FX Interventions, Financial Intermediation, and External Shocks in Emerging Economies
MEGA-B

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October 2019

Central Reserve Bank of Peru

Introduction

Sterilized Foreign Exchange (FX) interventions?

Dissonance between academic research and policy practice.

- *Academic view*: FX intervention should be irrelevant [Backus and Kehoe, 1989].
- Many central banks have engaged in FX interventions (especially, EMEs).

Introduction

[Chang, 2018]: FX interventions can affect equilibrium because the associated sterilization operation relax or tighten financial constraints. Assume CB sells foreign exchange,

- **Do no bind**. Domestic banks accommodate FX bonds borrowing less from the world market.
- **Bind**. This operation frees resources for banks, allowing them to increase supply of loans to the domestic private sector.

[Hofmann et al., 2019] find evidences on Substitution Effect.

- *Crowding out* of bank lending capacity by changes in the supply of FX bonds.
- To lean against the increase in bank lending capacity through the risk-taking channel of the exchange rate.

1. Introduction
2. The Model
3. Calibration Strategy
4. Quantitative Results

Model

Workers

- GHH preferences, CRRA, and Internal Habit Formation: [Greenwood et al., 1988], [Miao and Wang, 2010], and [Gertler et al., 2012].

Financial Sector

- Moral Hazard problems in interaction between banks and depositors: [Gertler and Kiyotaki, 2010], [Gertler and Karadi, 2013], [Gertler et al., 2012], and [Aoki et al., 2018].
- FX Bonds: [Chang et al., 2017], [Chang and Velasco, 2017], and [Chang, 2018].
- Credit Dollarization: [Castillo et al., 2006].

Production Sector

- Non-Commodity Sector is modelled in a NK traditional way: nominal rigidity a lá [Rotemberg, 1982].
- Commodity Sector.
- Both sectors face investment adjustment costs.

Rest of the model

- Foreign Sector based on SVAR-X.
- Monetary authority follows a conventional Taylor Rule and a FX intervention rule.

Households

Preferences:

$$\mathbb{E}_t \left[\sum_{j=0}^{\infty} \beta^j \frac{1}{1-\gamma} \left(C_{t+j} - \mathcal{H} C_{t+j-1} - \frac{\zeta_0}{1+\zeta} H_{t+j}^{1+\zeta} \right)^{1-\gamma} \right] \tag{1}$$

where $\beta \in (0,1)$, $h \in [0,1]$, and $\gamma > 0$.

Budget Constraint:

$$C_t + D_t + T_t = w_t H_t + \Pi_t + R_t D_{t-1} \tag{2}$$

where T_t denotes to lump-sum taxes needed to finance the central bank's quasi-fiscal deficit plus government expenditure and Π_t represents firm's profits plus transfers from financial system:

Financial System - Banks

Each banker member manages a bank until she retires with probability $1 - \sigma$.

Banks fund non-commodity businesses by lending loans in both domestic currency (l_t) and foreign currency (l_t^*). They also buy sterilized bonds (b_t) issued by the central bank.

Total assets are financed by borrowing from households (d_t), from foreigners (d_t^*), and using own net worth (n_t).

Table 1: Bank's Flow of funds

Uses of Funds	**Sources of Funds**
l_t	d_t
$e_t l_t^*$	$e_t d_t^*$
b_t	n_t

Net worth evolves according to

$$n_{t+1} = R_{t+1}^{l} l_t + R_{t+1}^{l*} e_{t+1} l_t^* + R_{t+1}^{b} b_t - R_{t+1} d_t - e_{t+1} R_{t+1}^{*} d_t^* \tag{3}$$

Central Bank - FX intervention

Central Bank's Balance Sheet: $B_t = e_t F_t$, where F_t is the amount of official reserves.

Official reserves are invested abroad at the external interest rate R_t^*. The central bank makes operational losses (*quasifiscal deficit*) given by

$$T_t = \left(R_t^b - \frac{e_t}{e_{t-1}} R_t^* \right) B_{t-1} - \chi^c \Pi_t^c + G_t \tag{4}$$

FX interventions rule:

$$\ln B_t = (1 - \rho_B) B + \rho_B \ln B_{t-1} - \upsilon_e (\ln e_t - \ln e_{t-1}) + u_t^B \tag{5}$$

where u_t^B could be interpreted as an unanticipated central bank purchase of reserves (e.g., in order to accumulate reserves).

