Essays in Monetary Policy with Risky Assets

Eduardo G. C. Amaral*
PUC-Rio
Banco Central do Brasil

Carlos Viana de Carvalho
PUC-Rio
(advisor)

October 3, 2021

*The views expressed in this work are those of the authors and do not necessarily reflect those of the Banco Central do Brasil or of its members.

There are 3 chapters in this thesis

1. **Interest, Prices, and Risk**
2. An Unpleasant Coincidence for Monetary Policy: Risky Assets and Fiscal Limits
3. On the Mechanics of New-Keynesian Models: Smoothing the Capital Controversy Out

Motivation

- Time-average **ex-ante real interest rates** can vary largely across countries[1]

  ▸ Methodology

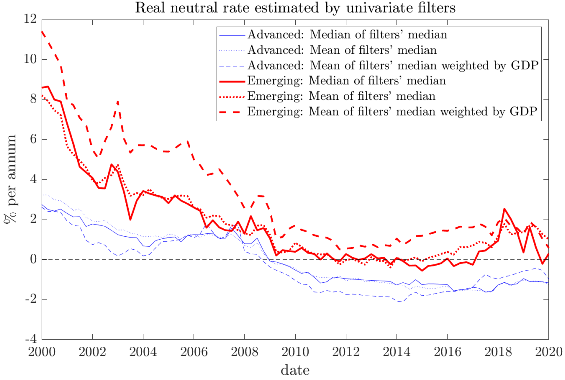


Figure: Real neutral rates estimated by univariate filters

[1] Miller, Paron and Wachter (2020), Du and Schreger (2016), Ferreira and León-Ledesma (2007), Mishkin (1984), this exercise, etc..

Motivation

- r^n is the reference for the **intercept of interest rate rules**
- **Concerns** on prescribing them without understanding the r^n wedge
- **If the policy asset is risky, then, how is monetary policy affected?**
  1. Risk may stem from the **credibility of the issuer** of the policy asset
     - i.e. outright or repos with risky federal government bonds
     - There have been defaults in local-currency debt (Reinhart and Rogoff, 2009; Beers, Jones and Walsh, 2020)
  2. Liquid assets are also **easy candidates to confiscation** in case a government wishes to collect extraordinary revenue (Turkey 1999) or curb inflationary liquidity (Brazil 1990)
  3. Part of government debt may be **indexed** to the policy rate (Brazil $\approx$ 37%)
- I believe this question has been neither properly posed nor addressed in the literature, **not even in the realm of a closed economy**

This paper

1. I introduce risk in the policy asset of a partial equilibrium closed-economy monetary model found in Woodford (2003*a*, sec. 4.3 of ch. 1)
2. I find that the **power** of monetary policy w.r.t. inflation **is reduced** at the same time that the price level is higher
3. These results generate a **novel argument** in favor of more hawkish monetary policy in case of, say, a fiscal or political crisis
4. If the CB accommodates policy-asset risk, it is enough to generate **positive correlation** between inflation and default risk (empirically validated)
5. **In an open economy**, it would offer an additional explanation for positive correlation between currency risk and default risk. Causality would flow as:
   - not (only) default risk $\Rightarrow$ currency risk $\Rightarrow$ inflation risk (pass-through)
   - default risk $\Rightarrow$ inflation risk $\Rightarrow$ currency risk

Related literature

- **This paper** can be seen as an **extension** of Woodford (2003*a*)'s interpretation of Wicksell (1898)
- **Inflation-targeting with risky assets:** Bi, Leeper and Leith (2018) commented by Reis (2018)
- **Determinacy with government default risk:** Schabert and Van Wijnbergen (2014), and Bonam and Lukkezen (2019)
- **Optimal control of monetary policy under uncertainty:** Orphanides and Williams (2002, 2008)
- **Monetary and fiscal policy interactions:** Sargent and Wallace (1981); Loyo (1999); Sims (1994); Woodford (1994); Uribe (2006); and Blanchard (2004)

The model

Given the **assumptions**:

1. Flexible prices
2. Exogenous real interest rate $\left\{r_j\right\}_{j=t}^{\infty}$, so $(r_t \equiv r_t^n)$
3. Rational agents
4. Fisher equation is valid
5. Central bank sets the nominal interest rate i_t

Up to first order in its log-linear form, the Fisher equation is

$$p_t = \mathbb{E}_t p_{t+1} + r_t^n - i_t^{RF} \tag{3}$$

or

$$\mathbb{E}_t \pi_{t+1} = i_t^{RF} - r_t^n \tag{4}$$

A defaultable bond

Adapting Duffie and Singleton (1999),

A net risky policy-asset interest rate, i_t^{Risky}, is a net nominal interest rate that in a market under no-arbitrage hypothesis satisfies the identity:

$$\begin{aligned} \mathbb{E}_t^Q \left(1 + i_{t+1}^{\text{Risky}}\right) &= \left[\left(1 - \mathbb{E}_t^Q \mathcal{D}_{t+1}\right)(1 + i_t) + \mathbb{E}_t^Q \mathcal{D}_{t+1} (1 + i_t)(1 - \delta_{t+1})\right] \\ &= \left(1 - \mathbb{E}_t^Q \mathcal{D}_{t+1}\delta_{t+1}\right)(1 + i_t) \end{aligned} \quad (7)$$

where i_t is the net risky policy-asset interest rate in case of non-default; $\mathcal{D}_{t+1}$ is the probability that the risky policy asset will default at maturity; and δ_{t+1} is the haircut in case of default

A few more assumptions:

6. No arbitrage
7. Policy-asset default probability and the haircut are exogenous
8. Risk-neutral agents

Case 1: Price-level targeting ▸ Exposition

Wicksellian rule: $i_t = \bar{\iota}_t + \phi \left(p_t - \overline{p} \right)$

$\left\{ \bar{\iota}_j \right\}_{j=t}^{\infty}$ is an exogenous process for a time-varying intercept

$\overline{p}$ is the log of the price level target

$\phi > 0$

Case 2: Inflation targeting

Taylor rule: $i_t = \bar{\iota}_t + \phi^{\pi} \left(\pi_t - \overline{\pi} \right)$

$\left\{ \bar{\iota}_j \right\}_{j=t}^{\infty}$ is an exogenous process for a time-varying intercept

