Twin Ds and Credit to the Private Sector

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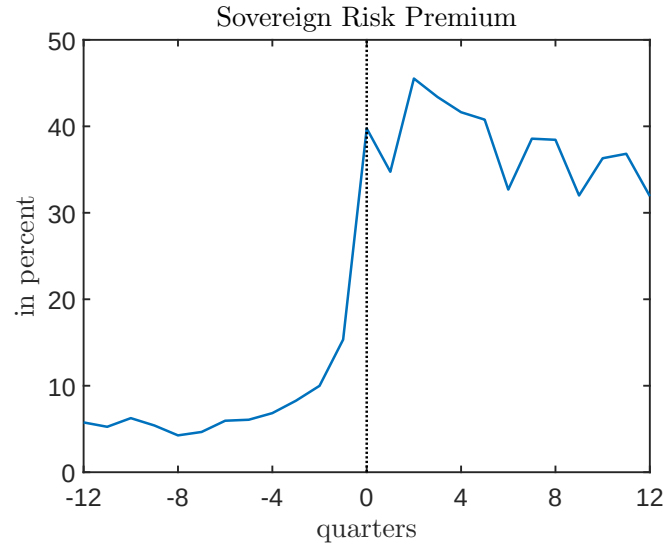
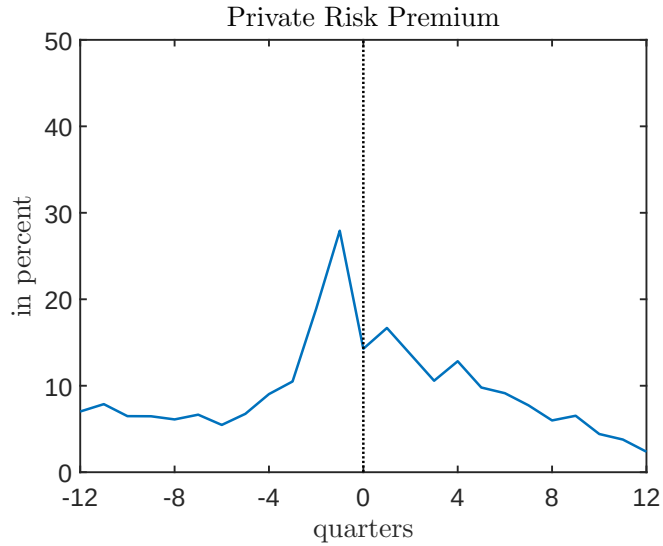
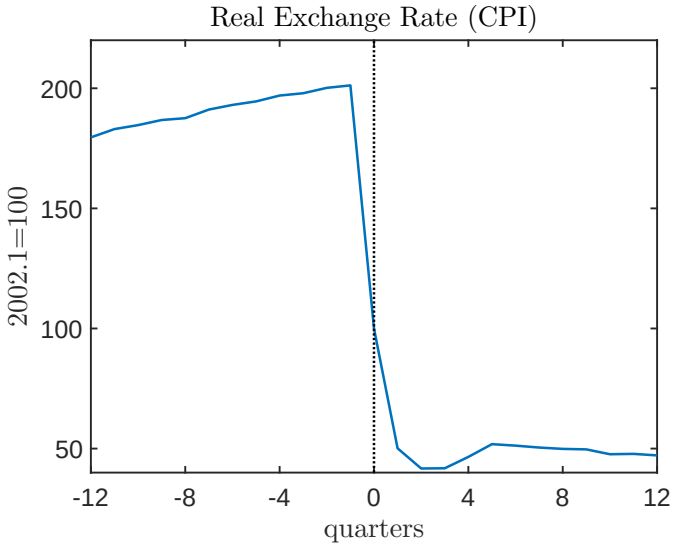
Introduction

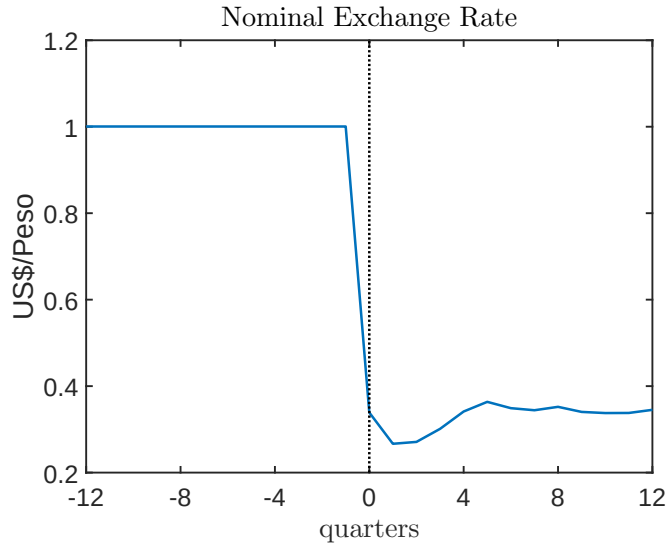
- Twin Ds ...
  - Sovereign default and devaluation crises often occur jointly (Reinhart, 2002).
- ... and Credit to the Private Sector
  - Foreign credit to private sector firms declines during
    - sovereign defaults (Arteta & Hale, 2008).
    - currency crises (Arteta & Hale, 2009).
  - Asymmetric foreign currency financing opportunities across nontradables (N-sector) and tradables sectors (T-Sector).
    - Credit driven boom-bust cycle in the N-Sector (Tornell & Westermann, 2002).

