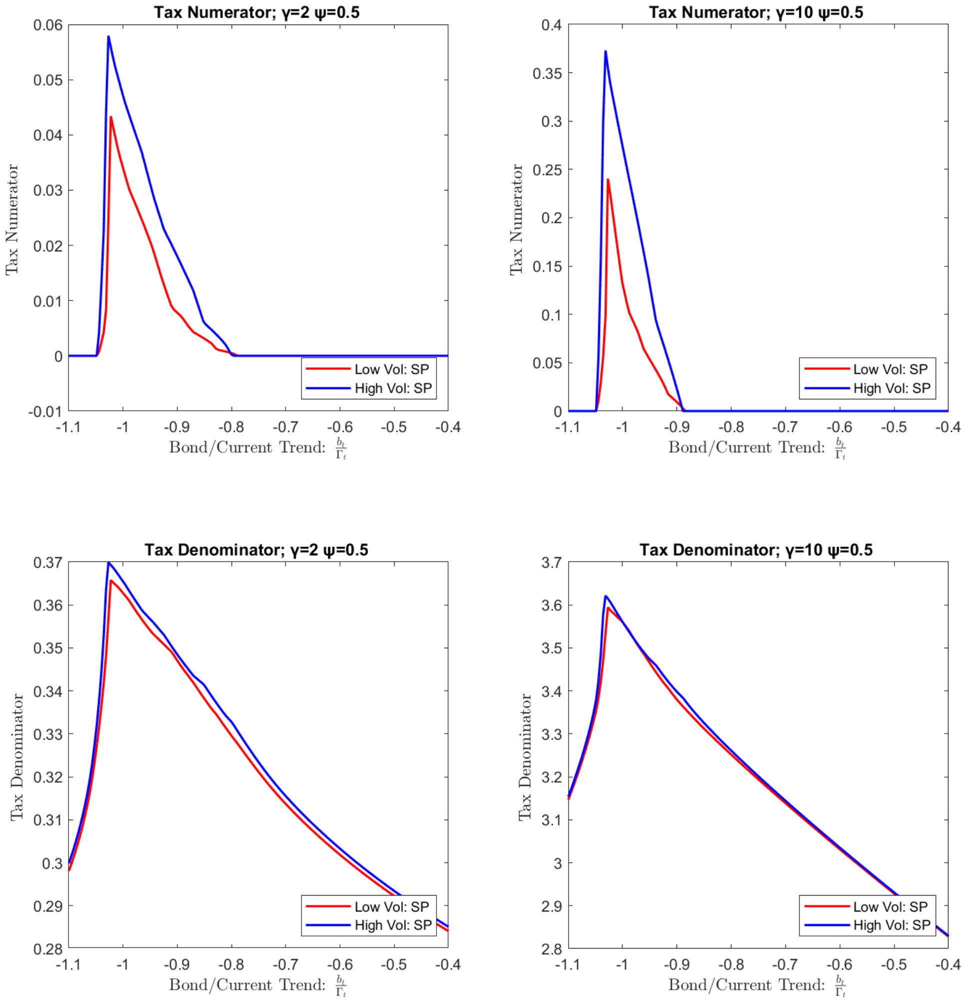


Figure 3: Macroprudential Tax Decompose: Growth-Trend Uncertainty

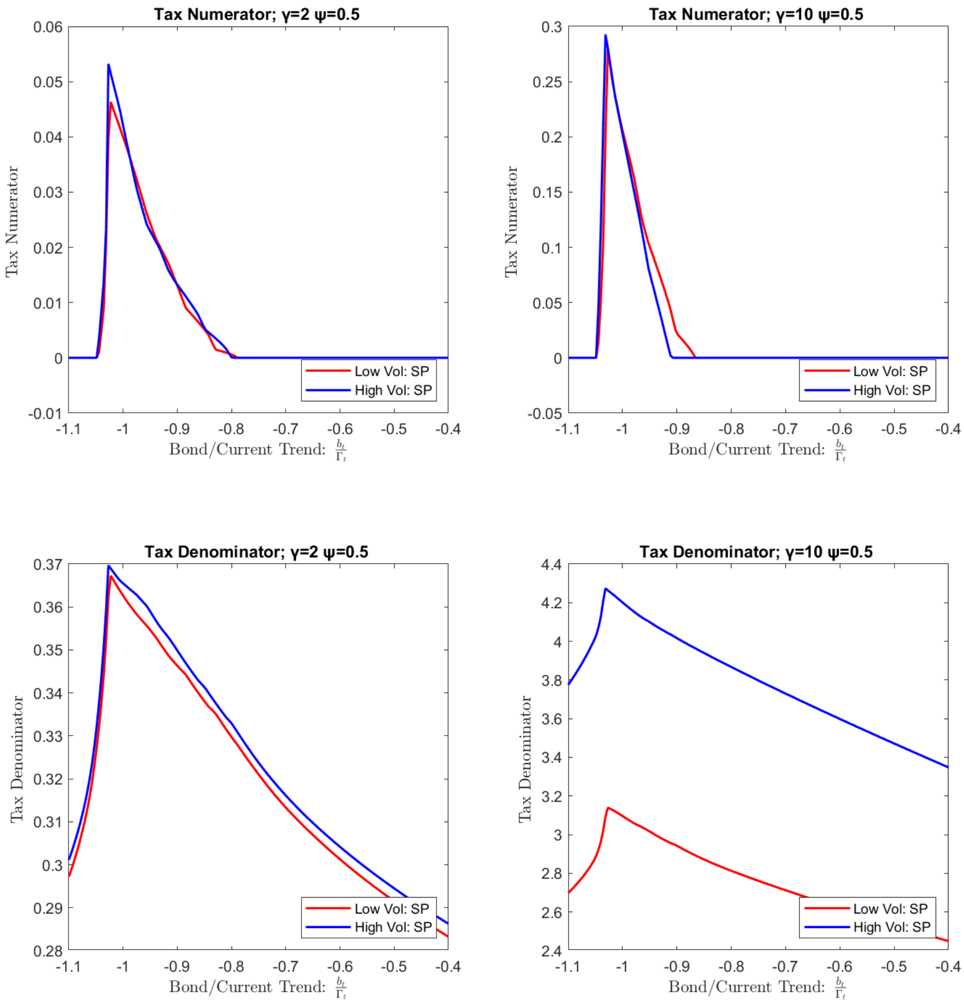


Table 2: Long-Run and Crisis Moments

	(1)	(2)	(3)	(4)
IES ψ	0.50	0.50	1.50	1.50
RRA γ	2.00	8.00	2.00	8.00
(b/y) (%) DE	-29.50	-21.46	-29.93	-28.57
(b/y) (%) SP	-28.77	-21.28	-29.07	-27.87
std(ca/y) (%) DE	2.88	2.08	3.38	1.82
std(ca/y) (%) SP	1.74	1.99	1.74	1.23
Prob of Crisis (%) DE	3.61	0.63	4.29	2.83
Prob of Crisis (%) SP	0.74	0.04	0.72	0.22
Prob of Binding (%) DE	8.20	1.50	10.57	4.89
Prob of Binding (%) SP	0.02	0.00	0.03	0.01
Macroprudential Tax (%)	3.45	0.52	3.49	1.51
Welfare gain (%)	0.05	0.00	0.06	0.03
Δc (%) DE	-16.23	-14.60	-17.26	-14.52
Δc (%) SP	-10.57	-11.69	-10.67	-10.46
Δrer (%) DE	39.00	28.24	42.70	29.64
Δrer (%) SP	18.90	18.20	18.92	15.78
$\Delta ca/y$ (%) DE	11.07	6.35	12.69	7.39
$\Delta ca/y$ (%) SP	3.76	2.73	4.03	2.30
Ω_c DE	3.67	1.88	3.34	2.03
Ω_c SP	2.22	1.50	1.90	1.40
Ω_{rer} DE	5.47	2.67	5.47	2.93
Ω_{rer} SP	2.29	1.71	2.02	1.41
$\Omega_{ca/y}$ (%) DE	-0.10	-0.04	-0.18	-0.60
$\Omega_{ca/y}$ (%) SP	-0.47	-0.09	-0.64	-1.03
Tax Before Crisis (%)	5.82	3.54	4.56	3.29