$\overline{\pi}$ is the log of the gross inflation target

$\phi^{\pi} > \frac{1}{1 - \mathbb{E}_t \, \mathcal{D}_{t+1} \delta_{t+1}}$

Case 2: Inflation targeting

After some algebra,

$$\pi_t = \sum_{j=0}^{\infty} \Upsilon^{\pi}_{j+1} \mathbb{E}_t \left(r^n_{t+j} - \left(1 - \mathbb{E}_t\, \mathcal{D}_{t+j+1}\delta_{t+j+1}\right) \bar{\iota}_{t+j} + \mathbb{E}_t\, \mathcal{D}_{t+j+1}\delta_{t+j+1} \right)$$

$$\Upsilon^{\pi}_{j+1} \equiv \underbrace{\Pi_{k=1}^{j+1} \left(\frac{1}{\left(1 - \mathbb{E}_t\, \mathcal{D}_{t+k}\delta_{t+k}\right) \phi^{\pi}} \right)}_{> \Upsilon^{\pi, RF}_{t, j+1} \quad \Rightarrow \quad \text{less active}} \quad \forall j \geq 0 \tag{8}$$

Determinacy conditions:

$\phi^{\pi} > \frac{1}{1 - \mathbb{E}_t\, \mathcal{D}_{t+1}\delta_{t+1}}$

and at least one infinite sequence $k_n \subset [1, \infty)$ such that $0 \leq \mathbb{E}_t\, \mathcal{D}_{t+k}\delta_{t+k} < 1$

Case 2: Inflation targeting

Optimal Taylor rule has the sequence of time-varying intercepts

$$\left\{\bar{\iota}_{t+j}\right\}_{j=0}^{\infty} \equiv \left\{\frac{r^n_{t+j}+\mathbb{E}_t\,\mathcal{D}_{t+j+1}\delta_{t+j+1}}{1-\mathbb{E}_t\,\mathcal{D}_{t+j+1}\delta_{t+j+1}}\right\}_{j=0}^{\infty}$$

If the CB does not update the intercept ($\bar{\iota}_t = r^n_t$), we obtain a **non-accelerating inflation bias**, which partially disconnects $\mathbb{E}\,\pi$ from $\overline{\pi} = 0$:

$$\mathbb{E}\,\pi = \underbrace{\frac{\mathbb{E}\,\mathcal{D}\delta}{(1-\mathbb{E}\,\mathcal{D}\delta)\,\phi^{\pi}-1}\,(1+\mathbb{E}\,r^n)}_{\text{inflation bias}} \tag{9}$$

- Bias collapses to $\overline{\pi} = 0$ only when $\mathbb{E}\,\mathcal{D}\delta = 0$
- If $\mathbb{E}\,r^n > -1$, the inflation bias is positive for $\mathbb{E}\,\mathcal{D}\delta < 1$ as long as $\phi^{\pi} > \frac{1}{1-\mathbb{E}\,\mathcal{D}\delta}$
- Bias reduces with the size of ϕ^{π}

Monetary policy with risk in the policy asset

How large is the inflation bias? Assuming ($\mathbb{E}\,\bar{\iota} = \mathbb{E}\,r^n$), $\mathbb{E}\,r^n = 4\%$

Interpretation: CBs of risky economies may end up **heuristically picking high values of** ϕ^π as these values are more likely to bring inflation to the target more often

Inflation bias (p.p.) with $\delta = 0.05$

	$\phi^\pi = 1.2$	$\phi^\pi = 1.5$	$\phi^\pi = 2.0$	$\phi^\pi = 2.5$	$\phi^\pi = 3.0$
$\mathcal{D} = 0.0\%$	0.0	0.0	0.0	0.0	0.0
$\mathcal{D} = 2.5\%$	0.7	0.3	0.1	0.1	0.1
$\mathcal{D} = 5.0\%$	1.3	0.5	0.3	0.2	0.1
$\mathcal{D} = 7.5\%$	2.0	0.8	0.4	0.3	0.2
$\mathcal{D} = 10.0\%$	2.7	1.1	0.5	0.3	0.3

Inflation bias (p.p.) with $\delta = 0.60$

	$\phi^\pi = 1.2$	$\phi^\pi = 1.5$	$\phi^\pi = 2.0$	$\phi^\pi = 2.5$	$\phi^\pi = 3.0$
$\mathcal{D} = 0.0\%$	0.0	0.0	0.0	0.0	0.0
$\mathcal{D} = 2.5\%$	8.6	3.3	1.6	1.1	0.8
$\mathcal{D} = 5.0\%$	19.0	6.9	3.3	2.2	1.6
$\mathcal{D} = 7.5\%$	32.0	10.8	5.1	3.4	2.5
$\mathcal{D} = 10.0\%$	48.8	15.2	7.1	4.6	3.4

Testable implications

1. **Correlations between expected loss ($\mathbb{E}_t\, \mathcal{D}_{t+1}\delta_{t+1}$) and inflation**

   We propose a few **proxies** for that risk measure

   1. 5-Year CDS (liquid for emerging, but not for advanced economies)
   2. 1-Year Local-Currency Spread ($i_t^{country} - i_t^{US}$)
   3. 5-Year Local-Currency Credit Spread (Du and Schreger, 2016)
      - Spread of local-currency bonds over synthetic local-currency risk-free rates constructed with cross currency swaps

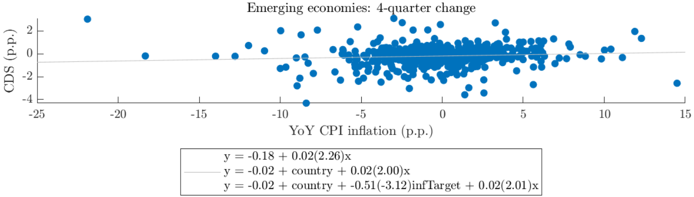
   We confirm **positive correlations** for the aggregate of emerging economies, and **no correlation** for the aggregate of advanced ones

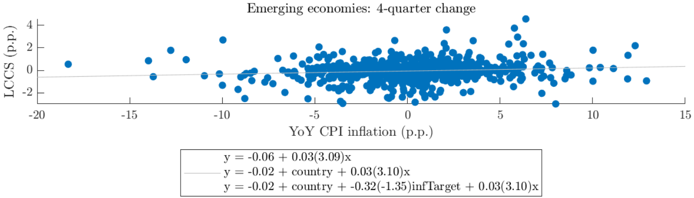
   At the **country-level**, there is heterogeneity, but **results tend to follow that pattern**

Testable implications

Emerging economies: positive correlation between default risk and inflation

Note: between parentheses are t-statistics; "country" is a country-fixed effect; "infTarget" is a dummy that equals 1 when inflation targeting is adopted at the observation.