Crisis Dynamics - Argentina 2002 Q1









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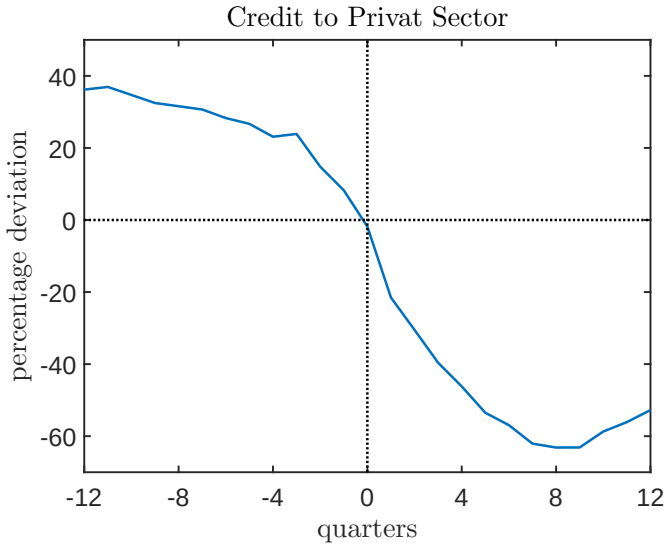
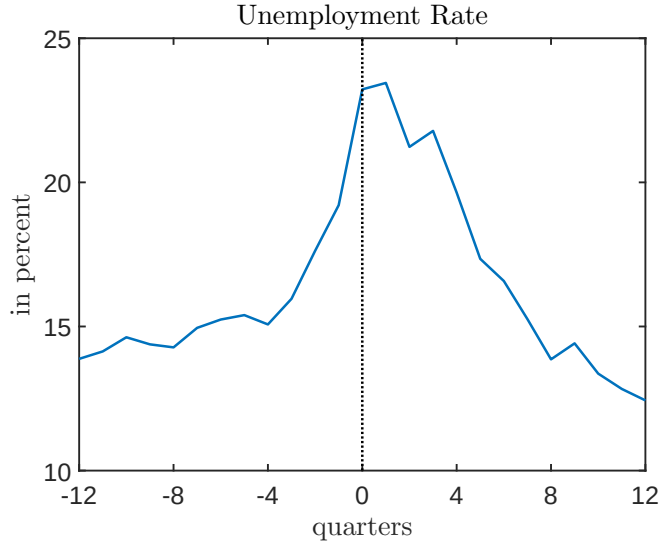
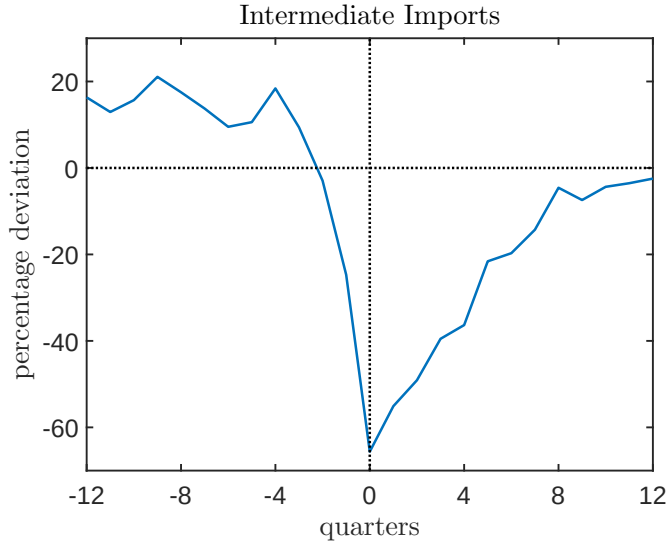






Research Questions

- How does the interaction between the exchange rate regime and private & sovereign default risk influence macroeconomic outcomes?
- Are flexible exchange rates optimal when sovereign and private default risks make nominal devaluations costly?

This Paper

- Dynamic stochastic model of a small open economy:
  - Tradable endowment (T-Sector) and nontradable production (N-Sector).
  - Working capital loans for intermediate imports in the N-Sector.
  - Benevolent government faces an exogenous exchange rate regime and provides transfers to households, financed by foreign debt.
  - There is sovereign and private default risk.
  - Unemployment due to downward rigid nominal wages.

Related Literature

- Sovereign & Private Default Risk:
  - Kaas et al. (2017), Arellano et al. (2017), de Ferra (2016)
- Sovereign Default & Devaluation:
  - Moussa (2013), Na et al. (2014)
- Private Sector Foreign Currency Debt:
  - Schneider & Tornell (2004), Cespedes et al. (2004), Ottonello (2014), Fornaro (2016)

Contribution

- Endogenous private and sovereign default risk under different exchange rate regimes.

Main Results

- Higher debt levels and higher default frequency in the flexible exchange rate regime.
- The model rationalizes stylized facts of Twin Ds.
  - Deep recession in default.
  - Nominal devaluation.
  - Credit crunch after the default.
- Flexible exchange rates dominate fixed exchange rates.

Mechanism I

- Nominal Devaluation & Private Default Risk
  - Nominal devaluation reduces the real wage and increases labor demand.
  - Nontradable output increases; tradable good becomes scarcer.
  - Relative price of nontradables falls (real depreciation).
  - Revenues in the nontradable good sector fall relative to foreign currency debt and private default risk rises.

Mechanism II

- Sovereign & Private Default Risk
  - Sovereign default risk increases sovereign spreads; the government becomes borrowing constrained.
  - The government reduces transfers to households; tradable good becomes scarcer.
  - Relative price of nontradables falls (real depreciation).
  - Revenues in the nontradable good sector fall relative to foreign currency debt and private default risk rises.

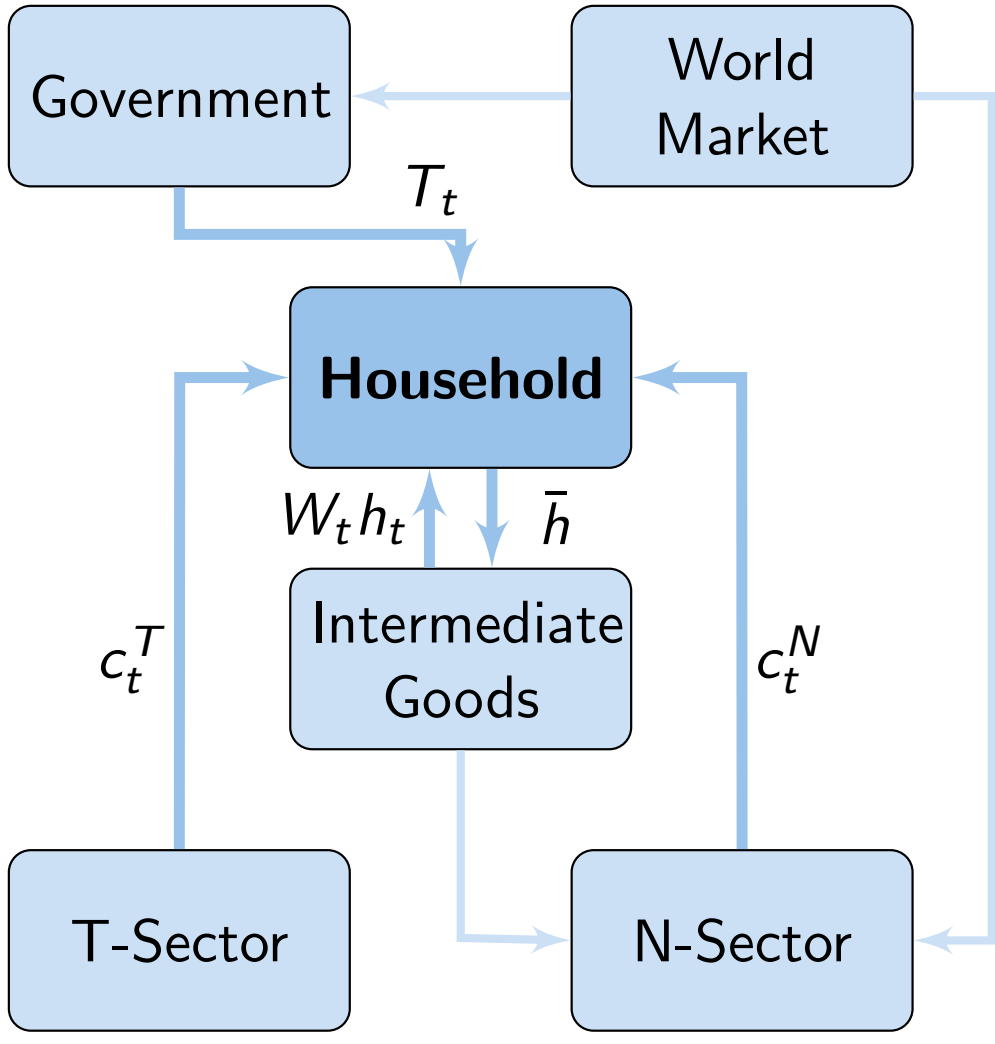
Model

Summary

- Small open economy with
  - a representative infinitely-lived household.
  - tradable (T-sector) and nontradable goods sector (N-sector).
  - intermediate good firms.
  - a benevolent government.
  - risk-neutral foreign creditors.

