Monetary Policy and Sovereign Risk in Emerging Economies (NK-Default)

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Motivation for NK-Default

- Many emerging markets adopted *inflation targeting* in early 2000s
  - Monetary policy targets nominal rates to keep inflation in band
- *New Keynesian theory* toolkit for monetary policy implementation
  - Theory for developed countries, mainly perfect capital markets
  - Useful for transmission of monetary policy to inflation and output
- Standard NK theory silent on interactions with *sovereign risk*
  - Emerging markets history of recurring sovereign debt crises
  - Both policies affect consumption, output, inflation

New Keynesian model with sovereign default risk

Emerging Markets Inflation Targeters

	Mean (%)		Stdev. Rel. Output		Corr. with Spread (%)		
	Inflation	Spread	Inflation	Spread	Inflation	Dom. Rate	Output
Brazil	5.6	2.8	0.6	0.3	57	60	−60
Chile	3.3	1.4	0.9	0.2	34	23	−57
Colombia	4.2	2.3	0.9	0.5	60	43	−43
Mexico	4.1	2.2	0.4	0.3	24	5	−53
Peru	2.8	2.0	0.5	0.3	53	13	−2
Philippines	3.8	2.1	1.3	0.8	68	64	−63
Poland	2.0	1.1	0.9	0.4	42	23	−43
S. Africa	5.4	2.2	1.0	0.5	50	8	−72
Mean	**3.9**	**2.0**	**0.9**	**0.4**	**49**	**30**	−49

- Single digit inflation and $ govt bonds carry spread over US bonds
- Inflation and sovereign spreads are less volatile than output
- Govt spread positively correlated with inflation and domestic rates (sovereign dollar spreads and local currency interbank rate)
- Govt spread negatively correlated with output

Default Risk Matters for Monetary Policy

- Construct New Keynesian model with option to default, *NK-Default*
  - Govt borrows foreign-currency debt with default risk
  - Monetary policy is a nominal interest rate rule
  - Two frictions: sticky prices and govt overborrowing
- Establish theoretically two mechanism + optimal monetary rule
  - Default amplification: govt default risk worsens monetary frictions
    High default risk $\Rightarrow$ low consumption & output, more distorted
  - Monetary discipline: monetary frictions lowers default risk
    Govt internalizes the effects of its policy on domestic outcomes
  - Optimal monetary rule
    Targets low default risk, achieves low inflation

Quantitative Toolkit

- Baseline monetary rule targets inflation (Taylor rule)

- Model predictions consistent with emerging market data
  - Positive co-movement of spreads, nominal rates, inflation
  - Contractionary monetary shock lowers sovereign spreads

- Alternative monetary rules
  - *Strict inflation targeting (IT)*: inflation always at its target
    $\Rightarrow$ zero monetary frictions, but high default risk
  - *Default inflation targeting*: on both inflation and default risk
    $\Rightarrow$ low monetary frictions, low default risk

- Welfare comparison
  - Strict IT possibly dominated by Benchmark rule
    In contrast to Gali & Monacelli (2005): Strict IT is optimal
  - Default IT generates higher welfare than Strict IT

Literature

- New Keynesian models for small open economies: Gali-Monacelli (2005), Aoki-Benigno-Kyotaki (2016), Devereux-Young-Yu (2019)
- Sovereign default: Aguiar-Gopinath (2006), Arellano (2008), Reinhart-Rogoff (2009), Chatterjee-Eyigungor (2012)
- Default risk & dilution: Hatchondo-Martinez-Sosa Padilla (2016), Aguiar-Amador-Hopenhayn-Werning (2018), Hatchondo-Martinez-Roch (2018)
- Inflation as default for local currency debt: Calvo (1988), Aguiar-Amador-Farhi-Gopinath (2013), Corsetti-Dedola (2016), Hur-Kondo-Perri (2018)
- Downward rigid nominal wages & default risk: Na-Schmitt-Grohe-Uribe-Yue (2018), Bianchi-Ottonello-Presno (2018), Bianchi-Mondragon (2018)
  Here NKPC with inflation expectations + nominal rates targeting inflation

