Green Bonds and The Energy Transition: Efficiency and Social Inequalities

Verónica Acurio Vásconez & Olivier Damette

University of Lorraine, Bureau d'économie théorique et appliquée (BETA)

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Purpose

Analyze the efficiency of different macroeconomic policies that can be used to incentivize the energy transition from different angles, with a special focus on green bonds.

By:

- Developing a theoretical macroeconomic analysis with a financial sector and two different household types (financial DSGE with Ricardian and non-Ricardian consumers)
- Evaluating the impact of the different measures over macroeconomic aggregates and social inequalities

Motivation

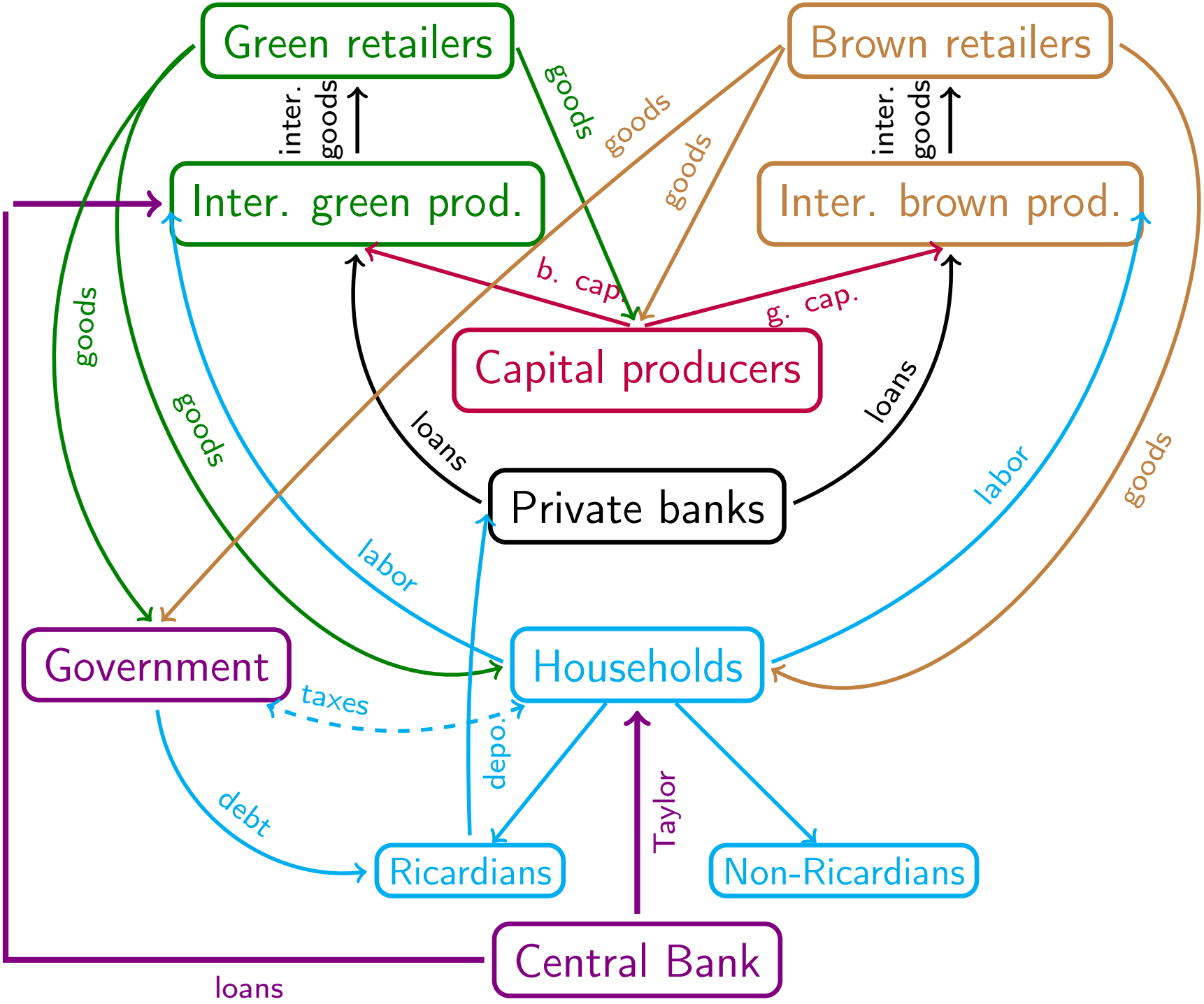
- The empirical evidences of the macroeconomic costs of climate change are undeniable (Nordhaus (1994), Hsiang et al. (2017), Dell et al. (2014), Carleton & Hsiang (2016)).
- However, the actions carried to deal with climate change prone to be insufficient.
- Recent studies have examined the potential of fiscal policy to achieve an energy transition (e.g., Bhattaraia &Trzeciakiewiczb (2017), Drygalla et al. (2017)).
- However, carbon taxes are no longer well accepted by populations ("Yellow Jackets" France in 2019, Ecuador's strikes in 2019 or in Kazakhstan in 2021).
- Is there another option?