Financial System - Agency Problem I

After raising funds and buying assets, the banker decides whether to operate honestly or divert assets for personal use.

Any financial arrangement between the bank and creditors must satisfy the following incentive constraint:

$$V_t \geq \Theta(x_t)\left[\Delta l_t + \Delta^* e_t l_t^* + \Delta^b b_t\right] \qquad (6)$$

We assume that it is harder to divert some kind of assets than others.

Financial System - Agency Problem II

We assume that

$$x_t = \frac{e_t d_t^* - e_t l_t^*}{l_t + e_t l_t^* + b_t} \tag{7}$$

We interpret x_t as a measure of **currency mismatch** in the financial system. Note that we are also assuming that in the steady state $d^* > l^*$, i.e. deposit in foreign currency are higher than foreign currency lending within the economy.

Financial System - Agency Problem III

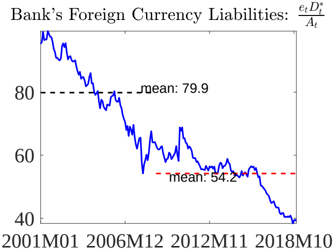
DATA

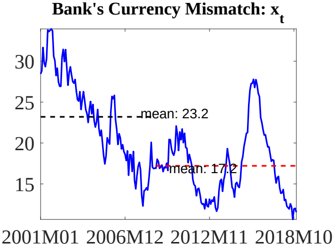
Assets:

- l_t: Banking Credit in Soles
- l_t^*: Banking Credit in Dollars
- b_t^*: Banking Investment

Liabilities:

- n_t: Banking Net Worth
- d_t^*: **Foreign Inflows + Domestic Deposits in Dollars**
- d_t: As residual.





More data here.

Financial System - UIP Deviations

Two UIP deviations:

$$\mu_t^{l*} = \mathbb{E}_t \left[\Omega_{t+1} \left(\frac{e_{t+1}}{e_t} R_{t+1}^{l*} - R_{t+1} \right) \right] \tag{8}$$

$$\mu_t^{d*} = \mathbb{E}_t \left[\Omega_{t+1} \left(R_{t+1} - \frac{e_{t+1}}{e_t} R_{t+1}^{*} \right) \right] \tag{9}$$

Financial System - Leverage Limits

Moreover,

$$\Phi_t n_t \geq \Delta l_t + \Delta^* e_t l_t^* + \Delta^b b_t \tag{10}$$

$$\Phi_t = \frac{\Delta v_t}{\Delta\Theta(x_t) - \left(\mu_t^l + \mu_t^{d*} x_t\right)} \tag{11}$$

where μ_t^l is the excess return of domestic currency loans over home deposit.

Whenever $\lambda_t^d > 0$, the leverage ratio Φ_t is increasing in both $(\mu_t^l + \mu_t^{d*} x_t)$ and Δv_t.

The leverage ratio also varies inversely with **exchange risk perceptions**, $\Theta(x_t)$.

Non-Commodity Sector: Final Good Sector

Final goods in non-commodity sector are produced from a variety of differentiated intermediate goods y_{jt}^{nc}, $j \in [0,1]$ under perfect competition according to a constant returns to scale technology as

$$Y_t^{nc} = \left(\int_0^1 y_{jt}^{nc \, \frac{\eta-1}{\eta}} \, dj \right)^{\frac{\eta}{\eta-1}}$$

where $\eta > 1$ is the elasticity of substitution across goods. Profit maximization implies

$$y_{jt}^{nc} = \left(\frac{p_{jt}^{nc}}{P_t^{nc}} \right)^{-\eta} Y_t^{nc} \qquad (12)$$

$$P_t^{nc} = \left(\int_0^1 p_{jt}^{nc \, 1-\eta} dj \right)^{\frac{1}{1-\eta}} \qquad (13)$$

Non-Commodity Sector: Intermediate Good Producer

At period t, jth firm

1. Buys $q_t^{nc} k_{jt}^{nc}$ borrowing from banks l_{jt} and l_{jt}^*.
2. Hires labor h_{jt} and acquires foreign goods m_{jt}.
3. Produces using a Cobb-Douglas Technology: $y_{jt}^{nc} = f(k_{jt-1}^{nc}, h_{jt}, m_{jt})$.
4. Sets prices (symmetric equilibrium).
5. Finally, she sells the used capital $\lambda_{nc} q_t^{nc} k_{t-1}^{nc}$ and pay financial costs $R_t^l l_{jt-1}$ and $R_t^{l*} e_t l_{jt-1}^*$.