Figure 4: Ergodic Distribution

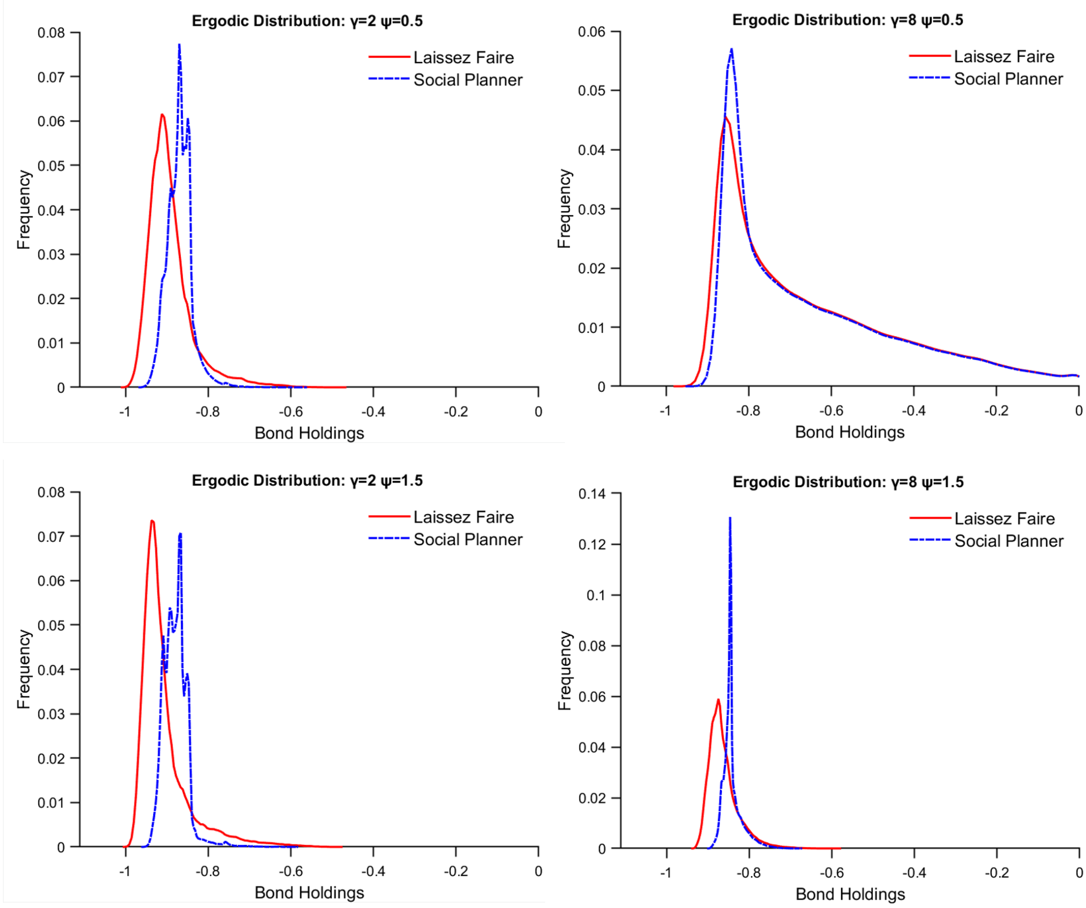


Figure 5: Evolution of States