NK-Default: Monetary policy targets inflation with sovereign default risk

Model

Small open economy: private sector, monetary auth, and fiscal govt

- Private sector:
  - Households: value domestic and imported goods, supply labor
  - Intermediate goods firms: produce with labor, subject to price-setting frictions (Rotemberg)
  - Final good: consumed domestically and exported
- Monetary authority:

  Follows interest rate rule, can target both inflation and default risk
- Government:

  Borrows long-term internationally, in foreign currency, can default

Households

- Values consumption of domestic and foreign goods, supply labor

$$\max \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_t, C_t^f, N_t)$$
$$\text{s.t.} \quad P_t^d C_t + P_t^f C_t^f + q_t^d B_{t+1}^d \leq W_t N_t + B_t^d + \Pi_t + T_t$$

- Domestic nominal bonds with price q_t^d, in zero net supply

- Receive profits from firms Π_t, transfers from government T_t

- Optimality conditions:

$$\frac{u_{C^f,t}}{u_{C,t}} = e_t, \qquad \frac{u_{N,t}}{u_{C,t}} = w_t, \qquad u_{C,t} = \beta i_t \mathbf{E}_t \left[\frac{u_{C,t+1}}{\pi_{t+1}} \right]$$

Nominal rate $i_t = 1/q_{t+1}^d$ is monetary policy instrument
Inflation $\pi_{t+1} = P_{t+1}^d / P_t^d$, terms of trade $e_t = P_t^f / P_t^d$ ($\uparrow$ depreciation)

Intermediate Goods Firms

- Monopolistic competition facing CES demand $y_{it} = \left(\frac{p_{it}}{P_t^d}\right)^{-\eta} Y_t$

- Produce with labor n_{it} and face productivity shocks z_t

$$y_{it} = z_t n_{it}$$

- Costly to change prices relative to target inflation $\overline{\pi}$ (Rotemberg)

- Dynamic choice of n_{it} and prices p_{it} (NKPC)

$$(\pi_t - \overline{\pi})\,\pi_t = \left(\frac{w_t}{z_t} - 1\right)\frac{\eta - 1}{\varphi} + \mathbf{E}_t\left[\beta \frac{u_{c,t+1}}{u_{c,t}} \frac{Y_{t+1}}{Y_t} (\pi_{t+1} - \overline{\pi})\,\pi_{t+1}\right]$$

- Monetary frictions hinder efficient production

$$1 + \text{monetary wedge} = \frac{z_t}{w_t} = \frac{z_t u_{C,t}}{u_{N,t}}, \qquad (> 0 \text{ depressed output})$$

Goods Market

- Economy faces elastic demand for its exports

$$X_t = e_t^{\rho} \xi$$

- Domestic good used for consumption and exports

$$z_t N_t = C_t + X_t + \langle \text{price-setting costs} \rangle_t$$

Government

- Govt services debt B_t, borrows abroad in foreign-currency $q_t \ell_t$
- Capital flows used to finance imports net of exports

$$C_t^f = X_t / e_t + q_t \ell_t - B_t$$

- Bonds are long-term perpetuities with decay rate δ and law of motion

$$B_{t+1} = \delta B_t + \ell_t$$

- Govt can default on its debt
  - Debt eliminated, balanced trade
  - Productivity reduced to $z_t^d \leq z_t$ and temporary market exclusion
  - Govt faces enforcement shock ν, lower ν more incentive to default
- Bond price schedule $q(z_t, B_{t+1})$ compensates for default risk