Non-Commodity Sector: Intermediate Good Producer

We can define three price

$$R_t^k = \frac{z_t + \lambda_{nc} q_t^{nc}}{q_{t-1}^{nc}} \tag{14}$$

$$z_t = \alpha_k mc_t \frac{y_{jt}^{nc}}{k_{jt-1}^{nc}} \tag{15}$$

$$e_t = \alpha_m mc_t \frac{y_{jt}^{nc}}{m_{jt}} \tag{16}$$

Marginal cost and NK Phillips Curve

$$mc_t = \frac{1}{A_t^{nc}} z_t^{\alpha_k} e_t^{\alpha_m} w_t^{1-\alpha_k-\alpha_m} \tag{17}$$

$$(1+\pi_t)\pi_t = \frac{1}{\kappa}(1-\eta+\eta mc_t) + \mathbb{E}_t\left[\Lambda_{t,t+1}(1+\pi_{t+1})\pi_{t+1}\frac{Y_{t+1}^{nc}}{Y_t^{nc}}\right] \tag{18}$$

Non-Commodity Sector: Intermediate Good Producer

She faces CES function in order to buy capital $q_t^{nc} k_{jt}^{nc}$

$$q_t^{nc} k_{jt}^{nc} = A_t^e \left[(1-\delta^f)^{\frac{1}{\vartheta_l}} (l_{jt})^{\frac{\vartheta_l - 1}{\vartheta_l}} + (\delta^f)^{\frac{1}{\vartheta_l}} (e_t l_{jt}^*)^{\frac{\vartheta_l - 1}{\vartheta_l}} \right]^{\frac{\vartheta_l}{\vartheta_l - 1}} \tag{19}$$

Demand schedules for each currency

$$l_{jt} = (1-\delta^f) \left(\frac{\mathbb{E}_t \Lambda_{t,t+1} R_{t+1}^k}{\mathbb{E}_t \Lambda_{t,t+1} R_{t+1}^l} \right)^{\vartheta_l} (A^e)^{\vartheta_l - 1} q_t^{nc} k_{jt}^{nc} \tag{20}$$

$$e_t l_{jt}^* = \delta^f \left(\frac{\mathbb{E}_t \Lambda_{t,t+1} R_{t+1}^k}{\mathbb{E}_t \Lambda_{t,t+1} \frac{e_{t+1}}{e_t} R_{t+1}^{l*}} \right)^{\vartheta_l} (A^e)^{\vartheta_l - 1} q_t^{nc} k_{jt}^{nc} \tag{21}$$

Non-Commodity Sector: Capital Good Producer

Capital good firms buy non-commodity good I_t^{nc} and the rest of the stock of capital $\lambda_{nc}K_{t-1}^{nc}$ and convert them into new capital goods K_t via

$$K_t^{nc} = I_t^{nc} + \lambda_{nc}K_{t-1}^{nc} \tag{22}$$

where K_t^{nc} is finally sold to intermediate good producers at the price q_t^{nc}.

Producing capital implies an additional cost $\Phi^{nc}\left(\frac{I_t^{nc}}{I_{t-1}^{nc}}\right) I_t^{nc}$.

$$q_t^{nc} = \left[1 + \Phi^{nc}(.)\right] + \left(\frac{I_t^{nc}}{I_{t-1}^{nc}}\right)\partial\Phi^{nc}(.) - \mathbb{E}_t\left[\Lambda_{t,t+1}\left(\frac{I_{t+1}^{nc}}{I_t^{nc}}\right)^2 \partial\Phi^{nc}(.)\right] \tag{23}$$