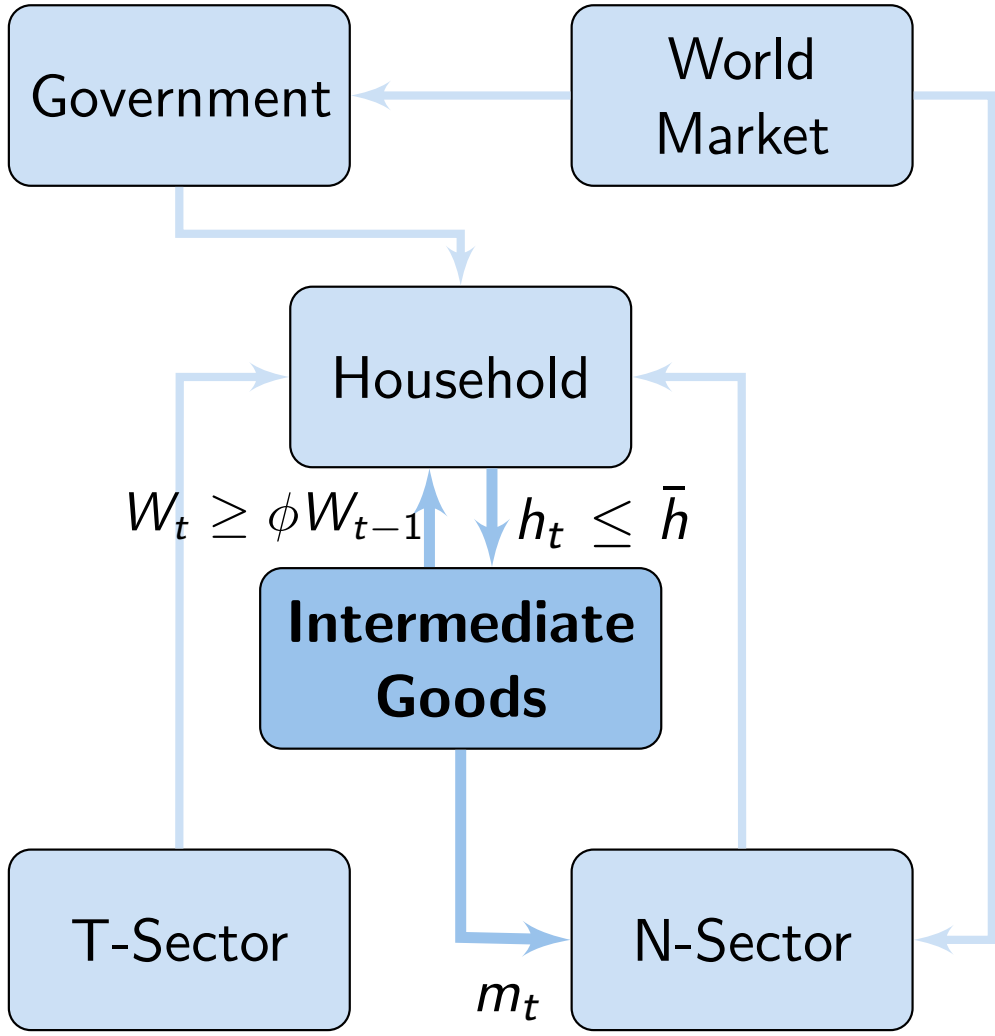
Model Setup I

- Household
  - inelastically supply labor, $\bar{h}$.
  - earn wage income.
  - own all firms.
  - receive lump-sum transfers.
  - consume: c_t^T & c_t^N.



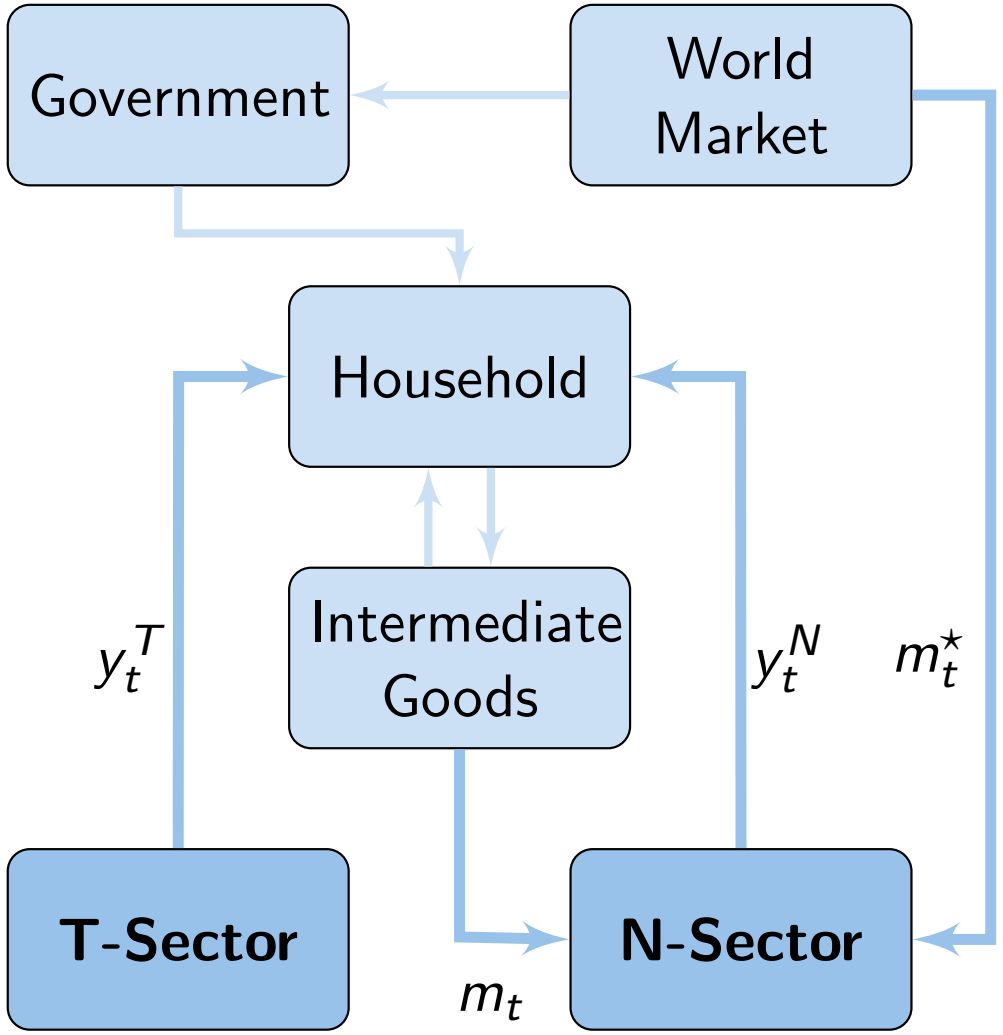
Model Setup II

- Intermediate input producer
  - use labor in production.
- Labor Market:
  - nominal downward rigid wage.
  - employment demand determined.