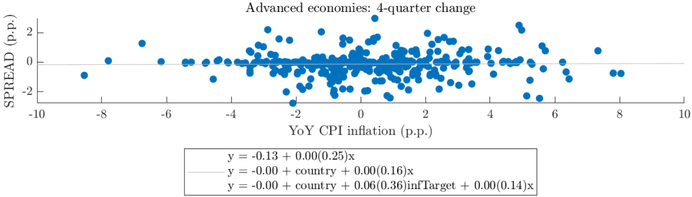


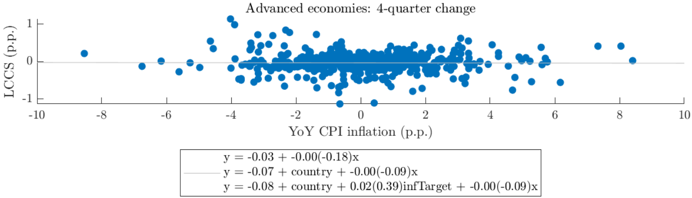


Testable implications

Advanced economies: no (or negative) correlation between default risk and inflation

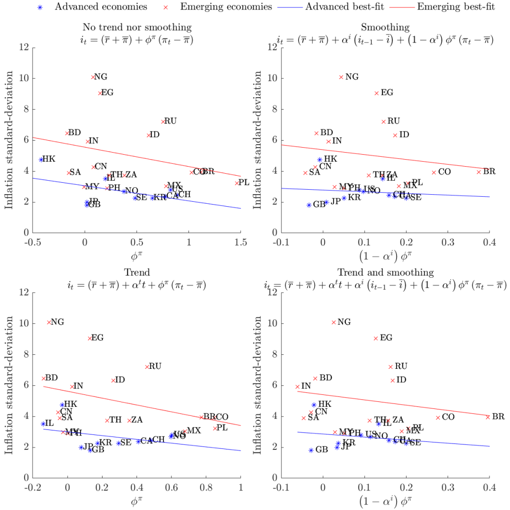
Note: between parentheses are t-statistics; "country" is a country-fixed effect; "infTarget" is a dummy that equals 1 when inflation targeting is adopted at the observation.





Testable implications

2. **Inflation volatility: larger for (risky) emerging given the same ϕ^{π}**



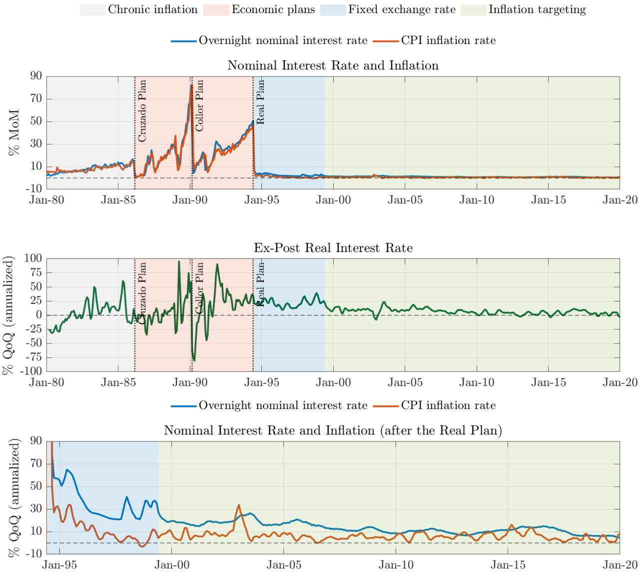
Conclusion

- This paper showed that when the policy asset is risky the **power of monetary policy w.r.t the price level and inflation is reduced**
- Uncompensated policy-asset **risk disconnects unconditional means from targets**, resulting in a bias that induces more aggressive reaction from the CB
- This phenomenon perceived as **"monetary policy conservatism"** is actually necessary to bring inflation to the target
- Non-optimal monetary policy induces **positive correlation** between default risk and inflation (empirically validated)
- Results represent a novel argument **in favor of a more hawkish stance** for monetary policy in the event of a fiscal or political crisis.

There are 3 chapters in this thesis

1. Interest, Prices, and Risk
2. **An Unpleasant Coincidence for Monetary Policy: Risky Assets and Fiscal Limits**
3. On the Mechanics of New-Keynesian Models: Smoothing the Capital Controversy Out

Motivation


Chronic inflation
Economic plans
Fixed exchange rate
Inflation targeting
Overnight nominal interest rate
CPI inflation rate
Nominal Interest Rate and Inflation
% MoM
Cruzado Plan
Collor Plan
Real Plan
Jan-80
Jan-85
Jan-90
Jan-95
Jan-00
Jan-05
Jan-10
Jan-15
Jan-20
Ex-Post Real Interest Rate
% QoQ (annualized)
Nominal Interest Rate and Inflation (after the Real Plan)

The model

- Two-agent New-Keynesian (TANK) model
    - Ricardian and non-Ricardian (hand-to-mouth) households
- Agents are rational and prices are sticky
- Distortionary taxes $\Rightarrow$ Laffer curve
- Government issues nominal debt
- Endogenous fiscal limits à la Bi (2012)
- Default implies partial confiscation and a large negative TFP shock
- Taylor rule sets the rate of government defaultable bonds
    - (1) targeting $r_t^{RF} + \overline{\Phi}$ with risky assets
    - (2) targeting $r_t^{RF} + \Phi_t$ with risky assets
- 3 stochastic shocks: TFP, government expenditures, and monetary
- Welfare: unexpected inflation (1) is a wealth tax on Ricardian agents, (2) reduces expected taxation levied on all agents in the future, (3) affects regime probabilities
- Given nonlinearities (peak of the Laffer curve and fiscal limit), I adopt Maih (2015)'s endogenous regime-switching approach

Related literature

- **Inflation-targeting with risky assets**

  Bi, Leeper and Leith (2018) commented by Reis (2018)

- **Fiscal limits**

  Bi (2012, 2017), Bi, Shen and Yang (2016, 2020), Battistini, Callegari and Zavalloni (2019), Pallara and Renne (2019)

- **Endogenous regime-switching**

  Maih (2015), Chang, Maih and Tan (2019) and Davig, Leeper and Walker (2010, 2011)

- **Monetary and fiscal policy interactions**

  Sargent and Wallace (1981); Loyo (1999); Sims (1994); Woodford (1994); Uribe (2006); and Blanchard (2004)

Monetary Policy

$$i_t = (1 + i_{t-1})^{\phi^i} \left((1 + \bar{\iota}_t)\, \overline{\Pi} \left(\frac{\Pi_t}{\overline{\Pi}} \right)^{\phi^\pi} \left(\frac{Y_t}{\overline{Y}} \right)^{\phi^Y} \right)^{1-\phi^i} e^{\mathcal{M}_t} - 1 \tag{10}$$