Commodity Sector

Commodity goods Y_t^c are produced using specific sector capital K_{t-1}^c by the following production technology:

$$Y_t^c = A^c (K_{t-1}^c)^{\alpha_c} \tag{24}$$

In addition, these firms face investment adjustment costs $\Phi^c\left(\frac{I_t^c}{I_{t-1}^c}\right)$.

$$1 = \mathbb{E}_t\left[\Lambda_{t,t+1}^c \frac{\alpha_c p_{t+1}^c \frac{Y_{t+1}^c}{K_{t+1}^c} + q_{t+1}^c \lambda^c}{q_t^c}\right] \tag{25}$$

$$K_t^c = I_t^c + \lambda_c K_{t-1}^c \tag{26}$$

A fraction $(1-\chi^c)$ of commodity profits is transferred abroad to foreign owners.

Foreign Sector

We assume that foreign demand for non-commodity final goods is an increasing function of relative price e_t and foreign incomes Y_t^* as

$$Y_t^{nc,x} = e_t^{\varphi_1} (Y_t^*)^{\varphi_2} \tag{27}$$

Let $X_t = \left[\ln \frac{Y_t^*}{Y^*},\ R_t^* - R^*,\ \ln \frac{p_t^{wc}}{p^{wc}} \right]$, we assume

$$X_t = \mathcal{C} X_{t-1} + \mathcal{B} u_t \tag{28}$$

Table 2: Baseline Calibration

	Description	Value	Target/Source
	Workers		
β	Subjective Discount Factor	0.99	Interest Rate 4.0% (p.a.)
ζ_0	Labor Supply Parameter 1	4.36e5	Normalization, $K^{nc} = 20$
ζ	Labor Supply Parameter 2	12.22	IFE $= 2.8$
χ	Worker's Management Cost	2.1e-3	$\frac{K^{nc,b}}{K^{nc}} = 0.80$
	Non-Commodity Sector		
α_k	NC Capital share	0.275	-
η	Demand Elasticity	6	[Castillo et al., 2006]
κ	Price adjustment cost	58	75% non-adjuster firms
δ^{nc}	NC Depreciation Rate (p.a.)	17%	-
	Commodity Sector		
δ^c	C Depreciation Rate (p.a.)	10%	-
χ^c	Domestic Share Comm. Profits	0.60	KFe SF
	Financial Sector		
δ^f	Foreign Currency Loans Bias	0.35	Credit Doll. Rate 35%
Δ	Moral Hazard Parameter 1	1	Normalization
Δ^*	Moral Hazard Parameter 2	1.34	FC Loan Return 3.5% (p.a.)
Δ^b	Moral Hazard Parameter 3	0.35	FX Bond Return 4.0% (p.a.)
ξ	Households to Banks Transfers	0.04	DC Loan Return 5.0% (p.a.)
θ	Θ's Parameter 1	0.14	$\phi_l = 3.3$
$\varkappa$	Θ's Parameter 2	6.14	$\frac{eD^*}{A} = 0.55$
	Government		
ρ_i	PR Inertia	0.70	-
ω_π	PR Response to Inflation	1.50	-
B	FX Bonds at SS	4.04	$\frac{B}{4GDP} = 0.20$
G	Gov. Expenditure at SS	0.76	$\frac{G}{4GDP} = 0.15$
	Exogenous		
R^*	Foreign Interest Rate at SS	$1.02^{1/4}$	Foreign Interest Rate 2.0% (p.a.)
Y^*	Foreign Output at SS	0.94	PPP Normalization, $e = 1$

Moment's Matching

The rest of the parameters are calibrated using moment's matching. Let Ξ be a subset of parameters calibrated in order to match moments $\mathcal{M}$, then Ξ are set to Ξ^*

$$\Xi^* = arg \min_{\Xi} \sum_{i=1}^{k} \varpi_i |\mathcal{M}_i^{\text{model}}(\Xi) - \mathcal{M}_i^{\text{data}}| \tag{29}$$