Monetary Policy

An interest rate rule targeting inflation $\overline{\pi}$ and govt default risk Φ^*

$$i_t = \bar{i}\left(\frac{\pi_t}{\overline{\pi}}\right)^{\alpha_P}\left(\frac{\Phi_t}{\Phi^*}\right)^{\alpha_D} m_t$$

subject to monetary shocks m_t

Recursive Markov Equilibrium

- States: debt B, shocks $s = (z, m)$ and enforcement shock ν
- Gov chooses policies of default D and borrowing B'

$$V(s,B) = \mathbf{E}_\nu \max\left\{W(s,B),\, W^d(s) - \nu\right\}$$
$$W(s,B) = \max_{B'}\left\{u(C, C^f, N) + \beta_g \mathbf{E}_{s'|s} V(s', \nu', B')\right\}$$

subject to private and monetary eqm, taking as given future govt policies

- Default is more likely when high debt B, low z, or low enforcement ν
  - Default iff $\nu \leq \nu^*(s,B)$ with cutoff $\nu^*(s,B) = W^d(s) - W(s,B)$
- Overborrowing
  - Impatient govt: $\beta_g < \beta$
  - long-term debt, as in Aguiar, Amador, Hopenhayn, Werning (2018)

Bond Price Schedule

- International lenders: competitive, risk neutral, world risk free rate r^*

- Bond price schedule reflects default and future borrowing

$$q(s,B') = \frac{1}{1+r^*}\mathbf{E}\left[1 - D(s',\nu',B')\right]\left[1 + \delta q(s', B''(s',B'))\right]$$

- Default risk

$$\Phi(s,B') = \mathbf{E}_{\nu',s'|s}\left[D(s',\nu',B')\right]$$

Private and Monetary Equilibrium

NKPC: $$(\pi - \overline{\pi})\,\pi = \left(\frac{u_N}{z u_C} - 1\right)\frac{\eta - 1}{\varphi} + \beta \mathbf{E}\frac{z' N' u'_C}{z N u_C}\,(\pi' - \overline{\pi})\,\pi'$$

Domestic Euler: $$u_C = \beta\, i\, \mathbf{E}\left[\frac{u'_C}{\pi'}\right]$$

Interest rate rule: $$i = \bar{i}\left(\frac{\pi}{\overline{\pi}}\right)^{\alpha_P}\left(\frac{\Phi}{\Phi^*}\right)^{\alpha_D} m$$

Relative consumption: $$u_{C^f}/u_C = e$$

Balance of payments: $$X/e = C^f + B - q(s, B')(B' - \delta B)$$

Resource constraint: $$C + X = \left[1 - \frac{\varphi}{2}(\pi - \overline{\pi})^2\right] zN$$

- Govt understands how its borrowing B' impacts economy
- Govt borrowing affects default risk and capital flows

Simplified Model with One-Time Deviation

Key points:

- Two frictions: sticky prices + govt overborrowing
- Two mechanisms: default amplification and monetary discipline
- Optimal monetary policy targets default risk, fixes both frictions

Simplified Model with One-Time Deviation

- Abstract from productivity shock, one-period bond
- Default driven by enforcement shock ν
  $\Rightarrow$ default iff $\nu \leq \nu^*(B)$, with $W(B) = W^d - \nu^*(B)$
- Quasi-linear preference: $u(C, C^f, N) = \log C + C^f - \frac{N^{1+\zeta}}{1+\zeta}$
  $\Rightarrow$ international capital flows affect (C, N) ONLY through default risk
- For any $t > 0$, strict inflation targeting, $\pi_t = \overline{\pi}$; govt discount $\beta_g = \beta$
  $\Rightarrow$ after period 0, no pricing frictions & no overborrowing
- One-time deviation at $t = 0$: monetary policy i; less patient govt $\beta_g < \beta$
  $\Rightarrow$ in period 0, two frictions