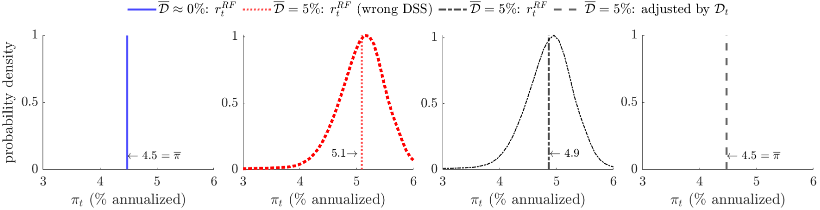
Rule 1: Risky policy asset, but the CB ignores default-risk dynamics

$$\bar{\iota}_t = r_t^{RF} + \overline{\Phi} \tag{11}$$

Rule 2: Risky policy asset, and the CB perfectly tracks default-risk dynamics

$$\bar{\iota}_t = r_t^{RF} + \Phi_t \tag{12}$$

We turn off $\mathcal{M}_t$, set $\phi^Y = 0$; $\phi^i = 0$, and simulate



Solution Method ▸ Calibration

1[st] step: Model has analytical solution with flexible prices: $X_t = f\left(\tau_t, \delta_t, A_t, G_t, \mathcal{M}_t\right)$

2[nd] step: The fiscal limit is the private sector's perception of that limit as in Bi (2012)

At the beginning of every period, an effective fiscal limit $\mathcal{B}_t$ is drawn from the fiscal limit distribution $\mathcal{B}^*\left(\overline{\mathcal{B}}, \sigma^2_{\mathcal{B}}\right)$ and compared to B_{t-1}

$$\mathcal{B}^*\left(A_t, G_t\right) \sim \sum_{t=0}^{\infty} \underbrace{\beta^t \frac{U_c^{\max}\left(A_t, G_t\right)}{U_c^{\max}\left(A_0, G_0\right)}}_{\substack{\text{stochastic discount factor} \\ \text{at the peak of the Laffer curve}}} \underbrace{\left(T^{\max}\left(A_t, G_t\right) - G_t\right)}_{\text{primary balance}} \tag{13}$$

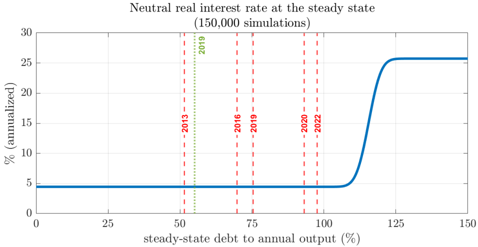
For its calculation it is assumed at all periods: $\tau_t = \tau_t^{max}$; $\delta_t = 0$; $\mathcal{M}_t = 0$

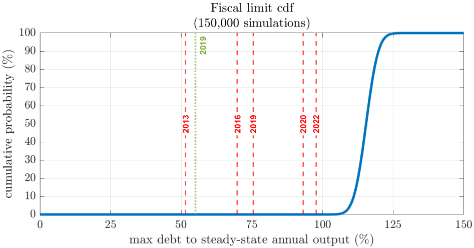
In favor of that approach and against the strategic default framework:

- Not only debt ratios, but also present and expected future fiscal policies matter as well as growth prospects!
- Instead of (explicitly) strategic for a benevolent government, the default decision carries an erratic political component (stochastic event)

Fiscal limit at the DSS

Vertical-dashed lines indicate actual and projected ratios of the gross debt at the end of the respective labeled years, where 2013, 2016, and 2019 are actual values, while 2020 and 2022 are projections made by the IFI (Instituto Fiscal Independente) on 17th of November 2020. Vertical-dotted lines indicate actual net debt at the end of the respective label years.





Solution Method

3rd step: Regime-switching

	Below $\tau^{\max}$	**At $\tau^{\max}$**
Below fiscal limit	**Regime 1**	Regime 2
Reached fiscal limit	Regime 3	Regime 4

Peak of the Laffer curve (shadow tax rate):

$$\begin{cases} \log\left(\frac{\tau_t}{\overline{\tau}}\right) = \rho_\tau \log\left(\frac{\tau_{t-1}}{\overline{\tau}}\right) + \gamma_\tau \log\left(\frac{B_{t-1}}{\overline{B}}\frac{\overline{Y}}{Y_{t-1}}\right) & \text{if} \quad \tau_t \leq \tau_t^{max} \\ \tau_t^{max} \quad \text{if} \quad \tau_t > \tau_t^{max} \end{cases} \tag{14}$$

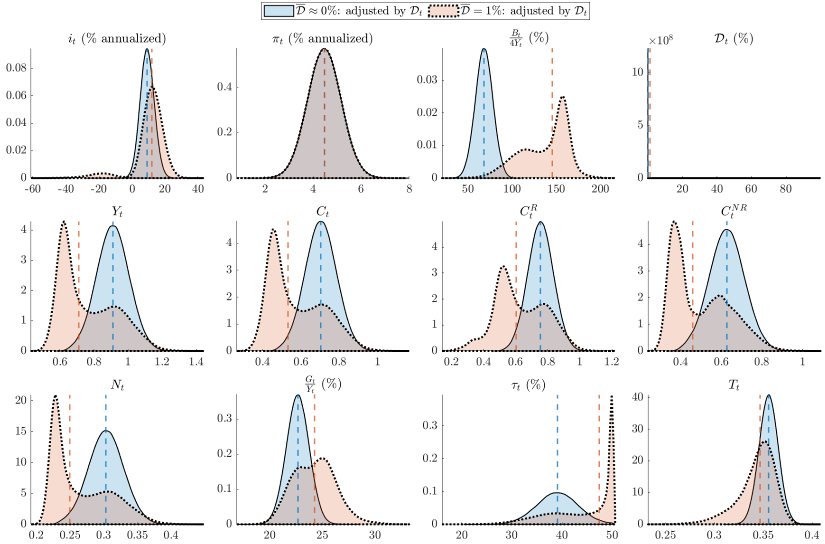
Fiscal limit (normal approx. => regress the mean on states => simulate $\{\gamma_0, \gamma_b, \gamma_a, \gamma_g\}$):

$$\delta_t = \begin{cases} \overline{\delta} \in (0,1] & \text{if} \quad B_{t-1} > \mathcal{B}_t \\ 0 & \text{if} \quad B_{t-1} \leq \mathcal{B}_t \end{cases} \tag{15}$$

$$Pr\left(B_t > \mathcal{B}_{t+1}\right)_t = \frac{1}{1 + \exp\left(\gamma_0 + \gamma_b\left(B_t - \mathbb{E}_t\,\mathcal{B}_{t+1}\right) + \gamma_a\left(\mathbb{E}_t\,A_{t+1}|_{(\text{no default})} - \overline{A}\right) + \gamma_g\left(\mathbb{E}_t\,G_{t+1} - \overline{G}\right)\right)} \tag{16}$$