Around Crisis

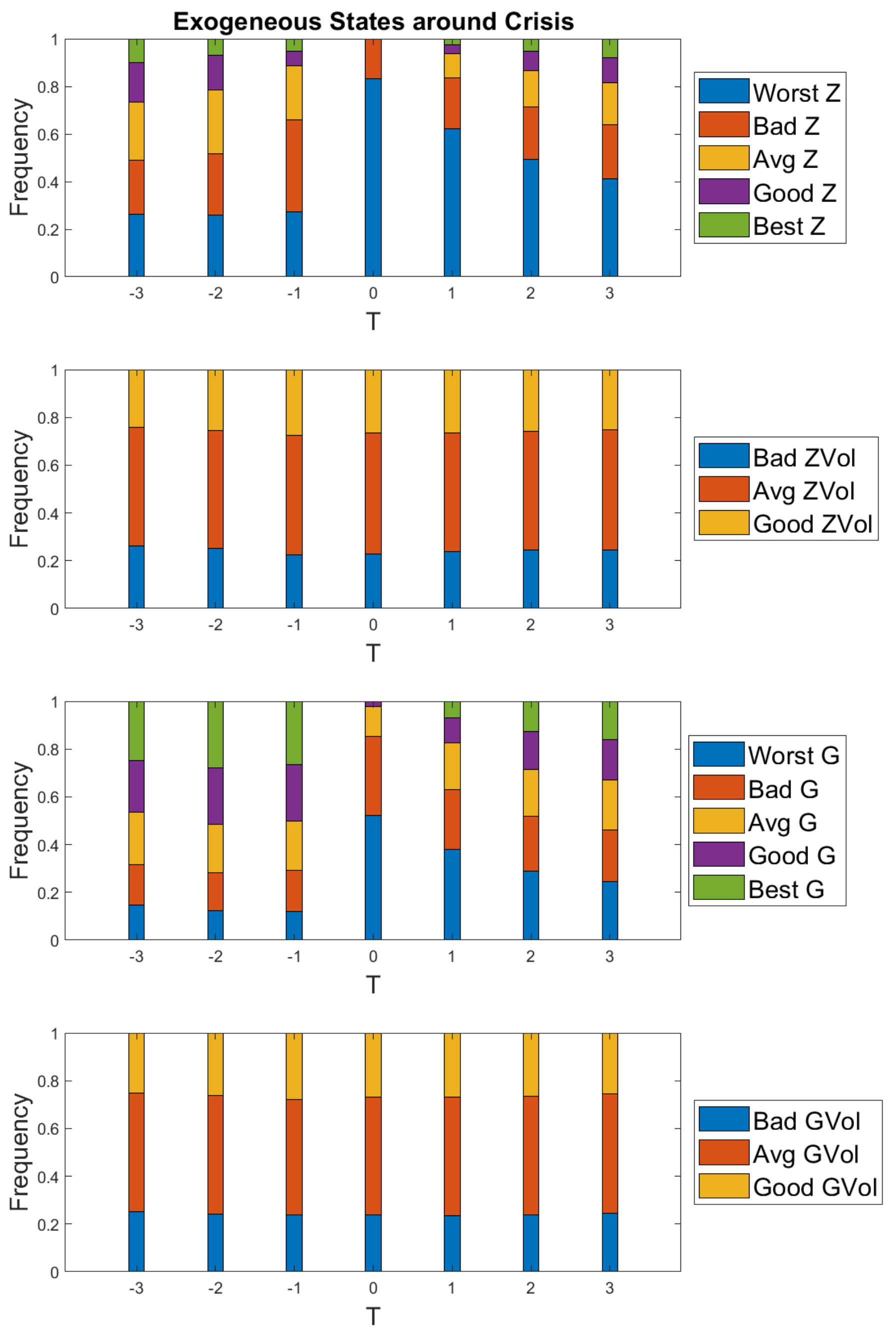
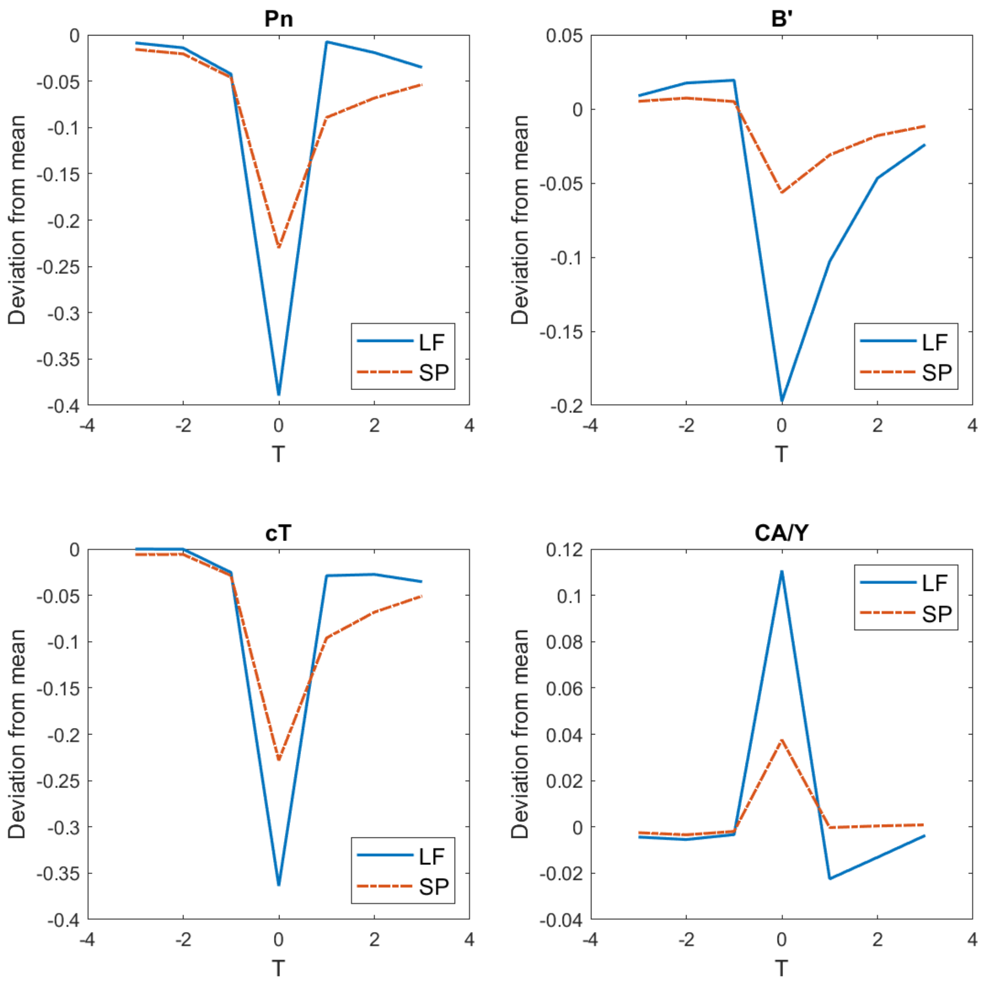


