Interest rate shocks and the composition of sovereign debt

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Fiscal Policy and Sovereign Debt

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Motivation

- Emerging countries borrow large share of their government debt from foreign investors

  $\rightarrow$ they are exposed to world interest rate fluctuations

- Increase in US interest rates associated with large declines in output in emerging countries

- Why not borrow *domestically* instead?
  - would avoid external shocks that affect interest rates
  - but, domestic debt *crowds out* investment in capital

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- This paper:
  - quantitative sovereign default model with endogenous decision on debt composition
  - accounts for patterns observed in data
  - quantify the role of financial development and domestic debt to mitigate exposure

Summary of empirical evidence

- Panel of 14 emerging countries during 1960-2007 (some analyses restricted to 1969-1996)
- Domestic debt and defaults data from Reinhart and Rogoff (2011)

Main results:

1. Financial development positively related to share of domestic debt
   - financial development measured as liquid liabilities to GDP (direct link to model)
2. Negative effects of increase in U.S. interest rate on emerging economies output
   - larger drop in output if less financially developed
3. Domestic debt crowds out capital
   - Broner et al (2014): ↑ banks' holdings of gov't debt, ↓ private credit in Euro Area
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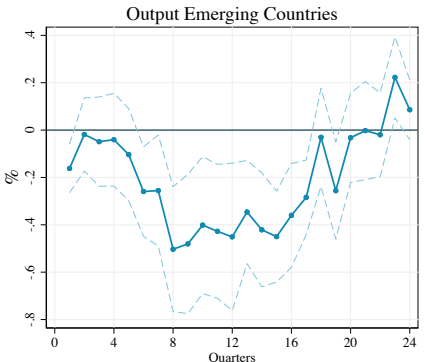
Output response to increase in U.S. interest rate

$$y_{it+h} = \beta_h u_t^r + \Gamma_{ih} X_{it}' + \alpha_{ih} + \varepsilon_{it+h} \tag{1}$$

- Controls, X_{it} include:
  - lagged output, interest rates, exchange rates, and linear and quadratic time trends
- After a shock that ↑ U.S. interest rate by 1 pp, real GDP ↓ 0.4% in emerging countries



- Romer-Romer shocks: 1969-1996
- Other specifications: [see]
  - real exchange rates
  - other shocks
  - time period 1960-2007

Output response and financial development

$$y_{it+h} = \beta_h u_t^r + \gamma_h (u_t^r \times \text{Fin Dev}_{it-1}) + \Gamma_{ih} X_{it}' + \alpha_{ih} + \varepsilon_{it+h} \tag{2}$$

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- If coefficient γ_h is positive: financial dev. *mitigates* the drop in output after shock

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	Interaction coefficient, γ_h					
Quarters after shock:	4	6	8	10	12	16
	0.008	0.012	0.018*	0.020**	0.022**	0.000
	(0.006)	(0.008)	(0.010)	(0.009)	(0.010)	(0.008)

Driscoll-Kray standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01

- At the 75th percentile of financial dev. (*high FD*), output drops less than 0.2pp
- At the 25th percentile (*low FD*), output drops 0.6pp

Output response and financial development

- Alternatively, consider two separate regressions: for low and high financial dev.

$$y_{it+h} = \beta_h^{\text{Low}} u_t^r + \Gamma_{ih}^{\text{Low}} X_{it}' + \alpha_{ih}^{\text{Low}} + \varepsilon_{it+h}^{\text{Low}} \quad \text{if} \quad \text{Fin Dev}_{it} < \text{P50}(\text{Fin Dev}_t)$$

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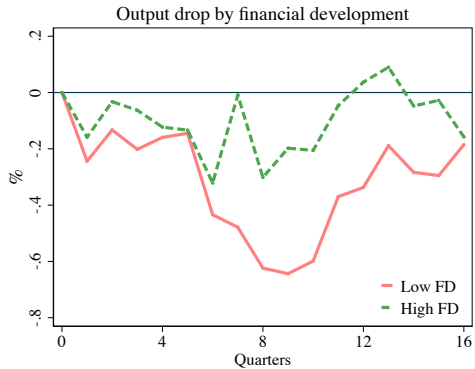

[other specifications]

Key ingredients and intuition for model

- Emerging countries suffer output losses after increase in international interest rates
  - exposed through sovereign debt issued to external creditors

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- Main intuition in line with empirical results
  - financial development mitigates effect on output of an increase in interest rates
  - because it allows countries to borrow more domestically
  - this mechanism is present in data: more financial dev., larger domestic debt share [see]