Strict Inflation Targeting at One-Time Deviation

- In period 0, the monetary authority can deliver $\overline{\pi}$ with $i = i^{ST}$
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Under linear C^f & $q = \frac{1}{1+r^*}[1 - \Phi(\nu^*(B'))]$

$$\underbrace{1 + \frac{\partial q}{\partial B'}\frac{B'}{q}}_{\text{marginal benefit, } \partial q/\partial B' < 0} = \underbrace{\beta_g(1 + r^*)}_{\text{marginal cost}}$$

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- Lower $\beta_g < \beta$ leads to higher borrowing B'
  $\Rightarrow$ govt borrows more than households desired

Default Amplification

Now consider arbitrary monetary policy i in period 0

Proposition 1 *Higher default risk increases the monetary wedge* $-zu_C/u_N$

- Domestic Euler in period $t = 0$

$$u_C = \frac{\beta i}{\pi}\mathbf{E}u_{C'} = \frac{\beta i}{\pi}\left[\frac{1-\Phi\left(\nu^*\left(B'\right)\right)}{C'} + \frac{\Phi\left(\nu^*\left(B'\right)\right)}{C'_d}\right]$$

- Consumption is lower under default state $C'_d \leq C'$ due to punishment
- High default risk $\Phi(\nu^*)$ increases expected future marginal cons. $\mathbf{E}u_{C'}$
- With constant rate i, current consumption is lower $C\downarrow$
- Terms of trade appreciates, $C\downarrow = u_{C^f}/u_C = e\downarrow \Rightarrow$ lower export
- Labor shrinks since both domestic C and export drop
- Monetary wedge ($-zu_C/u_N = \frac{z}{CN^{\zeta}}$) increases

Monetary Discipline

Proposition 2 *For any monetary policy $i > i^{ST}$, the monetary wedge is positive but the equilibrium default risk is lower than under strict inflation targeting*

- High i leads to high monetary wedge (low C & N)
- Govt. Euler for borrowing

$$1 + \frac{\partial q}{\partial B'} \frac{B'}{q} - \underbrace{\kappa u_C \frac{\partial \mathbf{E} u_{C'}}{\partial B'} \frac{1}{\mathbf{E} u_{C'}(B')}}_{\text{wedge}>0} = \beta_g (1 + r^*)$$

  - Multiplier on domestic Euler $\kappa > 0$ when positive monetary wedge
- Positive wedge lowers marginal benefit of borrowing $\Rightarrow$ lower B' & default risk
- Monetary trade-off: low default risk, high monetary wedge

Optimal Monetary Rule

Consider monetary rule

$$i = \bar{i}\left(\Phi/\Phi^{CE}\right)^{\alpha_D}$$

where constrained-efficient default risk Φ^{CE} associated with B^{CE} satisfying

$$1 + \frac{\partial q}{\partial B'}\frac{B'}{q} = \beta(1+r)$$

Proposition 3 *The central bank can achieve the constrained efficient default risk and any arbitrary small monetary wedge with a bounded α_D*

- Govt Euler

$$1 + \frac{dq}{dB'}\frac{B'}{q} - \kappa u_C\left[\frac{\partial \mathbf{E}u_{C'}}{\partial B'}\frac{1}{\mathbf{E}u_{C'}(B')} + \alpha_D\frac{\phi(\nu^*)}{\Phi(\nu^*)}\right] = \beta_g(1+r^*)$$

- Choose α^D to implement B^{CE} with κ pinned downed by monetary wedge

$$\kappa u_C\left[\frac{\partial \mathbf{E}u_{C'}}{\partial B'}\frac{1}{\mathbf{E}u_{C'}(B^{CE})} + \alpha_D\frac{\phi^{CE}}{\Phi^{CE}}\right] = (\beta-\beta_g)(1+r)$$

- Eliminates two frictions: efficient borrowing & $\pi \approx \overline{\pi}$

$$(\pi - \overline{\pi})\,\pi = \left(-\frac{u_N}{zu_C} - 1\right)\frac{\eta-1}{\varphi} \approx 0$$