  Yes, "green bonds" (The One Planet Summit 2017).

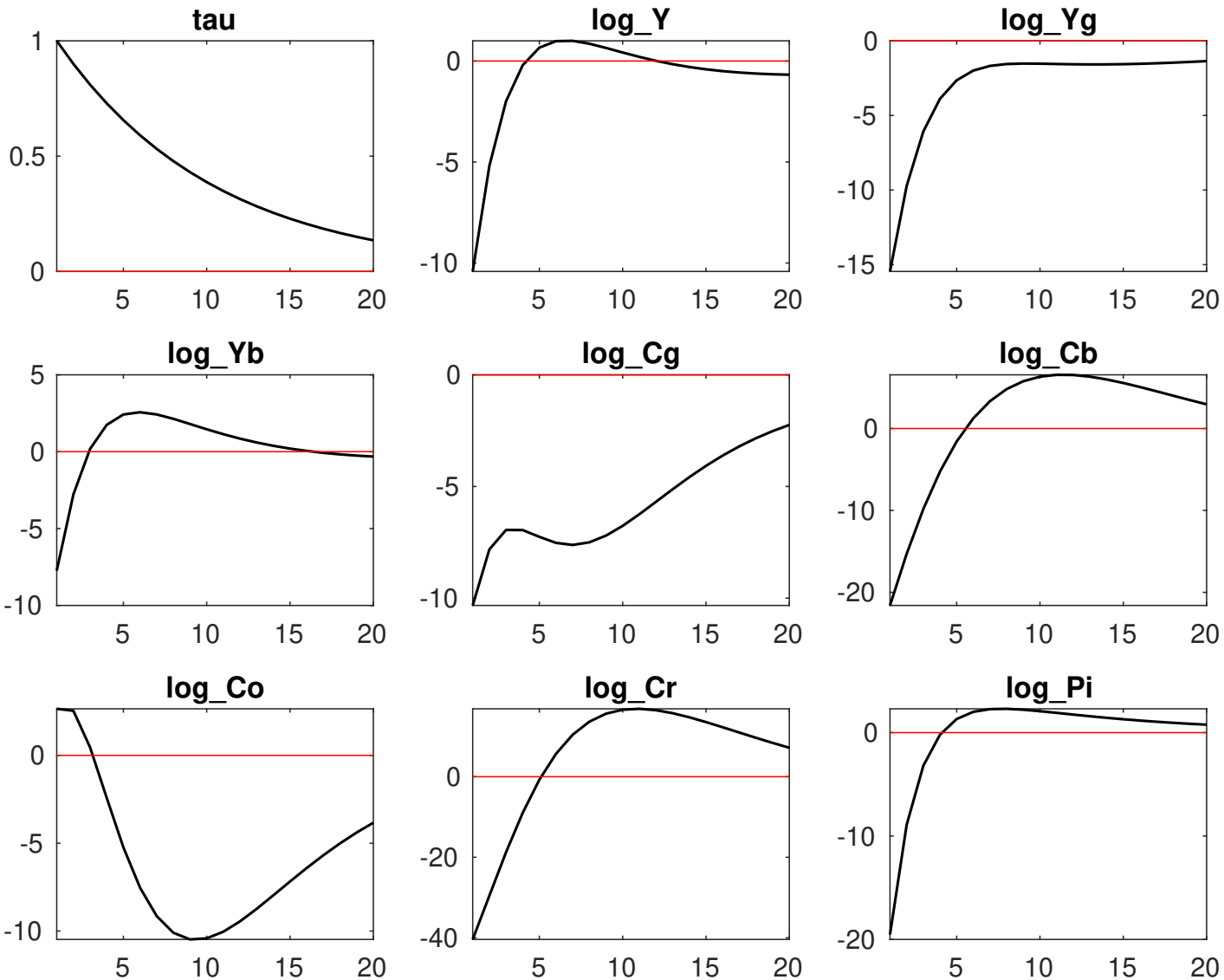
Research Questions

1. What is the efficiency of green bonds to achieve the energy transition?

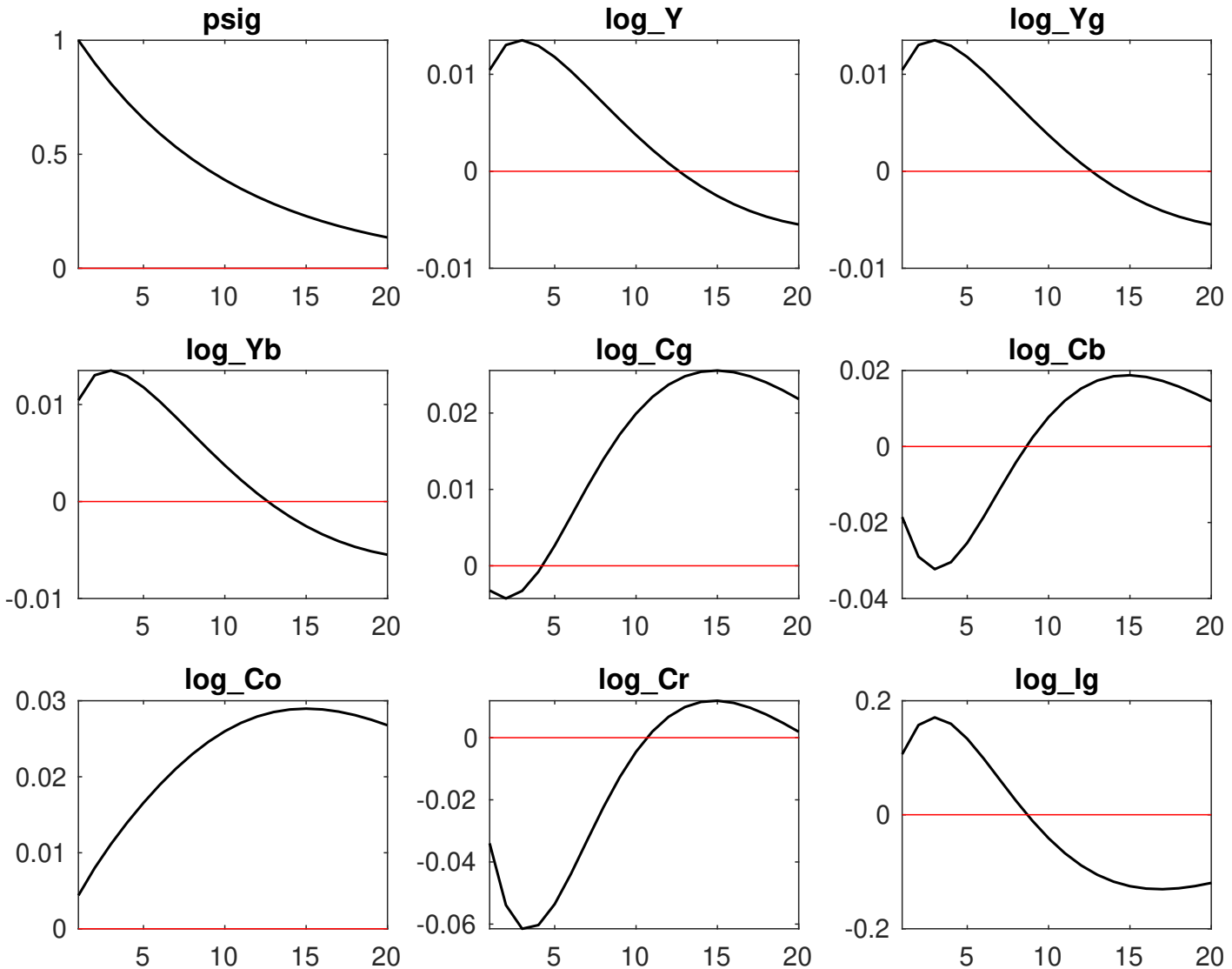
2. Are green bonds better than other classical economic policies, especially regarding their impact over social inequalities?


Green retailers
Brown retailers
inter. goods
inter. goods
Inter. green prod.
Inter. brown prod.
goods
goods
goods
goods
goods
b. cap.
g. cap.
Capital producers
loans
loans
Private banks
labor
labor
goods
Government
Households
taxes
depo.
debt
Taylor
Ricardians
Non-Ricardians
Central Bank
loans

1% carbon taxe



1% Green Bonds



Preliminary Contributions

- Carbon taxes reduces brown consumption, GDP and affects much more non-Ricardian households.
- Green bonds induces an increase in green consumption, bust GDP and harm less non-Ricardian households.