  → model must introduce financial intermediaries to capture notion of financial development

Model Overview

- Small open economy business cycle model that integrates
- banking sector (financial intermediaries)
- into sovereign default model with productivity and interest rate shocks
- domestic and external government debt

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  - production: $Y = zF(K, L)$
  - z is aggregate productivity shock that follows AR1 process
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- **Int'l creditors**:
  - risk neutral and unconstrained, invest in external government debt
  - stochastic international risk free rate, R^*

[see details]

Model Overview

- **Banks**: - financial intermediaries
  - receive deposits from households
  - invest in capital and domestic government debt
  - collateral constraint limits borrowing from households

→ *financial development* captured by collateral constraint

→ domestic gov't debt *crowds out investment* in capital due to collateral constraint

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- **Government**: - finances public expenditures using
    - ○ distortionary taxes on labor income
    - ○ government debt: external and domestic
  - can separately default on external and domestic debt

- note: bonds are long-term, but here for exposition show model with one-period bonds

Bank Problem

- Aggregate state: $S = (A, a, z, R^*)$
  - $A = (B^*, B, K, D)$ are assets: bonds, capital, and deposits
  - a is default or autarky state (defined later)
  - z and R^* are stochastic states

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  - z and R^* are stochastic states
- Banks receive deposits, d, from households at price q^D
- Invest in: - capital with stochastic returns $R_K = zF_K + 1 - \delta_K$
  - defaultable domestic bonds, b, at price q
- Collateral constraint: can only obtain fraction θ of net worth from deposits
- Die with probability $1 - \sigma$. If so, transfer net worth, n, to household
  - ensures banks build up of net worth limited, so collateral constraint binds

Bank Problem

Value of bank with net worth n:

$$V^b(n;S) = \max_{k',b',d'} \left\{ \beta \mathbb{E}[(1-\sigma)n' + \sigma V^b(n';S')] \right\}$$

s.t.

- Budget constraint: $k' + q(S)b' = n + q^D(S)d'$
- Collateral constraint: $q^D(S)d' \leq \theta n$
- Evolution of net worth: $n' = R_K(S')k' + \delta(S')b' - d'$

where $\delta(S) = \{0, 1\}$ is government repayment decision on domestic debt

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- note: assume households utility is $U(C, L) = C + v(L)$, so, deposits price: $q^D(S) = \beta$

Government

- Provides public goods G and maximizes utility by choosing
  - taxes on labor income: τ
  - domestic and external debt: B, B^*
  - domestic and external repayment: δ, δ^*
- Resulting optimal program: smoothes tax distortions by borrowing
- Exogenous default costs: identical for both types of default
  - autarky: lose access to credit market in which it defaults (re-enter with probability γ)
  - productivity during autarky: $h(z) \leq z$
- Autarky states $a = \{\text{normal}, \text{domestic autarky}, \text{external autarky}, \text{both}\}$

Government Budget Constraint

Government budget constraint in four states:

- Normal times:
$$G + \delta B + \delta^* B^* = \tau w(S)L + \delta q(S)B' + \delta^* q^*(S)B^{*\prime}$$
- Domestic autarky: no B
$$G + \delta^* B^* = \tau w(S)L + \delta^* q^* B^{*\prime}$$

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- External autarky: no B^*
$$G + \delta B = \tau w(S)L + \delta q(S)B'$$
- Autarky in both markets: no B or B^*
$$G = \tau w(S)L$$

Markov Equilibrium

- A Markov equilibrium consists of
  - policy functions $\pi(S) = (\delta^*, \delta, B^{*\prime}, B', \tau)$
  - allocation rules $Y(S) = (C, L, B^{*\prime}, B', K', D')$
  - pricing functions $P(S) = (q, q^*, q^D, R_K, w)$

  such that

  i. associated outcomes are competitive equilibria [see definition]

  ii. given allocation rules, pricing rules, and future policy rules, then the current policy $\pi(S)$ is optimal for the government

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- Use primal approach:
  - government directly chooses current allocations and policies
  - s.t. implementability constraints: constraints that summarize all FOC and budget constraints of competitive equilibrium

Main mechanisms of the model

1. Main trade-offs in sovereign debt compostion: [see FOC]

   - cost of domestic debt: it crowds out investment in capital
     - bank budget + collateral constraint: $K' = (1+\theta)N - qB'$