Quantitative Analysis

- Parameterize model to average of 8 inflation targeters
  Baseline monetary rule targets inflation only: $i = \bar{i}\,(\pi/\overline{\pi})^{\alpha_p}\,m$
- Highlight two mechanisms using policy rules & IRFs
- Alternative monetary rules: Strict IT and Default IT
  - Optimal monetary rule: default IT with high α_D
- Empirical evidence on two mechanisms

Functional Forms and Computation

- AR(1) productivity z and monetary shock m
  Business cycle mainly driven by z, small role for m

- Preferences

$$u(C,\ C^f, N) = \log\left[\left(\theta C^{\frac{\omega-1}{\omega}} + (1-\theta)(C^f)^{\frac{\omega-1}{\omega}}\right)^{\frac{\omega}{\omega-1}}\right] - \frac{N^{1+1/\zeta}}{1+1/\zeta}$$

- CPI-based Inflation and Nominal Devaluation Rate:

$$\text{CPI inflation} = \pi \frac{\left[\theta^{\omega} + (1-\theta)^{\omega} e^{1-\omega}\right]^{1/(1-\omega)}}{\left[\theta^{\omega} + (1-\theta)^{\omega} e_{-1}^{1-\omega}\right]^{1/(1-\omega)}}, \qquad \text{NER} = \pi \frac{e}{e_{-1}}$$

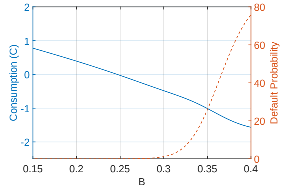
- Default productivity loss follows Chatterjee and Eyigungor (2012)

$$z^d(z) = z - \max\{0, \lambda_0 z + \lambda_1 z^2\}$$

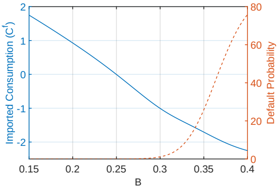
- Computation algorithm
  - Discrete choice multinomial logit: taste shocks for $\{B', D\}$
  - Sovereign default: Dworkin et al. (2018) and Gordon (2018)

Parameterization and Moment Matching

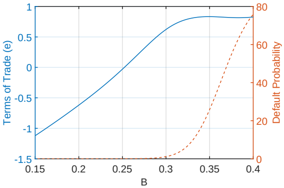
Para.	Value	Moments	Data	NK-Default
Moments matching Parameters		*Mean*		
Inflation target $\overline{\pi}$	1.01	CPI inflation	3.9	3.9
Discount factor β	0.996	Domestic rate	5.6	5.6
Gov discount β_g	0.983	Spread	2.0	2.0
		Standard deviation		
Vol. productivity σ_z	1.2%	Output	2.3	2.2
Rule coef α_P	1.45	CPI inflation	1.7	2.0
Default loss λ_0	-0.17	Spread	0.9	1.0
Default loss λ_1	0.19	Consumption	2.4	2.0
		Correlation		
Enforcement shock ϱ_D	$1e^{-4}$	Output & spread	-49	-45
		Out of sample moments		
		Standard deviation		
		Domestic rate	1.9	2.9
		Trade balance	2.8	0.4
		Nominal depreciation rate	8.6	2.2
		Correlation with Spread		
		CPI inflation	49	52
		Domestic rate	30	71
		Trade balance	11	20
Other parameters		Nominal depreciation rate	36	37



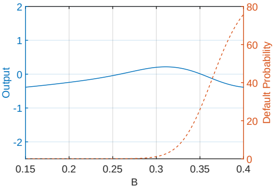
Domestic Consumption



Imports



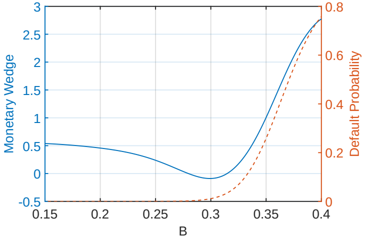
Terms of Trade



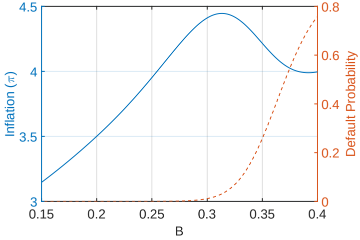
Output

- High B, low consumption and import; terms of trade depreciates
- Output (labor) first increases to repay debt then decreases due to default risk