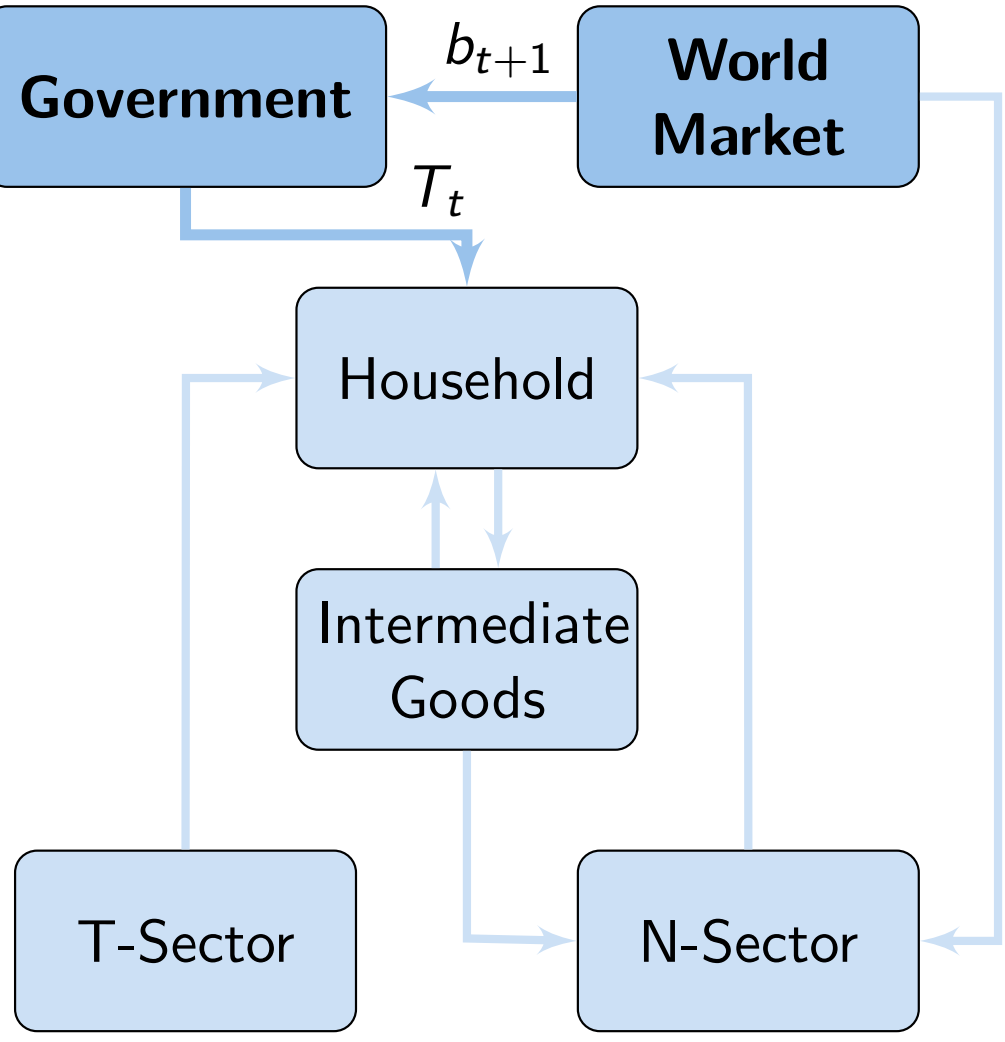
Model Setup III

- T-Sector
  - random endowment.
  - numeraire good.
- N-Sector firms
  - use m_t & $m_t^\star$ in production.
  - idiosyncratic productivity.
  - finance part of imports by foreign currency debt.
  - may default.



Model Setup IV

- Government
  - lump-sum transfers to HH.
  - borrows in terms of T-goods.
  - cannot commit to repay.
  - follows exogenous exchange rate policy.
- World Market:
  - Risk neutral investors.
  - Market for tradable goods.
  - PPP for tradable goods.



Timing

- Endowment shock is realized.
  - Government decides on default and borrowing and follows the exchange rate policy.
  - N-sector firms make import and borrowing decision.
  - Intermediate good firms employ labor and produce.
- Idiosyncratic productivity shock is realized.
  - N-sector firms repay or default.
  - Surviving N-sector firms buy domestic intermediate inputs and produce.

Representative Household I

- Household optimization problem

$$\max_{c_t^T, c_t^N} \mathbb{E} \sum_{t=0}^{\infty} \beta^t u\left(c_t\right)$$

subject to

$$P_t^T c_t^T + P_t^N c_t^N = W_t h_t + \Pi_t^M + \Pi_t^N + P_t^T \mathcal{I}_t,$$

$$c_t = A\left(c_t^T, c_t^N\right) \tag{1}$$

$$h_t \leq \bar{h}. \tag{2}$$

- Tradable income, $\mathcal{I}_t \equiv y_t^T + T_t$, consists of a random endowment and government transfers.

Representative Household II

- Purchasing power parity holds for T-goods: $P_t^T = \mathcal{E}_t P^{T\star}$ and $P^{T\star} = 1, \forall t$.

- Demand for N-goods

$$p_t = \frac{A_2\left(c_t^T, c_t^N\right)}{A_1\left(c_t^T, c_t^N\right)} \tag{3}$$

  - $p_t = \frac{P_t^N}{\mathcal{E}_t}$ is the real price of the N-good.
  - $\mathcal{E}_t$ is the nominal exchange rate (Peso/US$).

Intermediate Inputs

- Profit maximization

$$\max_{h_t} \Pi_t^M = P_t^M f(h_t) - W_t h_t$$

- Labor demand

$$f'(h_t) = \frac{W_t/\mathcal{E}_t}{p_t^M} \tag{4}$$

  - $p_t^M \equiv \frac{P_t^M}{\mathcal{E}_t}$ is the real price of the domestic intermediate input.

Labor Market

- Walrasian labor market.
- Nominal downward wage rigidity: $W_t \geq \phi W_{t-1}$
- If the constraint does not bind $W_t > \phi W_{t-1}$, $h_t = \bar{h}$.
- Otherwise employment is demand determined $h_t < \bar{h}$.
- Real rigidity:

$$w_t \geq \phi \frac{w_{t-1}}{\epsilon_t} \tag{5}$$

  - ϕ: wage rigidity.
  - $w_t \equiv \frac{W_t}{\mathcal{E}_t}$: real wage.
  - $\epsilon_t \equiv \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}$: devaluation rate.

N-Sector

- CRS technology:

$$x_{i,t} f^N(m_t, m_t^*)$$

  - $x_{i,t}$: idiosyncratic productivity, i.i.d. drawn from cumulative distribution function $X(.)$.