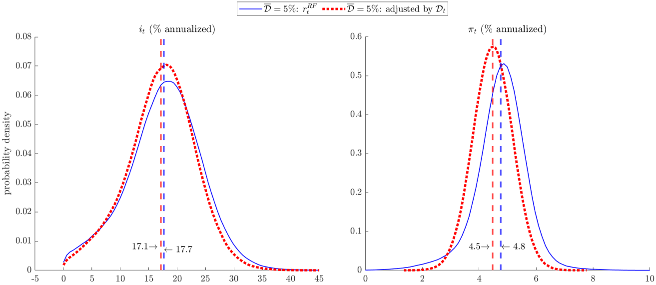
In each regime, the sticky-price version of the model is solved after 1st (or 2nd) order approximation around regime-specific DSS

Ergodic distribution of selected variables far and near the fiscal limit



Distribution under different monetary policy rules near the fiscal limit

Only observations in which the policy rate is above zero

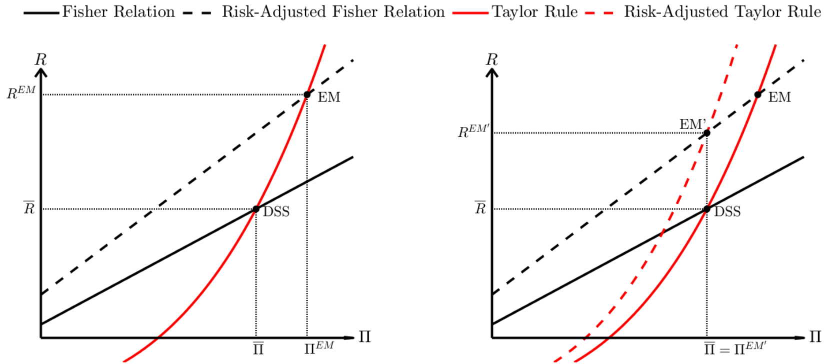


	i_t (% annualized)			π_t (% annualized)		
	DSS	EM	Bias	DSS	EM	Bias
$\overline{\mathcal{D}} = 5\%$: r_t^{RF}	9.7	17.7	8	4.5	4.8	0.3
$\overline{\mathcal{D}} = 5\%$: adjusted by $\mathcal{D}_t$	9.7	17.1	7.4	4.5	4.5	0

	r_t (% annualized)			r_t^{Gov} (% annualized)		
	DSS	EM	Bias	DSS	EM	Bias
$\overline{\mathcal{D}} = 5\%$: r_t^{RF}	5	12.2	7.2	5	12.2	7.2
$\overline{\mathcal{D}} = 5\%$: adjusted by $\mathcal{D}_t$	5	12.1	7.1	5	12.1	7.1

Stylized representation of the Taylor Rule and the Fisher Equation

Note: Left panel represents Policy Rule 1, when the central bank ignores the policy asset default risk, whereas right panel represents a switch from that rule to Policy Rule 2, when the central bank adjusts its policy rule to that risk. R is the gross nominal policy rate and Π is gross inflation. Variables with an overbar represent targets or deterministic values. DSS stands for deterministic steady state, while EM stands for ergodic mean.



Simulated means (Regime 1): $\overline{\mathcal{D}} = 2\%$; r_t^n in the intercept

i_t (% annualized, DSS $\bar{i} = 9.7$ in Regime 1)

	ϕ^i=0.000	ϕ^i=0.150	ϕ^i=0.300	ϕ^i=0.450	ϕ^i=0.600	ϕ^i=0.750	ϕ^i=0.900
ϕ^π=1.00	28.7	27	24.2	21.8	17.8	14.8	10.6
ϕ^π=1.25	14.9	14.3	13.8	13.3	13	12.6	11.3
ϕ^π=1.50	14.2	13.6	13.2	12.5	12.2	12.1	11.4
ϕ^π=2.50	13.6	13.4	12.9	12.7	12.4	12.2	12.1
ϕ^π=2.75	13.7	13.3	13.1	12.7	12.4	12.1	12
ϕ^π=3.00	13.8	13.2	12.9	12.6	12.3	12.1	12.1

r_t (% annualized, DSS $\bar{r} = 5.0$ in Regime 1)

	ϕ^i=0.000	ϕ^i=0.150	ϕ^i=0.300	ϕ^i=0.450	ϕ^i=0.600	ϕ^i=0.750	ϕ^i=0.900
ϕ^π=1.00	9.8	9.3	8.7	8.3	7.6	7.5	6.8
ϕ^π=1.25	8.9	8.4	8	7.6	7.4	7.3	7
ϕ^π=1.50	9	8.5	8.1	7.6	7.3	7.2	6.9
ϕ^π=2.50	8.7	8.5	8.1	7.9	7.6	7.4	7.2
ϕ^π=2.75	8.9	8.4	8.3	7.9	7.6	7.2	7
ϕ^π=3.00	8.9	8.3	8.1	7.8	7.5	7.2	7.1

π_t (% annualized, DSS $\overline{\pi} = 4.5$ in Regime 1)

	ϕ^i=0.000	ϕ^i=0.150	ϕ^i=0.300	ϕ^i=0.450	ϕ^i=0.600	ϕ^i=0.750	ϕ^i=0.900
ϕ^π=1.00	17.3	16.3	14.5	12.7	9.7	7.2	4.3
ϕ^π=1.25	5.4	5.3	5.3	5.3	5.4	5.4	4.9
ϕ^π=1.50	4.7	4.7	4.7	4.7	4.8	4.9	5
ϕ^π=2.50	4.5	4.5	4.5	4.6	4.7	5	5.5
ϕ^π=2.75	4.5	4.5	4.5	4.6	4.7	5	5.5
ϕ^π=3.00	4.5	4.5	4.5	4.6	4.7	5	5.6

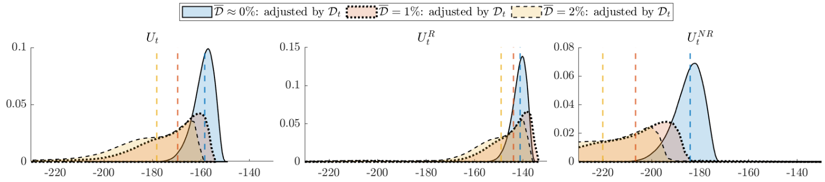
Why is it the case? Let us check the Euler equation at the ergodic mean

$$\mathbb{E}^{EM}\left[\frac{1}{1+r_t}\right] = \mathbb{E}^{EM}\left[\underbrace{\beta\left(\frac{C_{t+1}^R + \alpha_G G_{t+1} - \eta\frac{N_{t+1}^{1+\chi}}{1+\chi}}{C_t^R + \alpha_G G_t - \eta\frac{N_t^{1+\chi}}{1+\chi}}\right)^{-\sigma}}_{\Lambda_U}\underbrace{(1-\delta_{t+1})}_{\Lambda_D}\right] \tag{17}$$

$$= \underbrace{\mathbb{E}^{EM}\left[\Lambda_U\right]\mathbb{E}^{EM}\left[\Lambda_D\right] + \underbrace{\text{COV}^{EM}\left[\Lambda_U, \Lambda_D\right]}_{<0}}_{\mathbb{E}^{DSS}[r_t] < \mathbb{E}^{EM}[r_t]}$$