Policy Rules



Monetary Wedge

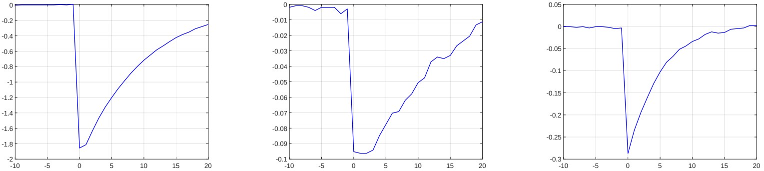


Inflation

Default amplification:

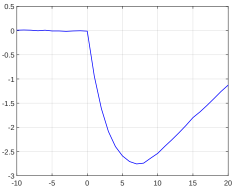
- High default risk: increasing monetary wedge, lowering inflation
  - Default tomorrow associated with low C' $\rightarrow$ depresses C

Impulse Responses to Monetary Shock

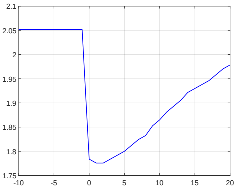


Inflation (π) — Output — Domestic Consumption (C)

- High $m \Rightarrow$ low π, output and domestic consumption
- Monetary wedge increases



Debt (B)

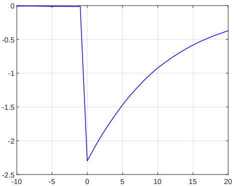


Spread

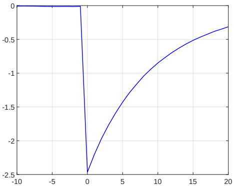
Monetary discipline:

- High monetary shock m lowers govt borrowing incentive and default risk

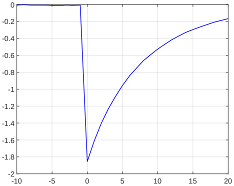
Impulse Responses to Productivity Shock



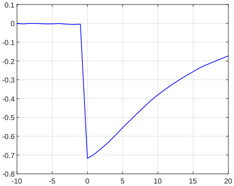
Output



Domestic Consumption (C)



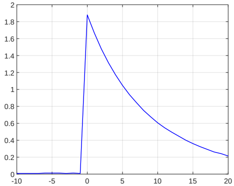
Imported Consumption (C^f)



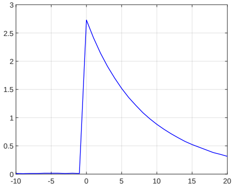
Terms of Trade (e)

- Adverse productivity leads to recession, terms of trade appreciates

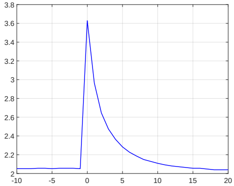
Impulse Responses to Productivity Shock



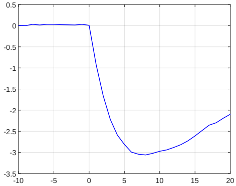
Inflation (π)



Nominal Interest Rate (i)



Spread



Debt (B)

- Positive co-movement of spread, inflation, and nominal rate

Alternative Monetary Rules

Recall monetary rule in the baseline (Baseline IT)

$$i = \overline{R} \left(\frac{\pi}{\overline{\pi}} \right)^{\alpha_p}$$

Alternatives

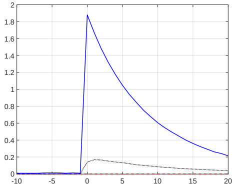
- Strict inflation targeting $\pi = \overline{\pi}$, nominal rate satisfies domestic Euler (*Strict IT*)