Private Default Decision

- A firm defaults if:

$$P_t^N x_{i,t} f^N(m_t, m_t^*) - P_t^M m_t - \xi R_t \mathcal{E}_t P^{M\star} m_t^\star < 0$$

- Defaulting firms realize losses: $(1-\xi)\,\mathcal{E}_t P^{M\star} m_t^\star$
- Surviving firms buy domestic intermediates:

$$m_{i,t} = m_t^\star \Phi\left(\frac{p_t x_{i,t}}{p_t^M}\right) \tag{6}$$

  - ξ is the fraction of imports financed by external credit.
  - R_t is the private-sector interest rate on external debt.
  - $p^{M\star} = \frac{P^{M\star}}{P^{T\star}}$ is the exogenous import price.

Private Default Decision

- A firm defaults if $x_{i,t} < \bar{x}_t$:

$$\pi^{BI}(p_t \bar{x}_t, p_t^M) = \xi R_t p^{M\star} \tag{7}$$

  - with profits before interest:

$$\pi^{BI}(p_t^N x_{i,t}, p_t^M) m_t^\star = p_t x_{i,t} f^N \left(\Phi \left(\frac{p_t x_{i,t}}{p_t^M} \right), 1 \right) m_t^\star - p_t^M \Phi \left(\frac{p_t x_{i,t}}{p_t^M} \right) m_t^\star$$

Import Demand

- After observing y_t^T and public policies, N-sector firms choose $m_t^\star$ to maximize expected profits:

$$\int_{\bar{x}_t}^{\infty} [\pi^{BI}(p_t x_{i,t}, p_t^M) - \xi R_t p^{M\star}] m_t^\star \; dX(x_t) - (1-\xi) p^{M\star} m_t^\star$$

- Optimality implies:

$$(1-\xi) p^{M\star} = \int_{\bar{x}_t}^{\infty} [\pi^{BI}(p_t x_{i,t}, p_t^M) - \xi R_t p^{M\star}] \; dX(x) \quad (8)$$

International Investor

- Risk-neutral international investors have access to an international bond market with constant gross interest rate $\bar{R}$.
- Zero expected profits:

$$\bar{R} = R_t \left[1 - X(\bar{x}_t) \right] + \eta X(\bar{x}_t) \tag{9}$$

  - $X(\bar{x}_t)$: default probability of N-sector firms.
  - η: recovery rate.

Exchange Rate Policies

- I explore two exchange rate regimes, $\mathcal{F}$
  - Fixed exchange rate regime, $\mathcal{F} = FIX$:

$$\epsilon_t = 1, \forall t$$

  - Full employment exchange rate regime, $\mathcal{F} = FE$

$$\epsilon_t = \max\left\{1, \phi\frac{w_{t-1}}{w_t^f}\right\}$$

    - w_t^f is the real wage that ensures labor market clearing: $w_t^f = p_t^M f'\left(\bar{h}\right)$.

Government I

- Sovereign default is punished by
  - a temporary exclusion from international financial markets.
  - an output cost on the T-good endowment:

$$y_t^T = \begin{cases} \mathcal{Y}(z_t, s_t = D), & \text{in financial autarky} \\ \mathcal{Y}(z_t, s_t = R), & \text{otherwise.} \end{cases}$$

    - z_t is the endowment shock.
    - $s_t \in \{D, R\}$ indicates the credit standing of the government.

Government II

- Conditional on being in a good credit standing, the government solves

$$V\left(z_t, b_t, w_{t-1}, R\right) = \max\left\{V^R\left(z_t, b_t, w_{t-1}\right), V^D\left(z_t, w_{t-1}\right)\right\}$$

  - $V^R\left(z_t, b_t, w_{t-1}\right)$: value function of repayment.
  - $V^D\left(z_t, w_{t-1}\right)$: value function of default.

Government III

$$V^R(z_t, b_t, w_{t-1}) = \max_{b_{t+1}, T_t} u(c_t) + \beta \mathbb{E}_z V(z_{t+1}, b_{t+1}, w_t, R)$$

subject to

$$T_t = -b_t + q(b_{t+1}, w_t, z_t) b_{t+1}$$
$$\mathcal{I}_t = T_t + \mathcal{Y}(z_t, R)$$
$$\epsilon_t = \begin{cases} 1, & \text{if } \mathcal{F} = FIX \\ \max\left\{1, \phi \frac{w_{t-1}}{w_t^f}\right\}, & \text{if } \mathcal{F} = FE \end{cases}$$
$$c_t = \mathcal{C}(\mathcal{I}_t, \epsilon_t, w_{t-1})$$

Government IV

$$V^D(z_t, w_{t-1}) = u(c_t) + \beta \mathbb{E}_z \left\{ \vartheta V(z_{t+1}, 0, w_t, R) + (1-\vartheta) V^D(z_{t+1}, w_t) \right\}$$

with

$$\mathcal{I}_t = \mathcal{Y}(z_t, D)$$

$$\epsilon_t = \begin{cases} 1, & \text{if } \mathcal{F} = FIX \\ \max\left\{1, \phi \frac{w_{t-1}}{w_t^f}\right\}, & \text{if } \mathcal{F} = FE \end{cases}$$

$$c_t = \mathcal{C}(\mathcal{I}_t, \epsilon_t, w_{t-1})$$

- Sovereign default set:

$$\Sigma_t^D = \left\{(z_t, b_t, w_{t-1}) \mid V^D(z_t, w_{t-1}) > V^R(z_t, b_t, w_{t-1})\right\}$$

- Sovereign default probability:

$$\delta(b_{t+1}, w_t, z_t) = \text{Prob}\left((z_{t+1}, b_{t+1}, w_t) \in \Sigma_t^D \,\middle|\, z_t\right)$$

- The zero-expected profit condition of foreign creditors implies:

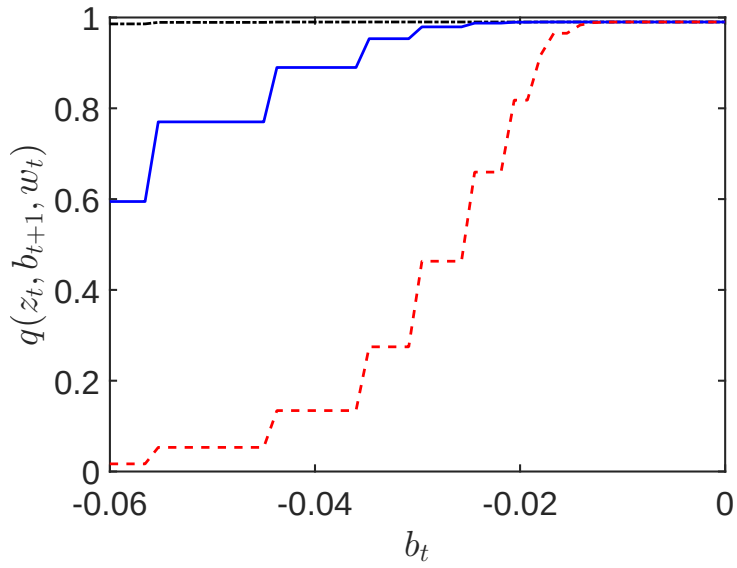
$$q(b_{t+1}, w_t, z_t) = \frac{1 - \delta(b_{t+1}, w_t, z_t)}{\bar{R}}$$