Figure 6: Sudden Stop Crisis Dynamics



B Proof of Proposition 1

Prove by construction and verify:

Construction: Suppose that there exist a tax plan $\tau = \tau(B, \mathbf{S})$, such that (a) decentralized household's decision rule value function and decision rules consist with the social planner $V_{de}(B, B, \mathbf{S}) = V_{sp}(B, \mathbf{S})$, $c^T_{de}(B, B, \mathbf{S}) = c^T_{sp}(B, \mathbf{S})$, $c^N_{sp}(B, B, \mathbf{S}) = c^N_{sp}(B, \mathbf{S})$, and $b'_{sp}(B, B, \mathbf{S}) = B'_{sp}(B, \mathbf{S})$, and (b) borrowing constraint for decentralized households binds if and only if it binds for social planner. The Euler equation for the social planner and decentralized household with tax are:

$$\beta(1+r)\hat{V}_{sp}^{\frac{1}{\psi}} \left\{ E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{sp} \right)^{1-\gamma} \right] \right\}^{\frac{\gamma - \frac{1}{\psi}}{1-\gamma}} E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{sp} \right)^{-\gamma} \hat{\lambda}'_{sp} \right] + \hat{\mu}_{sp} = \hat{\lambda}_{sp} \tag{28}$$

$$\beta\,(1+r)\,(1+\tau)\,\hat{V}_{de}^{\frac{1}{\psi}} \left\{ E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{1-\gamma} \right] \right\}^{\frac{\gamma - \frac{1}{\psi}}{1-\gamma}} E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{-\gamma} \hat{\lambda}'_{de} \right] + \hat{\mu}_{de} = \hat{\lambda}_{de} \tag{29}$$