- Default inflation targeting: both inflation and default risk (*Default IT*)

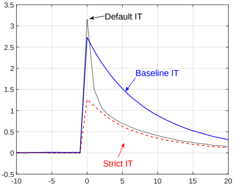
$$i = \overline{R} \left(\frac{\pi}{\overline{\pi}} \right)^{\alpha_p} \left(\frac{\Phi}{\Phi^*} \right)^{\alpha_D}$$

$\alpha_D = 8, \Phi^* = 0.3\%$, other parameters as in the benchmark

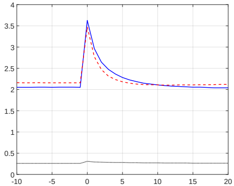
Impulse Responses to Productivity Shock



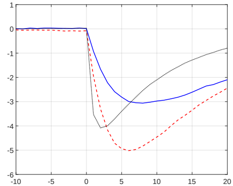
Inflation (π)



Nominal Interest Rate (i)



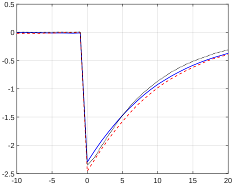
Spread



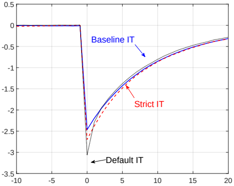
Debt (B)

- Default IT: nominal rate increases the most to lower spread, debt recovers faster

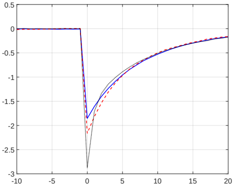
Impulse Responses to Productivity Shock



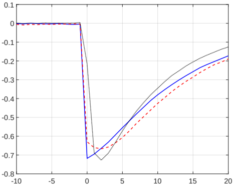
Output



Domestic Consumption (C)



Imported Consumption (C^f)



Terms of Trade (e)

- Aggressive mon policy in Default IT: larger recession on impact & quicker recovery

Business Cycle Moments

Mean	Baseline IT	Strict IT	Default IT
CPI inflation	4.0	4.3	4.0
Nominal domestic rate	5.6	5.8	5.7
Spread	2.0	2.2	0.3
Standard Deviation, Relative to Output			
CPI inflation	1.0	0.1	0.2
Nominal domestic rate	1.3	0.9	0.9
Spread	0.5	0.3	0.0
Correlation with Spread			
CPI inflation	52	−40	10
Nominal domestic rate	71	20	83

- Strict IT has low inflation volatility but high spreads
- Default IT targets default risk, generating low spread AND low inflation volatility

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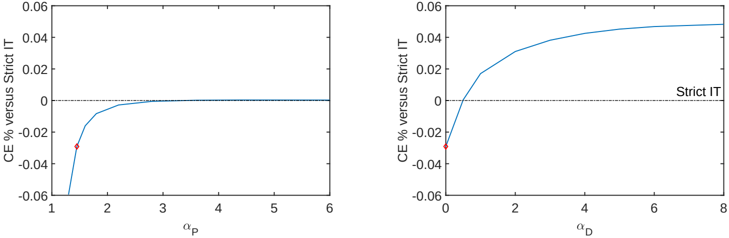
Welfare Comparison Across Monetary Policy Regimes



- Strict IT can be dominated by Baseline IT and Default IT
- In contrast to Gali & Monacelli (2005), which shows Strict IT is optimal

Empirical Evidence: Amplification

- Theory: Default risk increases monetary wedge
- Challenges:
  - Measuring monetary wedge zu_c/u_n requires labor and consumption
  - Need "pure default risk," by not driven by productivity shock
- Proxy for monetary wedge: unemployment
  - Under balanced trade and log preference

$$\text{output gap} = \hat{y}^{\text{flex}} - \hat{y}^{\text{sticky}} = -\hat{n} = \frac{\zeta}{1+\zeta}\text{labor wedge}$$