     → crowding out effect

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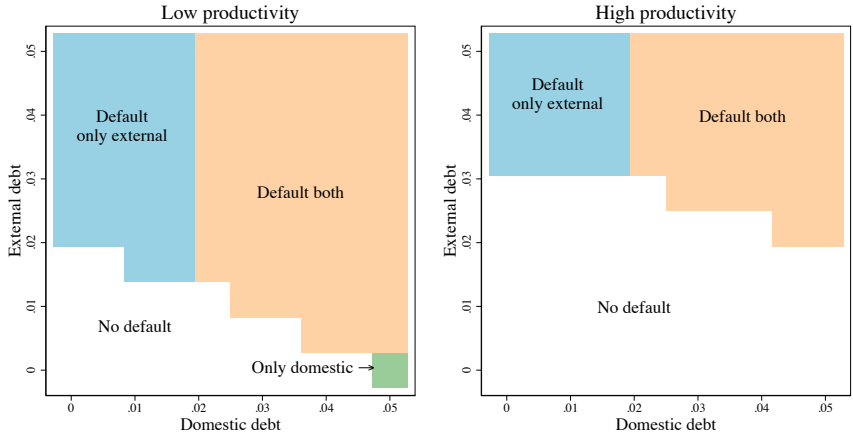
   - benefit of domestic debt: lower default probability on domestic $\Rightarrow$ lower interest rate
     - domestic default hurts own banks as it decreases its net worth

$$N = \sigma(R_K K + \delta B - D) + (1-\sigma)\bar{n}$$

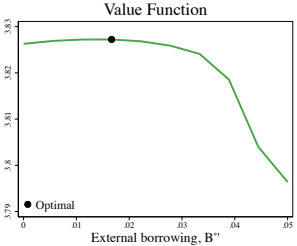
Ex-post incentives to default

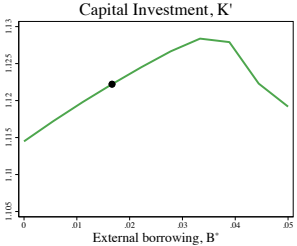
Default decisions for a given amount of external and domestic debt

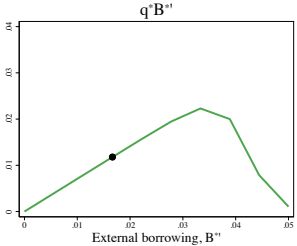


Government borrowing decisions

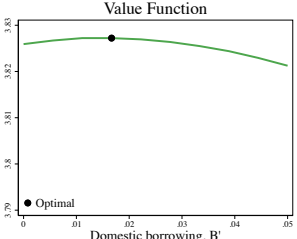
External borrowing

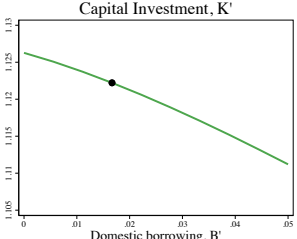


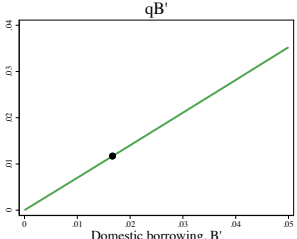




Domestic borrowing







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     - domestic default hurts own banks as it decreases its net worth

$$N = \sigma(R_K K + \delta B - D) + (1-\sigma)\bar{n}$$

2. How does an increase in interest rate affect output?
   - gov't budget constraint: $G + B + B^* = T(L) + qB' + \downarrow q^* B^{*\prime}$
   - substitute external debt with taxes ($\downarrow L$) and domestic debt ($\downarrow K'$)

Quantitative analysis

- Set model parameters to match features of emerging economies on average [see all]
  - government expenditures to GDP, total debt to GDP, default rates, and
  - share of domestic rate and deposits to GDP

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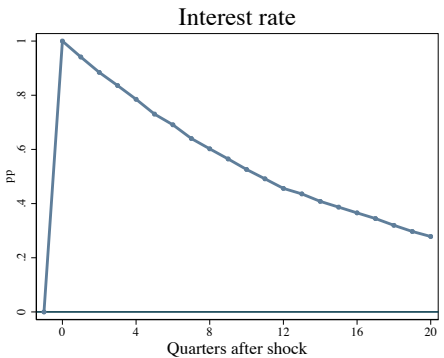
  - share of domestic rate and deposits to GDP