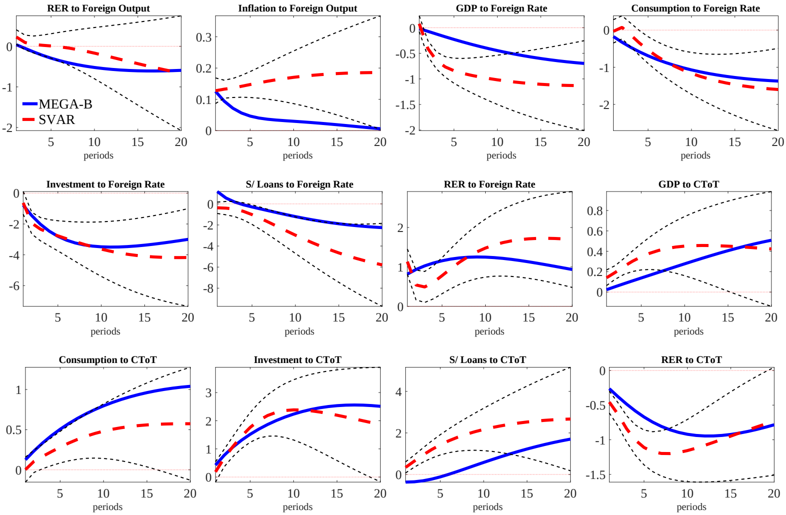
where ϖ_i is the relative weight for moment i.

Table 3: Second Moment Matching

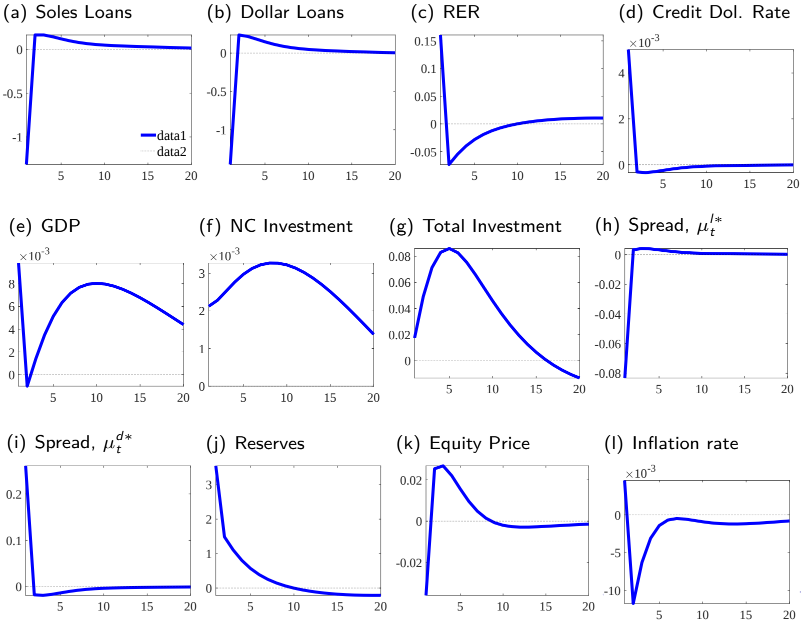
Variable	GDP	Consumption	Investment	RER
Empirical Variance	2.97	2.92	15.18	6.67
Model Variance	7.69	12.80	24.46	9.00

Variable	GDP	Consumption	Investment	RER
Empirical Autocorrelation	0.91	0.87	0.91	0.93
Model Autocorrelation	0.94	1.00	0.99	0.96