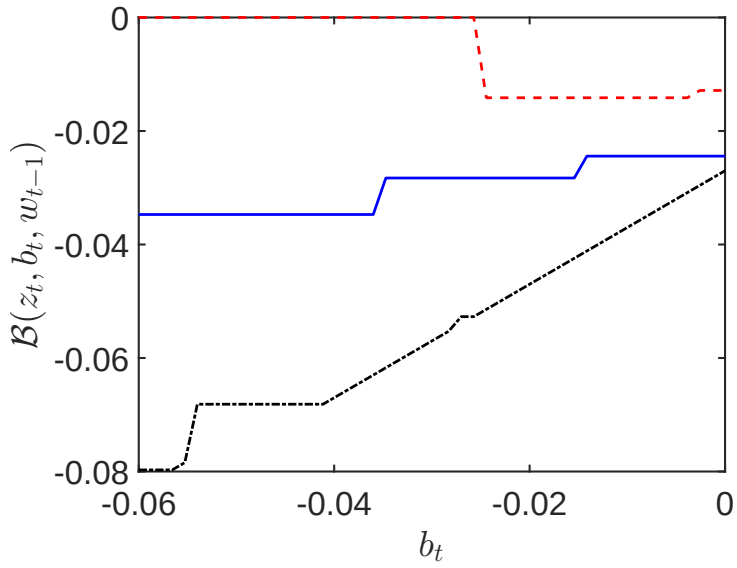
Quantitative Results

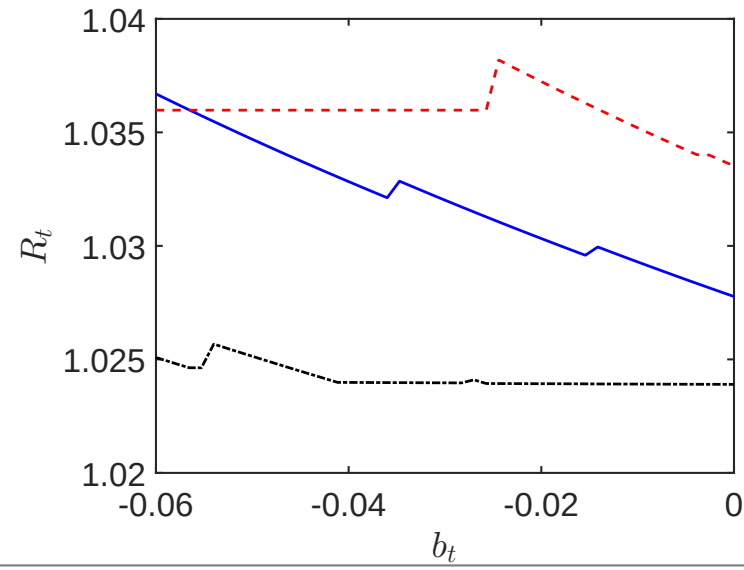
Functional Forms

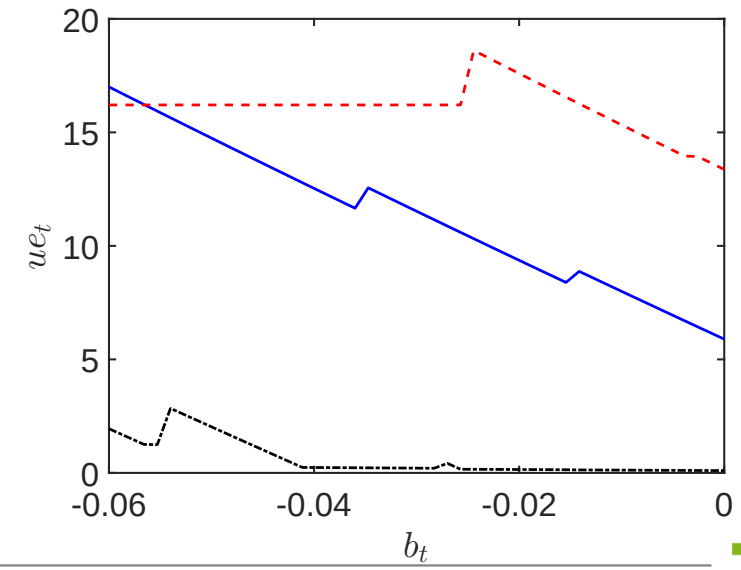
Parameters

Policy Functions - Fixed Exchange Rate Regime

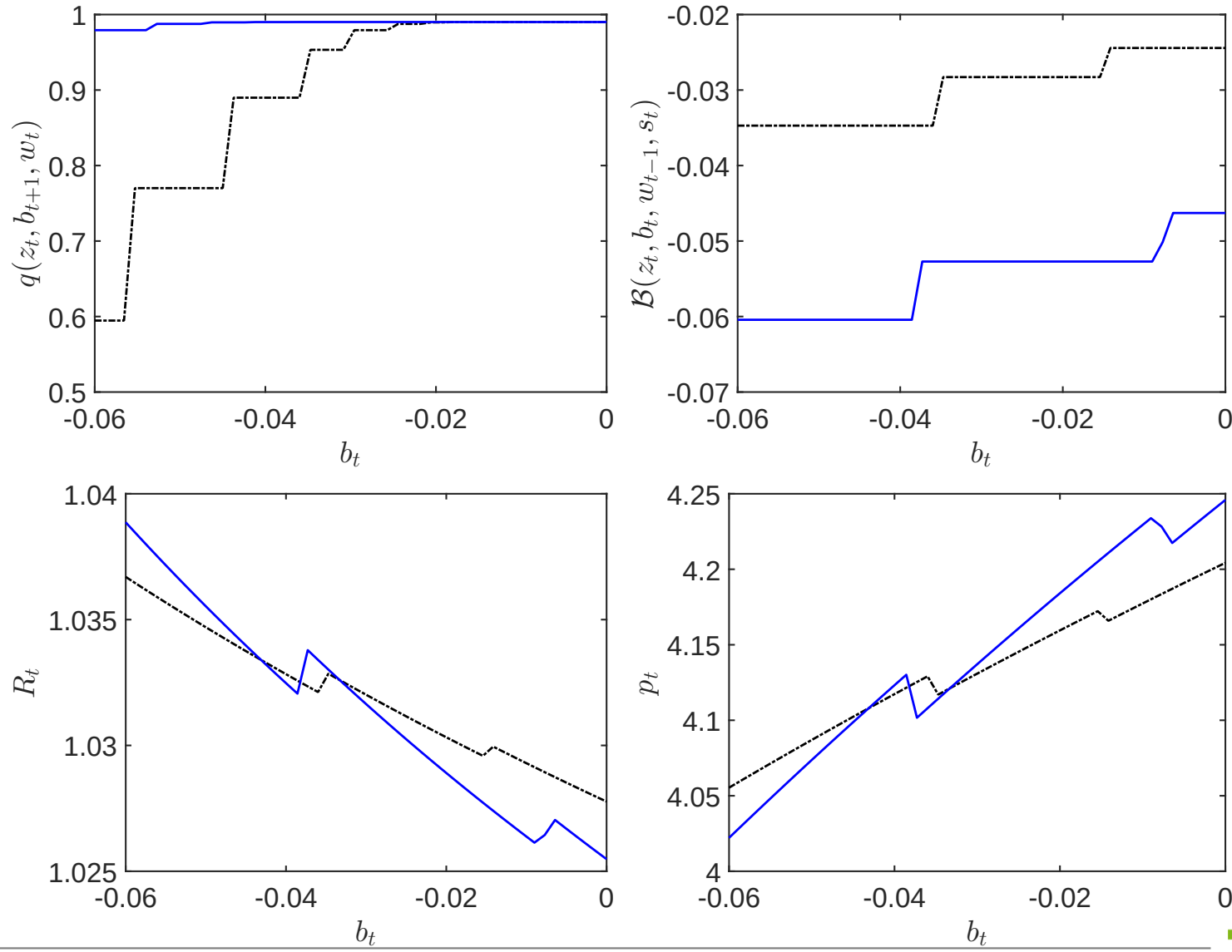








Policy Functions - Fixed vs Flexible Exchange Rate Regime



Business Cycle Moments

Exchange Rate:	Data	Fix	Flex
$E\left(\frac{y^T}{y^N}\right)$	26.36	25.06	25.19
$E\left(\frac{m^\star}{m}\right)$	4.7	2.94	2.82