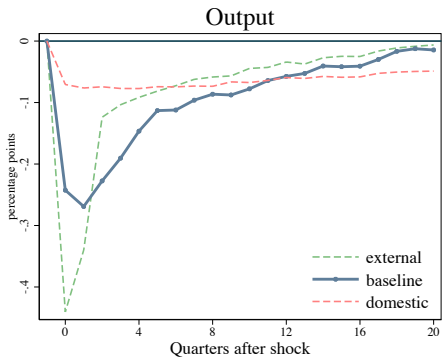
Results:

1. Model can generate drop in output after increase in R^*
   - role of domestic debt: mitigates the decrease in output
2. The role of financial development:
   - change collateral constraint parameter θ to capture *low* and *high* financial development
   - model accounts for key empirical findings on debt composition and financial dev.
3. *Pecking order* of default: in mild recessions default only on external

Output response to $\uparrow R^*$

- Impulse response to shock that increases R^* by 100 basis points
- Conterfactuals: only allow for domestic or external debt (keeping parameters the same)
  - domestic debt mitigates drop in output





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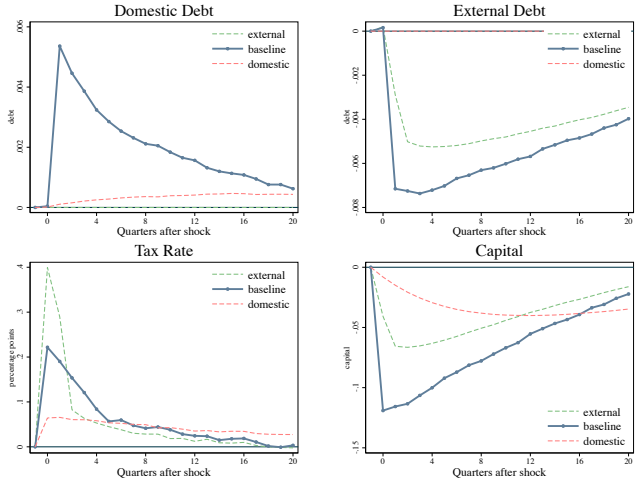


The role of financial development

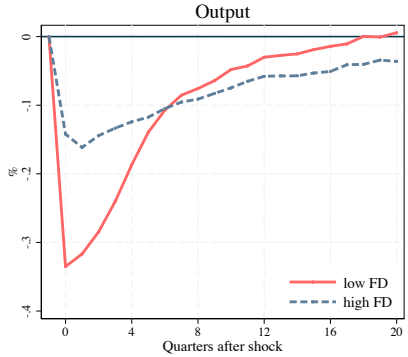
- Bank collateral constraint: $\beta D' \leq \theta N$
- Level of financial development captured by θ
  - baseline: choose θ to match average deposits to GDP
  - now: change only θ to match *low* (25th perc.) and *high* (75th) deposits to GDP from data

	Data		Model	
	Low FD	High FD	Low θ	High θ
Deposits to GDP	0.20	0.45	0.22	0.42
Domestic debt share	0.36	0.68	0.18	0.71

- Model predicts: less financial development, lower share of domestic government debt
  - consistent with data [see]

Financial development and output response

- Impulse response to shock that increases R^* by 1pp



- When financial development is low, output drop is larger, as in data
  - low financial development: larger crowding out effect of domestic debt
  - more costly to replace external debt by domestic debt due to crowding out

Output response to $\uparrow R^*$

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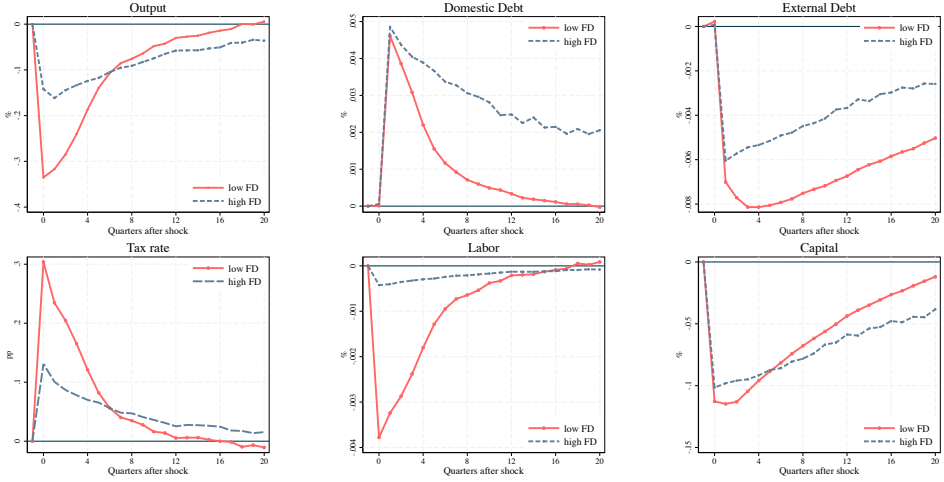