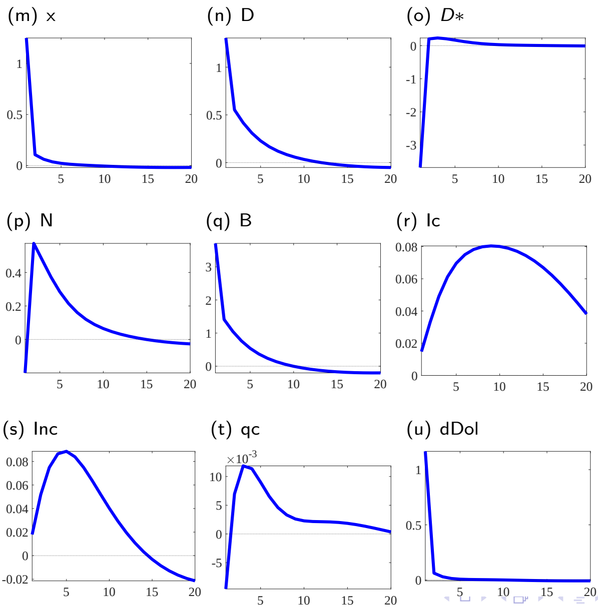
Figure 1: Impulse Response Matching



FX Interventions: Inspecting the Mechanisms



FX Interventions: Inspecting the Mechanisms



FX Interventions: Transmission Mechanism

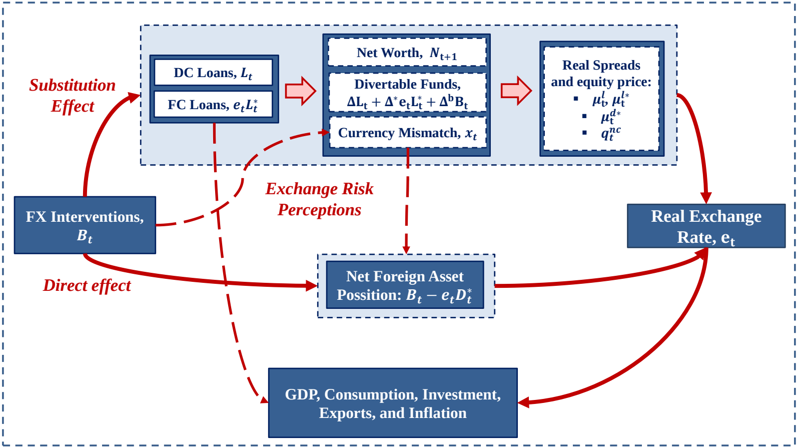


Table 4: Unconditional Standard Deviations

Variable	FX	no FX
GDP	7.69	8.16
Investment	24.46	28.08
Consumption	12.80	13.38
Inflation	2.25	2.55
DC Loans	24.06	29.97
FC Loans	29.13	40.57
RER	9.00	12.98
Spread R^k	1.29	2.23
Spread R^l	1.45	3.21
Spread R^{l*}	1.87	4.83
Reserves	181.64	6.78
NC Price Equity	3.30	3.25
Currency Mismatch	18.35	24.47
R^b	1.96	2.27
Policy Rate	2.03	2.27
Households Deposits	74.89	101.22
Dollars Deposits	56.94	11.95
Max. Leverage	23.63	14.94