First, when borrowing constraint is slack for social planner $\hat{\mu}_{de} = \hat{\mu}_{sp} = 0$, eq.(18) and eq.(26) implied that $\hat{\lambda}_{sp} = \hat{\lambda}_{de}$. Combining eq.(28) and eq.(29) gives the expression of optimal tax eq.(27):

$$\tau = \frac{E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{sp} \right)^{-\gamma} \left(\hat{\lambda}'_{sp} - \hat{\lambda}'_{de} \right) \right]}{E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{-\gamma} \hat{\lambda}'_{de} \right]} = \frac{E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{sp} \right)^{-\gamma} \left(\hat{\mu}'_{sp} \hat{\Psi}' \right) \right]}{E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{sp} \right)^{-\gamma} \lambda'_{de} \right]}$$

Second, when borrowing constraint binds for social planner $\hat{\mu}_{sp} > 0$, (b) requires that the borrowing constraint must also bind for the decentralized household $\hat{\mu}_{de} > 0$. eq.(29) therefore implies that τ have a upper bound $\bar{\tau}$:

$$\tau < \frac{\hat{\lambda}_{de}}{\beta(1+r)\hat{V}_{de}^{\frac{1}{\psi}} \left\{ E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{1-\gamma} \right] \right\}^{\frac{\gamma - \frac{1}{\psi}}{1-\gamma}} E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{-\gamma} \hat{\lambda}'_{de} \right]} - 1 \equiv \bar{\tau} \tag{30}$$

Then, prove $\bar{\tau} > 0$ if regularity condition $\hat{\Psi} < 1$ holds for all $\{B, \mathbf{S}\}$. Notice that this implies social planner can set $\tau = 0$ when borrowing constraint binds (Bianchi, 2011). To show $\bar{\tau} > 0$ under regularity condition, substitute $\hat{\lambda}_{sp}$ in eq.(28) using eq.(26) and use $V_{de}(B, B, \mathbf{S}) = V_{sp}(B, \mathbf{S})$:

$$0 < \beta(1+r)\hat{V}_{de}^{\frac{1}{\psi}} \left\{ E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{1-\gamma} \right] \right\}^{\frac{\gamma - \frac{1}{\psi}}{1-\gamma}} E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{-\gamma} \left(\hat{\lambda}'_{de} + \underbrace{\hat{\mu}'_{sp} \hat{\Psi}'}_{\geq 0} \right) \right] + \underbrace{\left(1 - \hat{\Psi} \right) \hat{\mu}_{sp}}_{>0} = \hat{\lambda}_{de}$$

which implies

$$\beta(1+r)\hat{V}_{de}^{\frac{1}{\psi}} \left\{ E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{1-\gamma} \right] \right\}^{\frac{\gamma - \frac{1}{\psi}}{1-\gamma}} E_{\mathbf{S}'|\mathbf{S}} \left[\left(\hat{V}'_{de} \right)^{-\gamma} \hat{\lambda}'_{de} \right] < \hat{\lambda}_{de} \quad \Rightarrow \quad \bar{\tau} > 0$$

Verify: I then prove that if macroprudential policy satisfies eq.(27) when borrowing constraint is slack and $\tau < \bar{\tau}$ when borrowing constraint binds, then (a) and (b) hold:

In case 1, borrowing constraint binds for social planner: $\tau < \bar{\tau}$ makes sure that the social planner's equilibrium conditions eq.(24) and eq.(25) is equivalent to decentralized household's equilibrium conditions eq.(15), eq.(16), eq.(19) and $Y^N = c^N$. This implies that decentralized household with tax must also have binding constraint and have same decision rules on bond and consumption.

In case 2, borrowing constaint is slack for social planner: The equilibrium of social planner is define by eq.(24) eq.(28), and eq.(26), and the equilibrium of decentralized household is define by eq.(15), eq.(20), eq(18) and $Y^N = c^N$. First, government balance budget and $Y^N = c^N$ make sure eq.(24) and eq.(15) are the same under same decision rules. Second, the eq.(27) makes sure that if decision rule and implied $\lambda_{de}, \lambda_{sp}$ in line with eq.(28) and eq(26), then they must also make eq.(20) and eq(18) hold.

In both cases, equilibrium conditions and decision rules are the same, therefore the value function and μ must also be the same.