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What do we do?

- Introduce non-Ricardian households into a financial DSGE model.
- Describe the transmission channels of different shocks (preference shocks, fiscal shocks, green government consumption, green bond shock).
- We individually vary a set of economic parameters to study the sensitivity of the shocks to changes in:
  - the share of non-Ricardian households.
  - the sensitivity reaction of the Central Bank to a change in the spread for green assets.

Public Loans vs Private Loans

Central Bank behaves as a private bank:

- Take savings from consumers at gross interest rate.
- Issue financial claims to intermediate non-financial producers.
- Earn a rate of return on the claims.

What is the difference between the Central Bank and a private bank?

- Central Bank only invests in green firms.
- Central Bank assets come with an efficiency cost of per claim.
- There are no limitations in the number of bonds Central Bank can supply.

What are green bonds?

- It is an exogenous increase in the share of green claims financed by the Central Bank.
- It is not a "helicopter money" policy.
- It is a quantitative easing policy that increases Central Bank intervention in a particular sector.

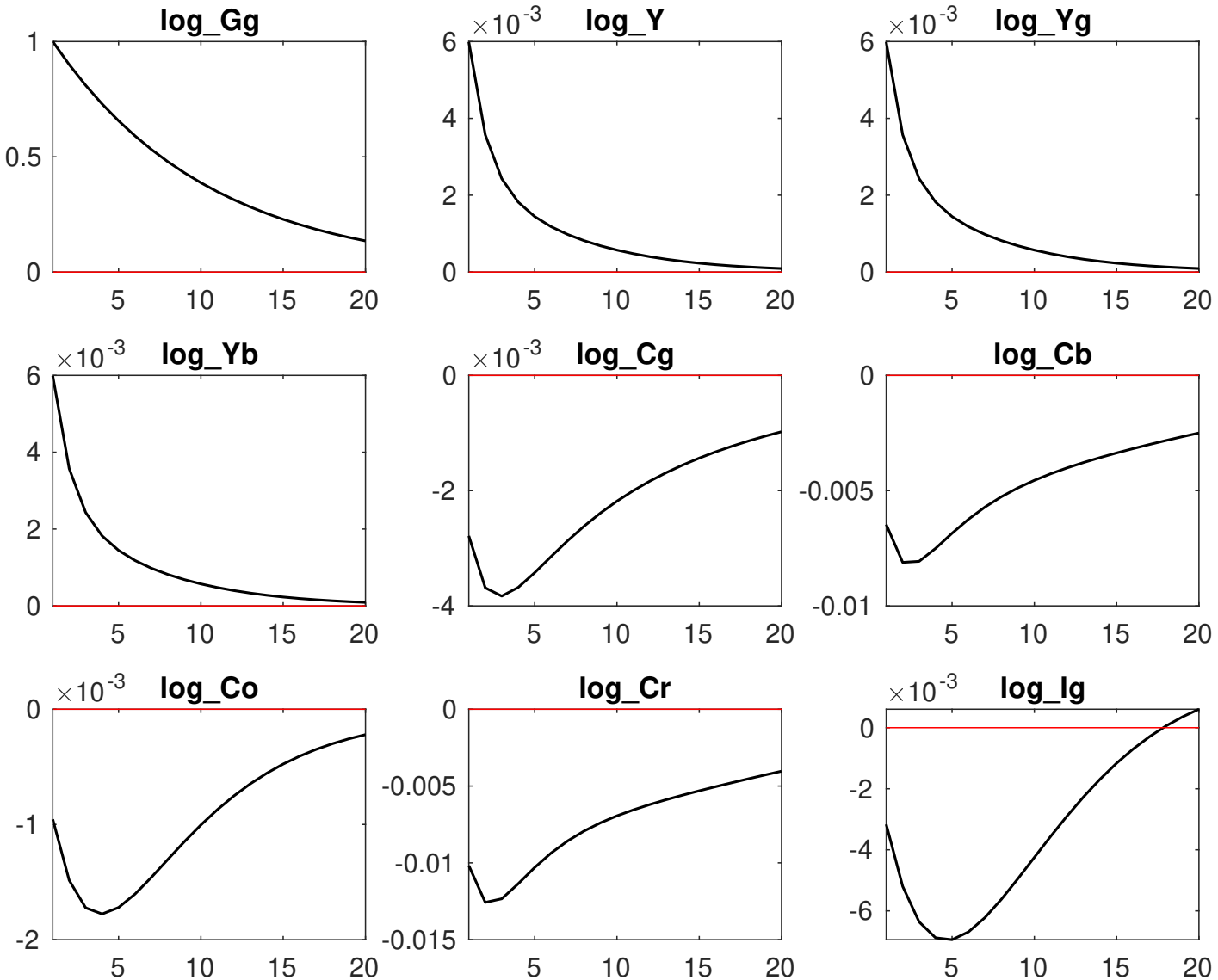
Government and Monetary Policy

Green bonds

$$\underbrace{\psi_{g,t}}_{\substack{\text{green loans share}\\ \text{financed by the}\\ \text{Central Bank}}} = \underbrace{\bar{\psi}_{g,t}}_{\substack{\text{an exogenous}\\ \text{process}}} + \omega_g \mathbb{E}_t \left[\underbrace{(logR_{g,t+1} - logR_{t+1})}_{\text{green spread}} - \underbrace{(logR_g - logR)}_{\substack{\text{green}\\ \text{steady state}}} \right]$$

where $\omega_g > 0$ is the Central Bank credit feedback parameter.

1% increase in Government green consumption



Households

A continuum of perfectly competitive households indexed by $j \in [0,1]$.

- Utility function: $U(C_t(j)) = (log(C_t(j) - hC_{t-1}(j)))\,, \quad h \in (0,1)$
- Maximization problem:

$$\max_{(C_t, B_{t+\mathbf{1}})_{t=\mathbf{0},\ldots+\infty}} \mathbb{E}_t \left[\sum_{i=0}^{\infty} \beta^i U\left(C_{t+k}\right) \right], \quad \beta \in (0,1) \tag{1}$$