$E\left(\frac{b}{y}\right)$	3.03	1.10	5.73
$E(SP)$	5.97	6.10	18.50
$E(PP)$	8.45	12.45	15.49
$\sigma(SP)$	2.75	36.42	55.47
$\sigma(PP)$	4.81	4.86	11.74
$\rho(y, SP)$	-0.85	-0.25	-0.57
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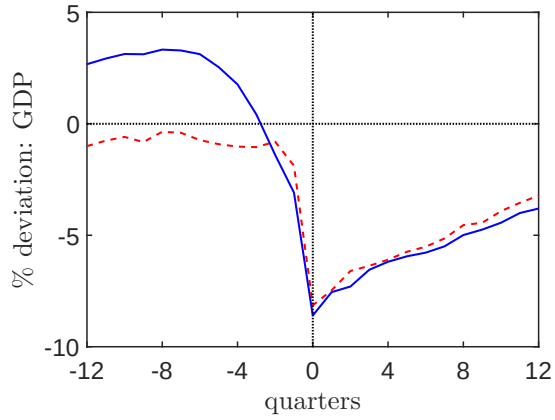
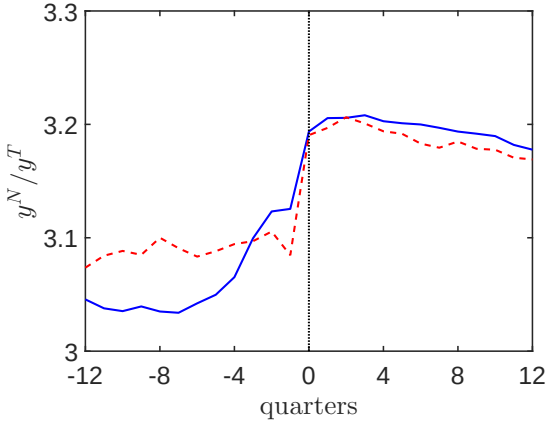
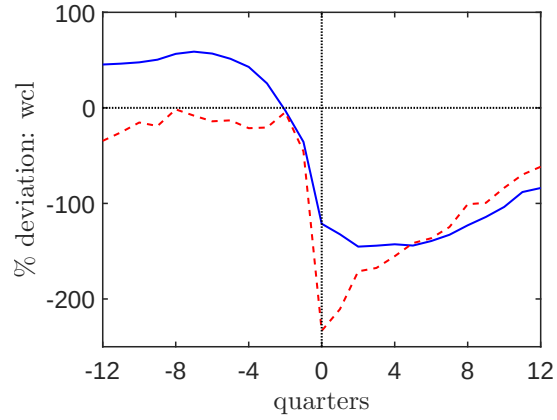
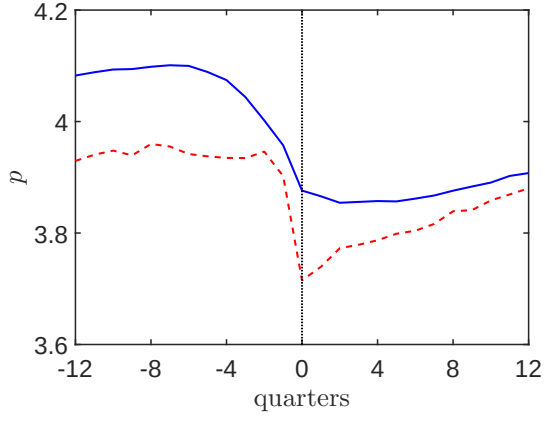
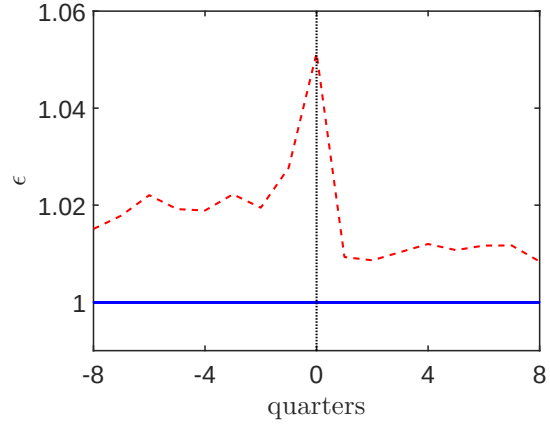
Default Events