- Default risk makes a regime switch more likely, turning the distribution of endogenous variables state-dependent (**no certainty equivalence!**)
- So, $|\,\mathbb{E}^{EM}[r_t] - \mathbb{E}^{DSS}[r_t]| > 0$
- Utility upon default is highly likely to be lower than at the period before of it due to default-enacted recession
- Therefore, covariance between SDF and expected return for the next period should be negative $=>$ **Ricardian household loses wealth when she needs the most!**
- So, $\mathbb{E}^{DSS}[r_t] \ < \ \mathbb{E}^{EM}[r_t]$

Welfare comparison (2nd Order): higher numbers are better



Aggregate welfare at $\overline{\mathcal{D}} = 5\%$

Rule 1: Risky policy asset, but the CB ignores default-risk dynamics

	γ_τ=0.100	γ_τ=0.125	γ_τ=0.150	γ_τ=0.175	γ_τ=0.200
ϕ^π=1.00	3718	-5271	NaN	NaN	NaN
ϕ^π=1.25	NaN	-2192	-949	-594	-465
ϕ^π=1.50	NaN	-2227	-1000	-627	-479
ϕ^π=2.00	NaN	-2243	-1005	-634	-473
ϕ^π=2.75	NaN	-466	-859	-591	-429
ϕ^π=3.00	NaN	-780	-775	-549	-303

Rule 2: Risky policy asset, and the CB perfectly tracks default-risk dynamics

	γ_τ=0.100	γ_τ=0.125	γ_τ=0.150	γ_τ=0.175	γ_τ=0.200
ϕ^π=1.00	NaN	NaN	NaN	NaN	NaN
ϕ^π=1.25	NaN	-2475	-1103	-693	-535
ϕ^π=1.50	NaN	-2428	-1081	-683	-458
ϕ^π=2.00	NaN	-2172	-984	-587	-201
ϕ^π=2.75	NaN	-614	-596	-300	-255
ϕ^π=3.00	NaN	-210	-607	-279	-256

Conclusion

- A **TANK model** with government, nominal debt, and endogenous fiscal limits, where monetary policy targets a risky rate
- **Proximity to the fiscal limit** raises r_t due to endogenous expectations of severe recessions in episodes of default
- If the CB ignores policy-asset risk, it delivers the **unpleasant coincidence** of higher π_t, r_t, and i_t
- This result sheds new light on a **long-standing discussion in Brazil**
- If CB ignores risk, it is o**nly optimal for low-to-moderate levels** of the latter
- Stabilizing the debt near the fiscal limit reduces welfare across the board. The **debt-to-output ratio of a country does matter!**, and the **coincidence of high levels of π_t, r_t, and i_t may be a symptom**
- The **stance of monetary policy** suggested by emerging economy models which neglect policy-asset risk **may be misleading**

There are 3 chapters in this thesis

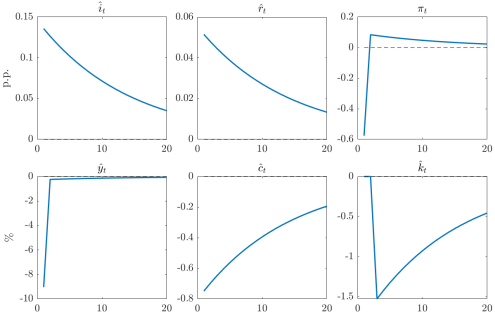
1. Interest, Prices, and Risk
2. An Unpleasant Coincidence for Monetary Policy: Risky Assets and Fiscal Limits
3. **On the Mechanics of New-Keynesian Models: Smoothing the Capital Controversy Out**

Motivation

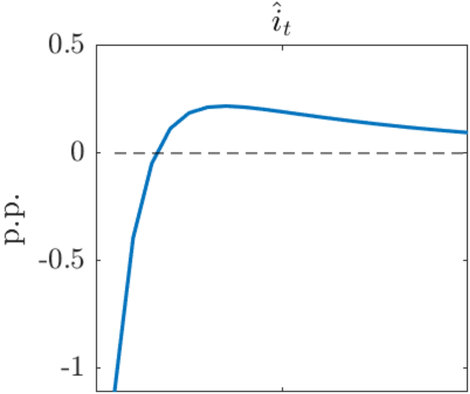
- Rupert and Šustek (2019) challenged the existence of a **real interest rate channel** of monetary policy transmission in textbook New-Keynesian models (Woodford (2003*a*); Galí (2015))

After introducing endogenous capital, we should have ...

$$\uparrow \varepsilon_t^m \quad \Rightarrow \quad \underbrace{\uparrow r_t}_{\text{if prices are sticky}} \quad \Rightarrow \quad \downarrow C_t \quad \Rightarrow \quad \downarrow Y_t \quad \Rightarrow \quad \downarrow \pi_t$$

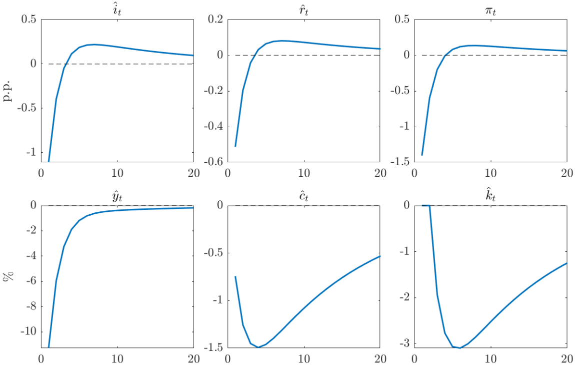


But if the monetary shock is **persistent**, then ...



Wait, we have seen this before! When the monetary shock affects inflation expectations so strongly that nominal interest rate falls in the present!

However, in the presence of endogenous capital, after a **persistent** monetary shock, real interest rate also falls



Rupert and Šustek (2019) conclude that the real interest rate channel in the canonical model is **not structural**! It is necessary considerable **capital adjustment costs** to restore the channel.

$$\uparrow \varepsilon_t^m \quad \Rightarrow \quad \downarrow \pi_t \quad \Rightarrow \quad \underbrace{\downarrow Y_t}_{\text{if prices are sticky}} \quad \Rightarrow \quad \downarrow C_t \quad \Rightarrow \quad \underbrace{?r_t}_{\substack{\text{depends on capital, shock persistence,} \\ \text{and capital adjustment costs}}}$$

Related literature

- Brault and Khan (2019) say investment (not capital) adjustment costs restore the channel

Our contribution? Smoothing in the Taylor rule restores the channel!

$$i_t = \rho^i i_{t-1} + \left(1 - \rho^i\right)\left(i + \nu\pi_t\right) + \xi_t^m \tag{18}$$

Why smoothing?