$$\text{subject to : } C_t + B_{t+1} \leq b_t\left(1 - L_t\right) + W_t L_t + R_t B_t + T_t + D_t$$

Financial Intermediates (1)

An infinite continuum of perfect competitive financial intermediates indexed by $j \in [0, 1]$.

- Banker's net worth period t:

$$\Omega_t(j) = Q_t Z_t(j) - B_{t+1}(j)$$

- Banker's net worth period $t+1$:

$$\Omega_{t+1}(j) = R_{k,t+1} Q_t Z_t(j) - R_{t+1} B_{t+1}(j)$$

- Expected discounted terminal wealth:

$$V_t(j) = \sum_{i=0}^{\infty} (1-\theta)\theta^i \Lambda_{t,t+1+i} \Omega_{t+1+i}(j)$$

- Leverage ratio:

$$\phi_t(j) := \frac{Q_t Z_t(j)}{\Omega_t(j)}$$

Financial Intermediates (2)

Some conditions are imposed to private bankers:

- No-default: $\mathbb{E}_t \Lambda_{t,t+1+i} \left(R_{k,t+1+i} - R_{t+1+i} \right) \geq 0, \quad i \geq 0$
- Liquidity constraint:

$$V_t(j) \geq \lambda Q_t Z_t(j) \tag{2}$$

Financial Intermediates (3)

Aggregated equations:

- Wealth of all existing bankers:

$$\Omega_{e,t+1} = \left(\left(R_{k,t+1} - R_{t+1}\right)\phi_t + R_{t+1}\right)\Omega_t$$

- Total net worth of all bankers (existing plus new bankers)

$$\Omega_t = \Omega_{e,t} + \Omega_{n,t}$$

- Given that the probability of a banker at time t remaining a banker at time $t+1$ is equal to θ:

$$\Omega_t = \theta\left(\left(R_{k,t} - R_t\right)\phi_{t-1} + R_t\right)\Omega_{t-1} + \epsilon Q_t Z_{t-1} \tag{3}$$

Intermediate Non-Financial Firms

An infinite continuum of perfectly competitive intermediate goods producers.

- Production factors: capital and labor.
- They finance physical capital by borrowing from public of private financial intermediates.
- After production, the firm may sell capital back to the capital producer and/or refurbish depreciated capital.
- The cost of replacement is unity and that there are no adjustment costs.
- Maximization problem:

$$\max_{(Y_{m,t},K_t,L_t)_{t=\mathbf{0},\ldots,+\infty}} P_{m,t}Y_{m,t} + (1-\delta)P_tQ_tK_t - R_{k,t}Q_{t-1}K_t - W_tL_t \tag{4}$$

$$\text{subject to : } Y_{m,t} = A_tK_t^{\alpha}L_t^{1-\alpha},\ \forall t \geq 0$$

Capital Producers

A continuum of perfectly competitive, homogeneous capital production firms.