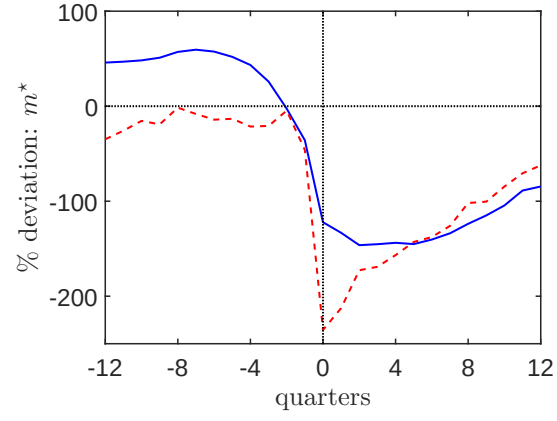


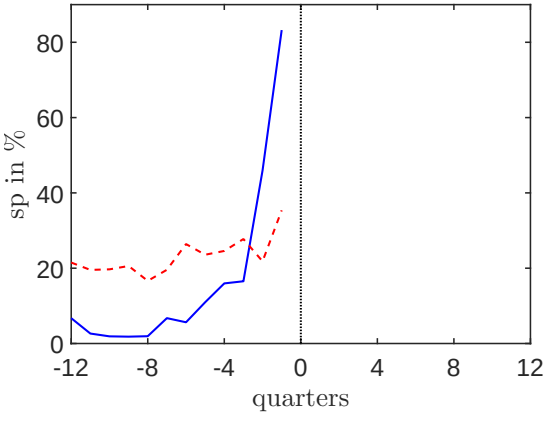


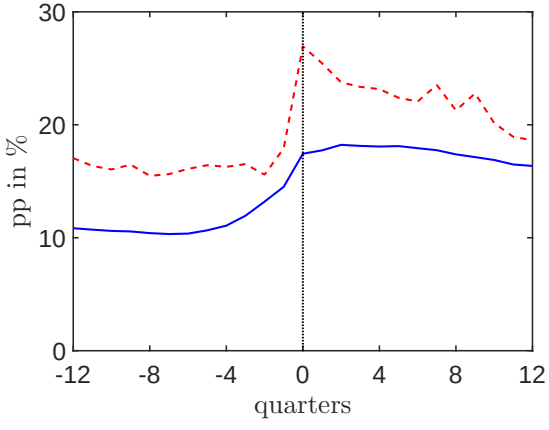


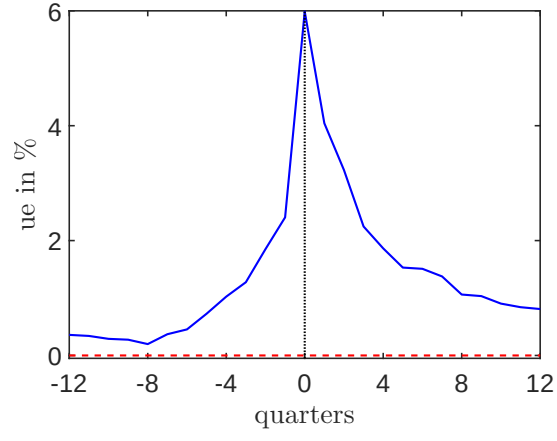












Welfare Analysis

- Fixed vs flexible exchange rate regime:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\left((1+\Delta)\, c_t^*\right) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(c_t^{\diamond}\right)$$

  - $*$: model with $\mathcal{F} = FIX$
  - $\diamond$: model with $\mathcal{F} = FE$

- Welfare cost of fixed exchange rate: $\Delta = 2.24\%$

Conclusion

Research Questions

- How does the interaction between the exchange rate regime and private & sovereign default risk influence macroeconomic outcomes?
- Are flexible exchange rates optimal when sovereign and private default risk makes nominal devaluations costly?

Main Results

- Higher debt levels and higher default frequency in the flexible exchange rate regime.
- The model rationalizes stylized facts of Twin Ds.
- Flexible exchange rates dominate fixed exchange rates.

Appendix

Private Sector Equilibrium I

- Aggregate Output

$$y_t^N = m_t^\star \int_{\bar{x}_t}^{\infty} x_i f^N \left(\Phi \left(\frac{p_t x_i}{p_t^M} \right), 1 \right) dX(x) \tag{10}$$

- Market clearing domestic intermediates:

$$f^M(h_t) = m_t^\star \int_{\bar{x}_t}^{\infty} \Phi \left(\frac{p_t x_{i,t}}{p_t^M} \right) dX(x) \tag{11}$$

- Market clearing N-good

$$c_t^N = y_t^N \tag{12}$$

- Market clearing T-good

$$c_t^T = \mathcal{I}_t + (1 - \xi + \xi(1 - X(\bar{x}))R_t)p^{\star M} m_t^\star \tag{13}$$

Private Sector Equilibrium II

- Labor Market

$$\left(w_t - \frac{\phi w_{t-1}}{\epsilon_t}\right)\left(\bar{h} - h_t\right) = 0 \tag{14}$$

- Definition: *The private sector equilibrium*

$$\left\{c_t, c_t^T, c_t^N, m_{i,t}, m_t^\star, h_t, \bar{x}_t, R_t, w_t, p_t^M, p_t\right\}$$

solves equations (1) *to* (14)*, taking* $\mathcal{S} = \{w_{t-1}, \epsilon_t, \mathcal{I}_t\}$ *as given.* $\mathcal{C}\left(w_{t-1}, \epsilon_t, \mathcal{I}_t\right)$ *denotes private sector equilibrium consumption.*

Quantitative Results

Functional Forms - Utility

- Utility Function:

$$u(c_t) = \frac{(c_t)^{1-\sigma}}{1-\sigma}$$

- Consumption aggregate:

$$A\left(c_t^T, c_t^N\right) = \left[\gamma\left(c_t^T\right)^{\frac{\rho^C-1}{\rho^C}} + (1-\gamma)\left(c_t^N\right)^{\frac{\rho^C-1}{\rho^C}}\right]^{\frac{\rho^C}{\rho^C-1}}$$

Functional Forms - Production

- Intermediate inputs:

$$f^M(h_t) = A^M(h_t)^{\alpha^M}$$

- N-sector:

$$f^N(m_t, m_t^\star) = A^N\left[\alpha^N(m_t)^\rho + \left(1-\alpha^N\right)(m_t^\star)^\rho\right]^{\frac{1}{\rho}}$$

- Idiosyncratic productivity: $X(x_i) = \frac{x_i - 1 + \zeta}{2\zeta}$

Functional Forms - Endowment

- T-endowment:

$$\mathcal{Y}(z_t, s_t) = \begin{cases} A^T \theta \exp\left(\mathbb{E}(z)\right), & \text{if } s_t = D \,\&\, z_t > \theta \mathbb{E}(z) \\ A^T \exp(z_t), & \text{otherwise} \end{cases}$$

- Endowment shock:

$$z_t = \rho_Z \, z_{t-1} + \epsilon_t^Z$$

with $\epsilon_t^Z \sim \mathcal{N}(0, \sigma_\epsilon^Z)$

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Parameters - Private Sector

Parameter	Values	Description	Targets
γ	0.26	weight on T-consumption	SGU (2016)
ρ^C	0.5	subst. elasticity consumption	SGU (2016)
ϕ	0.99	wage rigidity	SGU (2016)
ρ	0.65	subst. elasticity intermediates	MY (2012)
A^N	0.4258	normalization N-sector	GDP=1
α^N	0.5527	weight on domestic inputs	$\mathbb{E}\left(\frac{m^\star}{m}\right)$
A^T	0.26	normalization T-Sector	$\mathbb{E}\left(\frac{y^T}{y^N}\right)$
A^M	1	normalization M-sector	unemployment in default
α^M	0.70	labor share M-sector	MY (2012)
ξ	0.38	share of financed imports	KR (2015)
ζ	0.3015	volatility idiosyncratic shock	$\mathbb{E}(PP)$
η	0.80	recovery rate WCL-loans	$\sigma(PP)$
$p^{M\star}$	1	real price intermediate imports	$m^\star$ in default

Parameters - Government

Parameter	Values	Description	
σ	2	risk aversion	Standard value
β	0.88	time preference	$\mathbb{E}\left(\frac{b}{y}\right)$
φ	0.10	reentry probability	Moussa (2013)
θ	0.97	exogenous default cost	$\mathbb{E}(SP)$
ρ_Z	0.9317	persistence endowment shock	Na et al. (2014)
σ_{ϵ^Z}	0.037	vola. endowment shock	Na et al. (2014)

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