1. It is as prevalent (perhaps more) as endogenous capital in middle-scale new-Keynesian models (i.e. Smets and Wouters (2003), Smets and Wouters (2007))
2. It is actually there, Coibion and Gorodnichenko (2012)
3. It is optimal (Sack and Wieland (2000), Woodford (2003*b*))!

Side contribution? Realistic $\frac{\overline{K}}{\overline{Y}}$ demands significant capital adjustment costs

▸ The model

▸ The mechanics of smoothing

▸ Discussion on capital-to-output ratio

Sweeping the real interest rate channel

(+) when the real interest rate increases right after a positive monetary shock
(–) when it decreases
empty cells indicate that Blanchard and Kahn (1980) conditions are not satisfied

	$\rho^i = 0$	ρ^i =0.1	ρ^i =0.2	ρ^i =0.3	ρ^i =0.4	ρ^i =0.5	ρ^i =0.6	ρ^i =0.7	ρ^i =0.8	ρ^i =0.9
$\rho^m = 0$	+	+	+	+	+	+	+	+	+	+
ρ^m =0.1	-	-	-	-	+	+	+	+	+	+
ρ^m =0.2	-	-	-	-	-	-	-	+	+	+
ρ^m =0.3	-	-	-	-	-	-	-	-	+	+
ρ^m =0.4	-	-	-	-	-	-	-	-	-	+
ρ^m =0.5	-	-	-	-	-	-	-	-	-	+
ρ^m =0.6	-	-	-	-	-	-	-	-	-	+
ρ^m =0.7	-	-	-	-	-	-	-	-	-	+
ρ^m =0.8	-	-	-	-	-	-	-	-	-	+
ρ^m =0.9	-	-	-	-	-	-	-	-	+	+

Table: $\overline{K} = 5.5\overline{Y}$, $\delta = 0.025$, and $\kappa = 0.0$

How restricting is the switching behavior for the estimation of VARs and DSGEs?

Smets and Wouters (2003) estimate $\rho^i = 0.956$ for the Euro Area
Smets and Wouters (2007) estimate $\rho^i = 0.75 - 0.84$ for the United States

Ch 3: Smoothing the Capital Controversy Out

Sweeping the real interest rate channel

(+) when the real interest rate increases right after a positive monetary shock
(–) when it decreases
empty cells indicate that Blanchard and Kahn (1980) conditions are not satisfied

	$\rho^i = 0$	ρ^i =0.1	ρ^i =0.2	ρ^i =0.3	ρ^i =0.4	ρ^i =0.5	ρ^i =0.6	ρ^i =0.7	ρ^i =0.8	ρ^i =0.9
$\rho^m = 0$	+	+	+	+	+	+	+	+	+	+
ρ^m =0.1	+	+	+	+	+	+	+	+	+	+
ρ^m =0.2	+	+	+	+	+	+	+	+	+	+
ρ^m =0.3	+	+	+	+	+	+	+	+	+	+
ρ^m =0.4	+	+	+	+	+	+	+	+	+	+
ρ^m =0.5	+	+	+	+	+	+	+	+	+	+
ρ^m =0.6	-	-	+	+	+	+	+	+	+	+
ρ^m =0.7	-	-	-	+	+	+	+	+	+	+
ρ^m =0.8	-	-	-	+	+	+	+	+	+	+
ρ^m =0.9	-	-	-	+	+	+	+	+	+	+

Table: $\overline{K} = 5.5\overline{Y}$, $\delta = 0.025$, and $\kappa = 0.1$

	$\rho^i = 0$	ρ^i =0.1	ρ^i =0.2	ρ^i =0.3	ρ^i =0.4	ρ^i =0.5	ρ^i =0.6	ρ^i =0.7	ρ^i =0.8	ρ^i =0.9
$\rho^m = 0$	+	+	+	+	+	+	+	+	+	+
ρ^m =0.1	+	+	+	+	+	+	+	+	+	+
ρ^m =0.2	+	+	+	+	+	+	+	+	+	+
ρ^m =0.3	+	+	+	+	+	+	+	+	+	+
ρ^m =0.4	+	+	+	+	+	+	+	+	+	+
ρ^m =0.5	+	+	+	+	+	+	+	+	+	+
ρ^m =0.6	+	+	+	+	+	+	+	+	+	+
ρ^m =0.7	+	+	+	+	+	+	+	+	+	+
ρ^m =0.8	+	+	+	+	+	+	+	+	+	+
ρ^m =0.9	-	+	+	+	+	+	+	+	+	+

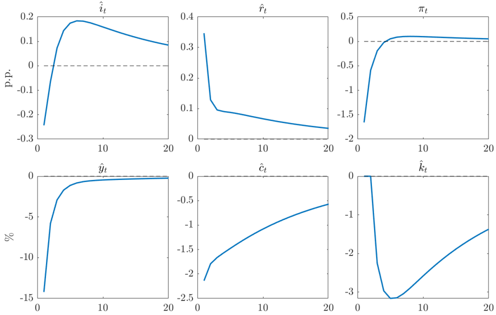
Table: $\overline{K} = 5.5\overline{Y}$, $\delta = 0.025$, and $\kappa = 0.5$

Conclusion

Smoothing in the Taylor rule **restores the real interest rate channel** of monetary policy transmission in NK models! Just pick a combination:

- High (but realistic) smoothing
- OR low smoothing with small adjustment cost

Impulse response function to a 1 p.p. ↑ monetary shock under $\rho^m = .50$, $\rho^i = 0.5$, $\frac{\overline{K}}{\overline{Y}} = 5.5$, and $\kappa = 0.1$



Thanks

Here, start the backup slides

Methodology: Real neutral rates estimated by univariate filters

Back

1. Quarterly country data from the IMF-IFS
2. All countries are sorted in descending order by forecasted nominal Q42020 GDP measured in USD as of 27/01/2020
3. Countries are classified using the IMF-WEO definition of emerging and advanced economies
4. The largest 20 advanced and the largest 20 emerging economies are selected from the dataset
5. The real ex-ante interest rate for each country is calculated according to a **linearized Fisher equation**, that is, subtracting a series of nominal interest rate by a series of inflation expectation, both with the same time horizon
6. For the nominal interest rate, we chose the annualized rate on national Treasury Bills (local-currency 1-year-maturity federal government bonds)

Methodology: Real neutral rates estimated by univariate filters

8. For the inflation expectation, we estimated AR(p) models for each country's quarterly CPI inflation series with p ranging from 0 to 4 lags

9. For each country, we selected the model with the lowest BIC information criterion. Since not all selected countries had enough observations for estimation, some of the initially selected countries had to be removed from the sample

10. Having defined each country's inflation forecast model, we built a series of 1-year-ahead inflation forecast for each country

11. After calculating all country-specific ex-ante real rate series, we applied three statistical filters on them: HP ($\lambda = 1600$), Baxter-King (min=6, max=32, order=12), and Christiano-Fitzgerald (min=6, max=32).[2] We calculated the median of these filters.