- Production factors: final goods, capital from intermediate good producers, depreciated capital.
- Output: capital.
- Capital accumulation rule: $K_{t+1} := (1-\delta)K_t + I_{n,t}$
- Maximization problem:

$$\max_{(I_{n,t})_{t=\mathbf{0},\ldots,\infty}} \mathbb{E}_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \left((Q_t - 1) I_{n,t} - f\left(\frac{I_{n,t}}{I_{n,t-1}} \right) I_{n,t} \right) \tag{5}$$

Normal retailers

A continuum a continuum of monopolistic *normal retailers* indexed by $h \in [0, 1]$.

- Production factors: intermediates goods.
- Output: Normal retailers goods.
- Stickiness: only a fraction can optimize prices. The others indexed prices with inflation.
- Maximization problem:

$$\max_{(P_t(h))_{t=\mathbf{0},\ldots,\infty}} \mathbb{E}_t \sum_{i=0}^{\infty} \theta_p^i \Lambda_{t,t+i} \left(\Pi_{t+s-1}^{\chi} \frac{P_t(h)}{P_{t+i}} - \hat{P}_{m,t+i} \right) Y_{t+i}(h) \quad (6)$$

$$\text{subject to : } Y_{t+i}(h) = \left(\Pi_{t+s-1}^{\chi} \frac{P_t(h)}{P_{t+i}} \right)^{-\epsilon_p} Y_{t+i}, \ \forall t \geq 0$$

Super retailers

A continuum a continuum of perfect competitive *super retailers*.

- Production factors: normal final goods.
- Output: final aggregated good.
- Maximization problem:

$$\max_{(Y_t)_{t=\mathbf{0},\ldots,\infty}} P_t Y_t - \int_0^1 P_t(h) Y_t(h) dh \tag{7}$$

$$\text{subject to } : Y_t := \left(\int_0^1 Y_t(h)^{\frac{\epsilon_p - \mathbf{1}}{\epsilon_p}} dh \right)^{\frac{\epsilon_p}{\epsilon_p - \mathbf{1}}}$$

Government and Monetary Policy

- Budget constraint:

$$G_t + \tau \psi_t Q_t K_{t+1} + b_t(1 - L_t) + \psi_t Q_t Z_t = T_t + (R_{k,t} - R_t) B_{g,t} + B_{g,t+1} \tag{8}$$

- Conventional Monetary Policy:

$$1 + i_t = (1 + i_{t-1})^{\phi_i} \left(\frac{1}{\beta} \left(\frac{\Pi_t}{\Pi} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_{ss}} \right)^{\phi_y} \right)^{1-\phi_i}, \tag{9}$$

- Unconventional Monetary Policy:

$$\psi_t = \bar{\psi}_t + \omega \mathbb{E}_t \left[(logR_{k,t+1} - logR_{t+1}) - (logR_k - logR) \right] \tag{10}$$

Parameter Calibration

Parameter	Symbol	Calibrated Value/Baseline
Epidemic block		
Initial condition of susceptible	S_0	0.9
Initial condition of infected	$\widetilde{I}_0$	0.1
Initial condition of recovered	$\widetilde{R}_0$	0
Transmission rate	α_v	0.4
Recovery rate	γ_v	0.1
Financial Intermediates		
Leverage ratio at steady state	ϕ	4
Central Bank and Government		
Feedback parameter	ω	10
Exogenous fraction of publicly intermediate assets	$\bar{\psi}$	0

Sensitivity of GDP losses to epidemic parameters.

Economic Response to Changes in Epidemic Structure

- At moderate to high recovery rates the model is relatively insensitive to the infection rate.
- A higher R_0 does not necessarily translate to greater GDP losses.

Sensitivity to the steady state leverage ratio (ϕ)

Sensitivity to the steady state leverage ratio

- The higher the leverage ratio, the higher the injection of funds from the Central Bank into the economy.
- But no effect on GDP looses.

Sensitivity to the feedback parameter (ω)

Sensitivity to a Change in the Spread

- The higher the sensitivity to the spread, the higher the injection of funds from the Central Bank into the economy.
- Changes in the quantity and composition of bankers' wealth.
- But no effect on GDP looses.