  - Clarida, Gali and Gertler (2000)
- Residualize spreads using output growth and inflation
  - Model, $spr(z, m, B')$, high B' increases def risk and mon wedge
  - Output growth and inflation captures fluctuations in (z, m)

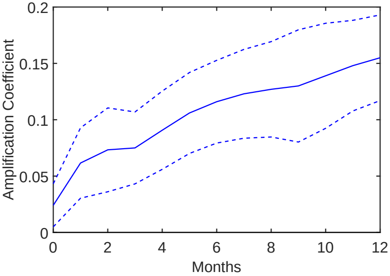
Empirical Evidence: Amplification

Local projection based on Jorda (2005)

$$\text{unemployment}_{c,t+h} = \alpha_c + \beta_h \widehat{\text{spr}}_{c,t} + \Gamma Z_{c,t} + v_{c,t}$$

- $\widehat{\text{spr}}_{c,t}$ residualized spreads country by country
- Controls $Z_{c,t}$ six lags of output growth and inflation
- 8 emerging inflation targeters, 2004M1-2019M12, monthly
- All variables are standardized
- Hypothesis $\beta_h > 0$

Empirical Evidence: Amplification



Cumulative impact of 1% increase of residualized spread in the first quarter

- Increase unemployment by 0.38%, output gap by 0.76% (Okun's law) monetary wedge by 4%

Empirical Evidence: Discipline

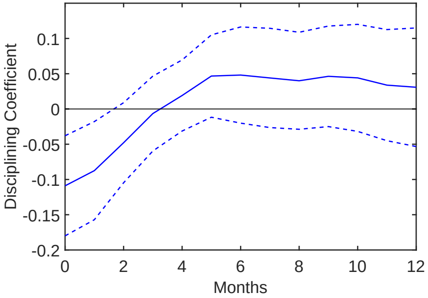
- Theory: high monetary shock m lowers sovereign spread
- Empirics: local projection based on Jorda (2005)

$$\text{spr}_{c,t+h} = \alpha_c + \beta_h \varepsilon^m_{c,t} + \Gamma Z_{c,t} + \nu_{c,t}$$

  - Recover monetary shock $\varepsilon^m_{c,t}$ from Taylor rule, country by country
  - Controls $Z_{c,t}$ six lags of output growth and inflation
  - 8 emerging inflation targeters, 2004M1-2019M12, monthly
- Coefficient β_h captures the elasticity of spread w.r.t monetary shock

Theory: $\beta_h < 0$

Empirical Evidence: Discipline



- Cumulative impact of 1% increase in monetary shock in the first quarter
  - Lower spreads by -0.92%
- Robust to (1) with/without COVID periods (2) number of lags (3) monetary shocks from Taylor rule with only inflation (4) VAR

Empirical Evidence: Summary

	Data	Baseline IT
Amplification	0.16	0.11
Discipline	-0.24	-0.18

- Model and Data (cumulative) estimates for the first quarter
- Model accounts for 70-75% of effect in data

Conclusion

- Integrated framework of monetary policy and sovereign risk
  New Keynesian model with default
- Important interactions between monetary frictions and default risk
  - Default risk amplifies monetary frictions and response
  - Monetary frictions discipline borrowing
- Optimal monetary rule targets low default risk
- Framework potentially useful for central banks

Other Parameter

- Frisch ela. $\zeta = 0.33$
- Ela. of substitution $\omega = .85$
- Domestic con weight $\theta = 0.62$
- Variety ela. $\eta = 6$
- Price adj. cost $\varphi = 58$
- Shocks persistence $\rho_z = \rho_m = 0.9$
- Export ela. $\rho = 3$
- Reentry prob. 4.2%
- Standard deviation of m=0.0025 from data

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