Figure 2: Responses to Commodity Price Shock

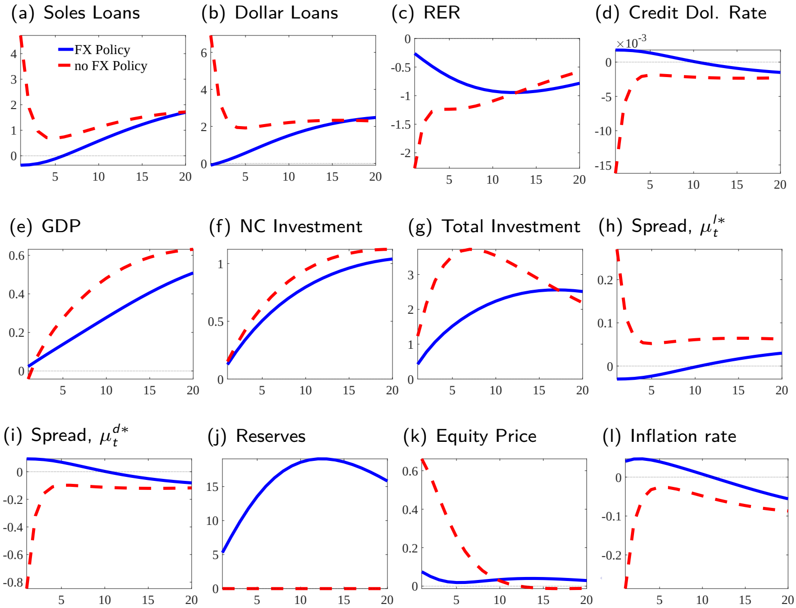


Figure 3: Responses to Commodity Price Shock

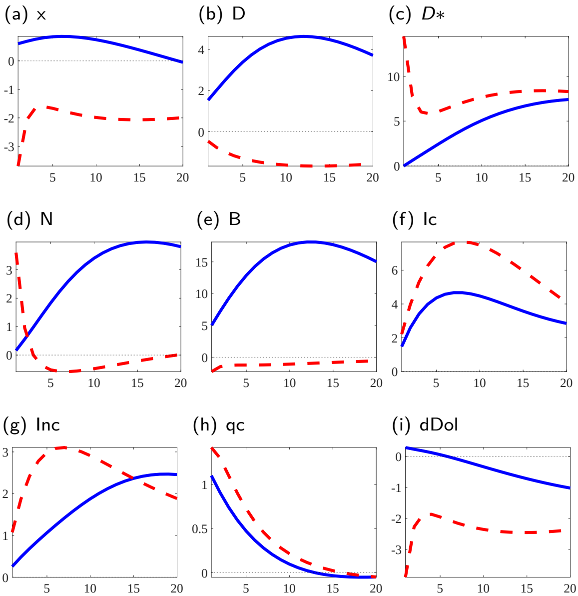


Table 5: Pass-Through: Commodity Price Shock

	Year 2		Year 3	
	FX	no FX	FX	no FX
GDP	0.02	0.04	0.04	0.06
Investment	0.24	0.55	0.33	0.64
Consumption	0.08	0.10	0.11	0.14
Inflation	0.01	-0.01	0.01	-0.01
DC Loans	-0.02	0.26	0.03	0.27
FC Loans	0.09	0.51	0.17	0.52
RER	-0.11	-0.25	-0.14	-0.26
Spread R^k	0.00	-0.01	0.00	-0.01
Spread R^l	0.01	-0.02	0.00	-0.02
Spread R^{l*}	0.01	-0.02	0.01	-0.01
Reserves	2.21	0.00	2.87	0.00
NC Price Equity	0.01	0.06	0.01	0.05
Currency Mismatch	0.14	-0.37	0.15	-0.40
R^b	-0.00	0.00	0.00	0.00
Policy Rate	0.00	-0.00	0.00	-0.00
Households Deposits	0.38	1.38	0.63	1.53
Dollars Deposits	0.56	-0.21	0.71	-0.26
Max. Leverage	-0.15	0.18	-0.22	0.23

Let the contingent plans for consumption and hours associated with a particular policy regime be denoted by C_t^b and H_t^b. Then we measure welfare as the conditional expectation of lifetime utility as of time zero, that is,

$$\text{welfare} = W_0^b \equiv \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \frac{1}{1-\gamma} \left(C_t^b - \mathcal{H} C_{t-1}^b - \frac{\zeta_0}{1+\zeta} (H_t^b)^{1+\zeta} \right)^{1-\gamma} \right] \quad (30)$$

We measure ς_{cond} as the fraction of consumption process that a household would be willing to accept (to give up) to be as well off under regime *a* as under regime *b*

$$W_0^a = \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \frac{1}{1-\gamma} \left((1-\varsigma_{cond}) \left[C_t^a - \mathcal{H} C_{t-1}^a \right] - \frac{\zeta_0}{1+\zeta} (H_t^a)^{1+\zeta} \right)^{1-\gamma} \right] \quad (31)$$

Table 6: Welfare Analysis: $\varsigma_{cond} \times 100\%$

$\omega_\pi \backslash \nu_e$	0	1	10	**18.25**	25	30	50	75
1.25	−45.2	−42.5	−40.1	−35.4	−31.1	−28.0	−18.5	−12.2
1.50	−7.2	−4.8	−3.0	0.0	2.4	4.0	8.5	10.9
2.00	17.2	18.4	19.1	20.2	20.9	21.3	21.9	21.4
3.00	26.9	27.3	27.5	27.6	27.6	27.5	26.8	25.4
5.00	30.0	30.2	30.2	30.0	29.8	29.6	28.5	26.9
10.00	31.0	31.2	31.1	30.8	30.6	30.3	29.3	27.9

Aoki, K., Benigno, G., and Kiyotaki, N. (2018).
Monetary and Financial Policies in Emerging Markets.
Technical report, Mimeo.

Backus, D. K. and Kehoe, P. J. (1989).
On the denomination of government debt : A critique of the portfolio balance approach.
Journal of Monetary Economics, 23(3):359–376.

Castillo, P., Montoro, C., and Tuesta, V. (2006).
An Estimated Stochastic General Equilibrium Model with Partial Dollarization: A Bayesian Approach.
Working Papers Central Bank of Chile 381, Central Bank of Chile.