Patterns of discriminatory default

- In mild recessions: default only on external debt
- In severe/long recessions: default on both

	Data		Model	
Output deviation from trend:	External only	Both	External only	Both
Before default	-0.8%	-1.9%	-0.3%	-2.5%
Default period	-0.7%	-4.2%	-2.9%	-2.9%
After default	-0.6%	-2.2%	-2.3%	-3.4%
Frequency of default:	74%	26%	67%	33%

Note: the periods before and after default correspond to the average over the previous and following year of default, respectively.

- Key for this result: model generates countercyclical share of domestic debt (as in the data)

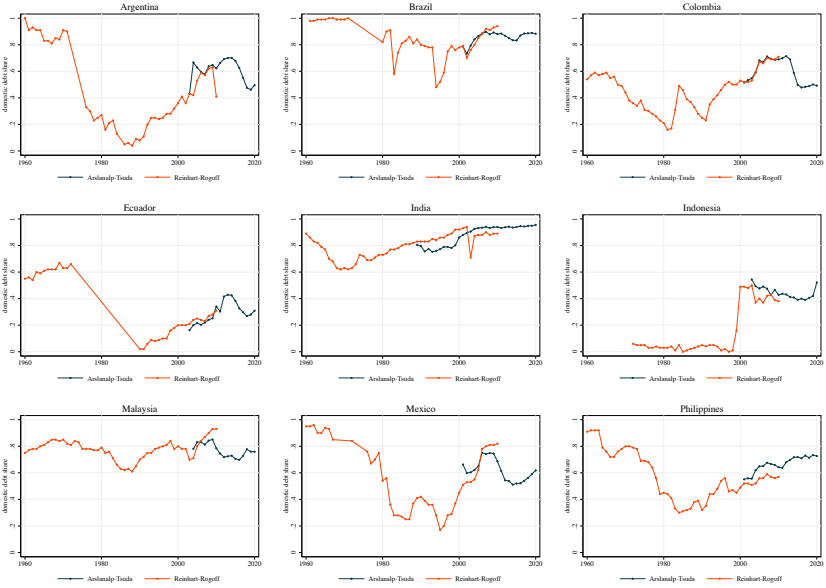
Conclusions

- This paper develops a business cycle model of sovereign default with
  - endogenous debt composition
  - separate default by type of debt
  - theory of vulnerability by level of financial development

- Model consistent with
  - relationship btw financial development and vulnerability of countries to external shocks
  - patterns of discriminatory default and pecking order to default

- Evaluate policies to limit vulnerability
  - domestic debt mitigates effect of external shocks: but only if financially developed
  - restricting external debt could depress economy by crowding out capital

Comparison of domestic debt databases



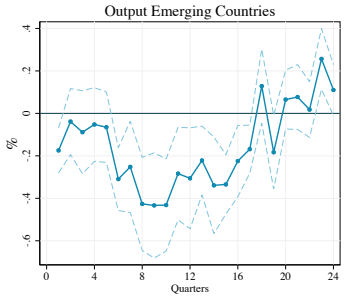
[back]

Output response: alternative specifications

- Real exchange rates:
  - an increase in U.S. interest rates might cause a change in real exchange rates
  - this could affect decision on domestic vs. external debt, and output response to the shock

- Add current bilateral real exchange rates, e_{it} in regressions

$$y_{it+h} = \beta_h u_t^r + \rho_{ih} e_{it+h} + \Gamma_{ih} X_{it}' + \alpha_{ih} + \varepsilon_{it+h} \tag{3}$$



Output response: alternative specifications

- Large literature on how to measure *monetary policy shocks*
- In the baseline specification, I considered Romer and Romer shocks
  - most used in recent studies
- Other shocks:
  - define shock to interest rate as residual from Taylor rule

$$r_t^{\text{US}} = \sum_{j=1}^{4} \beta_{1j} y_{t-1}^{US} + \sum_{j=1}^{4} \beta_{2j} r_{t-1}^{US} + \sum_{j=1}^{4} \beta_{3j} p_{t-1}^{\text{US}} + \sum_{j=1}^{4} \beta_{4j} M_{t-1}^{US} + u_t \tag{4}$$