Chang, R. (2018).
Foreign Exchange Intervention Redux.
NBER Working Papers 24463, National Bureau of Economic Research, Inc.

Chang, R., Fernández, A., and Gulan, A. (2017).
Bond finance, bank credit, and aggregate fluctuations in an open economy.
Journal of Monetary Economics, 85(C):90–109.

Chang, R. and Velasco, A. (2017).

Financial frictions and unconventional monetary policy in emerging economies.
IMF Economic Review, 65(1):154–191.

Gertler, M. and Karadi, P. (2013).
QE 1 vs. 2 vs. 3. . . : A Framework for Analyzing Large-Scale Asset Purchases as a Monetary Policy Tool.
International Journal of Central Banking, 9(1):5–53.

Gertler, M. and Kiyotaki, N. (2010).
Financial intermediation and credit policy in business cycle analysis.
In Friedman, B. M. and Woodford, M., editors, *Handbook of Monetary Economics*, volume 3, chapter 11, pages 547–599. Elsevier, 1 edition.

Gertler, M., Kiyotaki, N., and Queralto, A. (2012).
Financial crises, bank risk exposure and government financial policy.
Journal of Monetary Economics, 59(S):17–34.

Greenwood, J., Hercowitz, Z., and Huffman, G. (1988).
Investment, capacity utilization, and the real business cycle.
The American Economic Review, (3):402–417.

Hofmann, B., Shin, H. S., and Villamizar-Villegas, M. (2019).
FX intervention and domestic credit: evidence from high-frequency micro data.

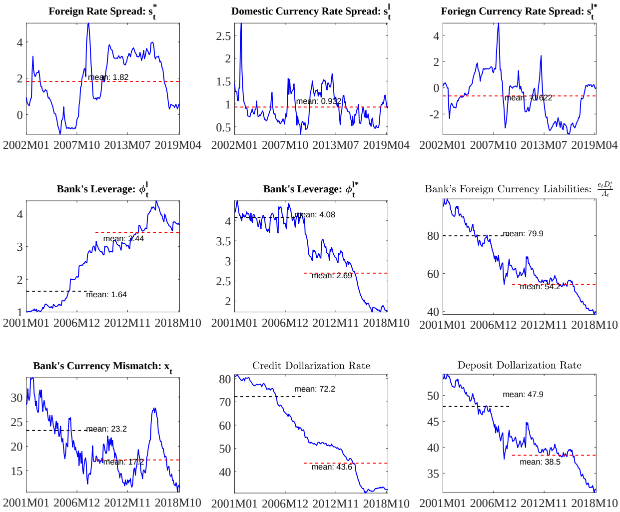
Borradores de Economia 1069, Banco de la Republica de Colombia.

Miao, J. and Wang, P. (2010).
Credit Risk and Business Cycles.
Boston University - Department of Economics - Working Papers Series WP2010-033, Boston University - Department of Economics.

Rotemberg, J. (1982).
Monopolistic price adjustment and aggregate output.
Review of Economic Studies, 49(4):517–531.

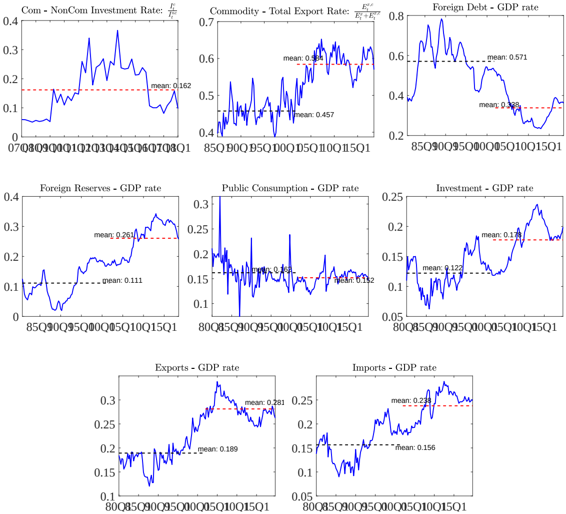
DATA I

Figure 4: Financial System



Back to banking

Figure 5: Real Variables



Back to banking