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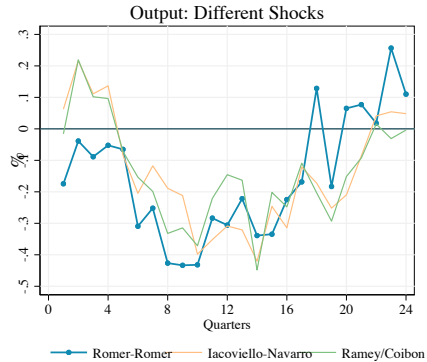

- Very similar results when using other shocks specifications

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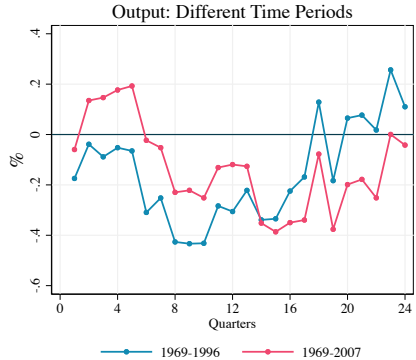
Output response: alternative specifications

- For the period 1969-2007: similar in magnitude but maximum response comes later



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Output response and financial development

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- If coefficient γ_h is positive:
  - higher financial dev. *mitigates* the drop in output after a shock that ↑ U.S. interest rate

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Quarters after shock:	1	4	6	8	10	12	16
1969-1996	0.006	0.008	0.012	0.018*	0.020**	0.022**	0.000
	(0.005)	(0.006)	(0.008)	(0.010)	(0.009)	(0.010)	(0.008)
1969-2007	0.004	0.014**	0.024***	0.021***	0.018**	0.010	-0.006
	(0.003)	(0.005)	(0.008)	(0.008)	(0.008)	(0.009)	(0.010)

Driscoll-Kray standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01

- At the 75th percentile of financial dev. (*high FD*), output drops less than 0.2pp
- At the 25th percentile (*low FD*), output drops 0.6pp

Household Problem

- State of households: existing deposits, D
- Aggregate state $S = (A, a, z, R^*)$ where $A = (B^*, B, K, D)$ are assets and a is default state
- Value of the household:

$$V^h(D; S) = \max_{L, D'} \{C + v(L) + G + \beta \mathbb{E} V^h(D'; S')\}$$

subject to budget constraint

$$C + q^D(S) D' = (1 - \tau) w(S) L + D + X - (1 - \sigma) \bar{n}$$

where

- X are aggregate dividends from banks
- w are wages
- $(1 - \sigma)\bar{n}$ are transfers s.t. each newborn bank has initial net worth $\bar{n}$

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Firm Problem

- Rent capital from banks at price R_K, depreciates at rate δ_K
- Hire workers at wage w
- Working capital: pay a fraction κ of salaries in advance

$$\max_{K,L} zF(K,L) + (1-\delta_K)K - R_K K - wL(1+r^*\kappa)$$

- FOC:

$$R_K = zF_K(K,L) + 1 - \delta_K$$
$$w(1+r^*\kappa) = zF_L(K,L)$$

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International Creditors

- Competitive risk neutral international creditors can invest in
  - defaultable external government debt
  - international risk free asset: return R^* follows AR1
- Given the repayment rule of the government, $\delta^*(\cdot)$, schedule of bond prices $q^*(\cdot)$ offered to a government depends on
  - new assets: $A' \equiv (B^{*\prime}, B', K', D')$
  - productivity z, world interest rate, R^*, and autarky state $\tilde{a}$
- Bond prices: lenders indifferent risk free asset and lending to gov't

$$R^* = \frac{\mathbb{E}\left[\delta^*(A'; a', z', R^{*\prime}) \middle| \tilde{a}, z, R^*\right]}{q^*(A'; \tilde{a}, z, R^*)}$$

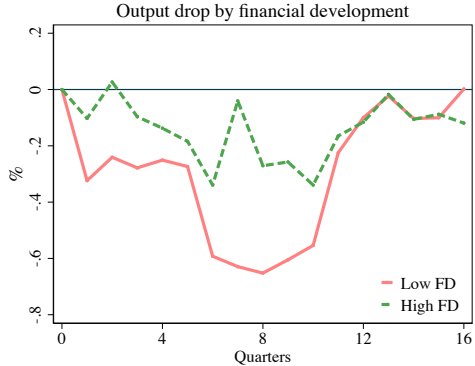
determines bond schedule $q^*(\cdot)$ [back]

Output response and financial development

- Alternatively, consider two separate regressions: for low and high financial dev.

$$y_{it+h} = \beta_h^{\text{Low}} u_t^r + \Gamma_{ih}^{\text{Low}} X'_{it} + \alpha_{ih}^{\text{Low}} + \varepsilon_{it+h}^{\text{Low}} \qquad \text{if} \quad \text{Fin Dev}_{it} < \text{P50}_t(\text{Fin Dev}_t)$$

$$y_{it+h} = \beta_h^{\text{High}} u_t^r + \Gamma_{ih}^{\text{High}} X'_{it} + \alpha_{ih}^{\text{High}} + \varepsilon_{it+h}^{\text{High}} \qquad \text{if} \quad \text{Fin Dev}_{it} > \text{P50}_t(\text{Fin Dev}_t)$$



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Competitive Equilibrium

Given policy $\pi(S) = (\tau, B', B^{*\prime}, \delta, \delta^*)$ a competitive equilibrium consists of

- allocations $Y(S) = (C, L, A')$,
- value functions of households and banks, $V^h(S), \nu(S)$
- pricing functions $P(S) = (q, q^*, q^D, R_K, w)$

such that:

i. solve households, banks, and firms optimization problem

ii. international creditors' condition is satisfied

iii. policy satisfies government budget constraint

iv. allocation satisfies country-level budget constraint

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Parameters

- Disutility of labor: $v(L) = \psi \frac{L^{1+\phi}}{1+\phi}$
- Exogenous productivity loss in autarky: $h(z) = z - \max\{\zeta_0 z + \zeta_1 z^2, 0\}$

Assigned parameters:		
Parameter		Source
Average world risk free rate	$\mu_R = 0.017$	Average US interest rate (quarterly rate)
Risk free rate autocorrelation	$\rho_R = 0.955$	AR(1) on US interest rate
Risk free rate standard dev.	$\sigma_R = 0.003$	AR(1) on US interest rate
Capital share	$\alpha = 0.3$	Standard capital share
Debt decay rate	$\lambda = 0.05$	Average maturity
Autarky duration	$\gamma = 0.080$	Gelos et al 2011
Inverse Frisch elasticity	$\phi = 0.5$	Keane and Rogerson 2012
Productivity autocorrelation	$\rho_z = 0.95$	Neumeyer and Perri 2005
Working capital	$\kappa = 0.26$	Neumeyer and Perri 2005

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Parameters

Parameters from Matching Moments:		
Parameter		Moment matched
Discount factor	$\beta = 0.986$	Default probability
Banks survival rate	$\sigma = 0.92$	Share of domestic debt
Collateral constraint	$\theta = 0.46$	Deposits to GDP
Banks initial net worth	$\bar{n} = 0.70$	Returns on equity
Gov. expenditures	$G = 0.035$	Government expenditures to GDP
Disutility of working	$\xi = -2.15$	Hours worked
Productivity standard dev.	$\sigma_z = 0.009$	Volatility of GDP
Productivity cost of default	$\zeta_0 = -0.182$	Debt to GDP
Productivity cost of default	$\zeta_1 = 0.195$	Average spread

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Model fit

	Data	Model
Default probability, annual %	4.51	1.05
Debt to GDP, %	32.5	30.9
Deposits to GDP	0.32	0.33
Share of domestic debt	0.54	0.52
Return on equity, %	12.5	16.5
Government expenditures to GDP	0.14	0.13
Hours worked	0.22	0.22
Output volatility	3.08	3.11
Average spread	2.45	2.14

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Financial development and domestic debt

- Panel regression: share of domestic debt on financial development + controls

$$\text{Dom Debt}_{it} = \beta \text{Fin Dev}_{it-1} + \Gamma X'_{it-1} + \alpha_i + \delta_t + \varepsilon_{it}$$

	1960-1996			1960-2007		
	(1)	(2)	(3)	(4)	(5)	(6)
Financial dev.	0.464***	0.399***	0.343***	0.331***	0.388***	0.200***
Debt to GDP	-0.247***	-0.249***	-0.255***	-0.155***	-0.138***	-0.105***
GDP	-2.341*	-17.781***	-11.059**	-0.023	-10.091***	-2.406
Country Effects	No	Yes	Yes	No	Yes	Yes
Year Effects	No	No	Yes	No	No	Yes
Observations	365	365	365	516	516	516

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

- A 10pp increase in financial dev., increases share of domestic debt by $\approx$ 2–4.6pp

Problem with Only External Debt: FOC

μ = Lagrange multiplier on government budget constraint

$$\mu(S): \quad G + B^* \leq q^*(B^{*\prime}, K', D'; z, R^*)B^{*\prime} + T(L; S)$$

Only external debt:

$$\underbrace{\left(q^* + \frac{\partial q^*}{\partial B^{*\prime}} B^{*\prime}\right)}_{\text{revenue effect}} (1+\mu) = \beta \mathbb{E}\Big[\underbrace{\delta' \left(1+\mu'\right)}_{\text{repayment effect}} \Big] \quad + X_e(S')$$

- Revenue effect: how much more government gets from increasing debt
  - gets q^* but additional unit of borrowing decreases q^*
  - increases consumption and relaxes gov't budget constraint
- Repayment effect: cost of repaying debt tomorrow
  - decreases consumption and tightens gov't budget constraint

Both External and Domestic Debt: FOCs

μ = Lagrange multiplier on government budget constraint

ρ = Lagrange multiplier on bank budget constraint

FOC($B^{*\prime}$):

$$\mu\left(q^{*}+\frac{\partial q^{*}}{\partial B^{*\prime}}B^{*\prime}+\frac{\partial q}{\partial B^{*\prime}}B^{\prime}\right)+q^{*}+\frac{\partial q^{*}}{\partial B^{*\prime}}B^{*\prime}=\beta\mathbb{E}\left[\tilde{\delta}^{\prime}\left(\mu^{\prime}+1\right)\right]+\rho\frac{\partial q}{\partial B^{*\prime}}B^{\prime}$$

where $\frac{\partial q}{\partial B^{*\prime}}B^{\prime}<0$ captures indirect effect on the price of the other type of debt

Both External and Domestic Debt: FOCs

μ = Lagrange multiplier on government budget constraint

ρ = Lagrange multiplier on bank budget constraint

η = Lagrange multiplier on bank collateral constraint

FOC($B^{*\prime}$):

$$\mu\left(q^{*}+\frac{\partial q^{*}}{\partial B^{*\prime}}B^{*\prime}+\frac{\partial q}{\partial B^{*\prime}}B^{\prime}\right)+q^{*}+\frac{\partial q^{*}}{\partial B^{*\prime}}B^{*\prime}=\beta\mathbb{E}\left[\tilde{\delta}^{\prime}\left(\mu^{\prime}+1\right)\right]+\rho\frac{\partial q}{\partial B^{*\prime}}B^{\prime}$$

FOC($B^{\prime}$):

$$\mu\left(q+\frac{\partial q}{\partial B^{\prime}}B^{\prime}+\frac{\partial q^{*}}{\partial B^{\prime}}B^{*\prime}\right)+\frac{\partial q^{*}}{\partial B^{\prime}}B^{*\prime}=\beta\mathbb{E}\left[\tilde{\delta}^{\prime}\left(\mu^{\prime}-\sigma\left(\rho^{\prime}+\theta\eta^{\prime}\right)\right)\right]+\rho\left(q+\frac{\partial q}{\partial B^{\prime}}B^{\prime}\right)$$

where $\rho\left(q+\frac{\partial q}{\partial B^{\prime}}B^{\prime}\right)>0$ captures crowding out effect

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Markov Problem

The problem for the government under repayment in normal times is then

$$V(S) = \max \quad C + v(L) + \beta \mathbb{E} \max\{V(S'), W^{\text{default}}(S')\}$$

subject to the implementability constraints:

- Country aggregate budget constraint: $zF(K,L) = C + K' - (1-\delta_K)K + G + \delta^* B^* - \delta^* q^* B^{*\prime}$
- Government budget constraint

$$G + \delta B + \delta^* B^* = \underbrace{(zF_L - v'(L))L}_{T(L;S)} + \delta q(S) B' + \delta^* q^*(S) B^{*\prime}$$

- Bank aggregate budget constraint
- Bank aggregate collateral constraint
- And, pricing equations for domestic and external bonds

Markov Problem

- International lenders break-even condition

$$\frac{\mathbb{E}\Big[\delta^*(S')\Big|z, R^*\Big]}{q^*(A'; z, R^*)} = R^*$$

- Domestic bank first order condition

$$\frac{\mathbb{E}\Big[m(S')\delta(S')\Big]}{q(A'; z, R^*)} = \mathbb{E}\big[m(S')(z'F_K(S') + 1 - \delta_K)\big]$$

  - where, $m(S) = 1 - \sigma + \sigma\nu(S)$
  - and, $\nu(S) = \mathbb{E}\big[m(S')\big((1+\theta)(z'F_K(S') + 1 - \delta_K) - \theta\big)\big]$