12. Finally, we obtained with the country-specific medians three statistics for each country group: the group median, the arithmetic group mean, and the country-weighted group mean using the aforementioned GDP values (Figure 1).

[2] The original reference of each filter is, in order, Hodrick and Prescott (1997), Baxter and King (1999), and Christiano and Fitzgerald (2003).

Methodology: Real neutral rates estimated by univariate filters

	Name	Status	NR Start	NR End	CPI Start	CPI End
US	United States of America	Advanced	1950Q1	2020Q1	1955Q2	2020Q1
GB	United Kingdom	Advanced	1964Q1	2016Q3	1955Q2	2020Q1
IT	Italy	Advanced	1977Q1	2020Q1	1955Q2	2020Q1
CA	Canada	Advanced	1950Q1	2017Q2	1949Q2	2020Q1
ES	Spain	Advanced	1987Q3	2020Q1	1954Q2	2020Q1
SE	Sweden	Advanced	1960Q1	2017Q2	1955Q2	2020Q1
BE	Belgium	Advanced	1957Q1	2017Q4	1955Q2	2020Q1
IL	Israel	Advanced	1995Q1	2020Q1	1952Q2	2020Q1
HK	Hong Kong	Advanced	1992Q4	2018Q4	1981Q1	2020Q1
BR	Brazil	Emerging	1995Q1	2020Q1	1980Q1	2020Q1
MX	Mexico	Emerging	1978Q1	2020Q1	1957Q2	2020Q1
SA	Saudi Arabia	Emerging	2009Q2	2018Q1	1980Q2	2020Q1
PL	Poland	Emerging	1992Q1	2017Q1	1988Q2	2020Q1
TH	Thailand	Emerging	2001Q1	2020Q1	1965Q2	2020Q1
ZA	South Africa	Emerging	1957Q1	2020Q1	1957Q2	2020Q1
PH	Philippines	Emerging	1976Q1	2019Q4	1957Q2	2020Q1
BD	Bangladesh	Emerging	2006Q3	2020Q1	1993Q4	2020Q1
EG	Egypt	Emerging	1997Q1	2020Q1	1957Q2	2019Q4

Table: Filters: Summary of the data sample

Methodology: Real neutral rates estimated by univariate filters

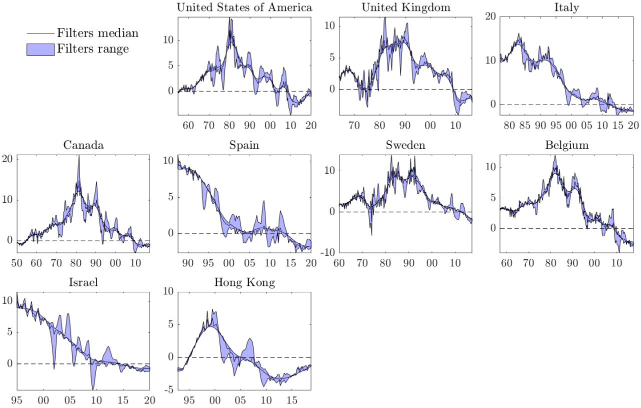


Figure: Advanced Economies: Real neutral rates estimated by univariate filters

Methodology: Real neutral rates estimated by univariate filters

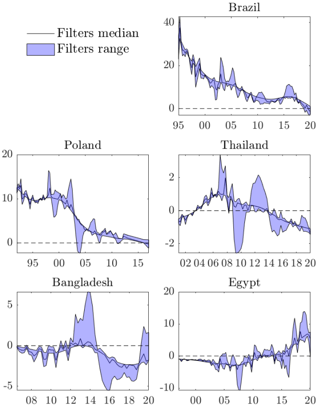


Figure: Emerging Economies: Real neutral rates estimated by univariate filters

Methodology: Empirical correlations

Back

1. We collect a CDS dataset of emerging economies from Bloomberg and merge it with the same data we used for the estimation of the natural interest rate Methodology
2. For each country, we calculate the contemporaneous four-quarter moving correlation between quarterly-mean nominal policy rates, Q/(Q-4) CPI inflation, and a measure of risk
3. For emerging economies, we use 5-year CDS in USD (usually the most liquid)
4. For advanced economies, we opt for the 1-year nominal interest rate spread w.r.t. to 1-year nominal U.S. Treasuries, as CDS contracts are not liquid for these economies
5. Sample ranges from 2000Q1 to 2019Q4, and includes 12 of the 20 largest emerging economies, in addition to 7 of the 20 largest developed economies, where the missing countries were due to lack of data. We adopted a small arbitrary minimum threshold: 10 available observations

Methodology: Empirical correlations

Back

6. We remove outliers identified as observations more than 3 scaled median absolute deviations (MAD) from the median[3]
7. We reproduce this exercise using Du and Schreger (2016)'s measure of 5-year local-currency credit spread, which arguably controls for exchange-rate expectations and exchange-rate risk

[3] The scaled MAD formula is given by c*median(abs(A-median(A))), where A is the vector of observations, and c=-1/(sqrt(2)*erfcinv(3/2)).

Back **Case 1: Price-level targeting**

After some algebra,

$$p_t = \sum_{j=0}^{\infty} \Upsilon_{t,j+1} \mathbb{E}_t \left(r^n_{t+j} - \left(1 - \mathbb{E}_t\, \mathcal{D}_{t+j+1} \delta_{t+j+1}\right) \bar{\iota}_{t+j} + \mathbb{E}_t\, \mathcal{D}_{t+j+1} \delta_{t+j+1} \right)$$

$$\Upsilon_{t,j+1} \equiv \underbrace{\Pi_{k=1}^{j+1} \left(\frac{1}{1 + \left(1 - \mathbb{E}_t\, \mathcal{D}_{t+k} \delta_{t+k}\right) \phi} \right)}_{> \Upsilon^{RF}_{t,j+1} \quad \Rightarrow \quad \text{less active}} \quad \forall j \geq 0, \forall t \tag{19}$$

Determinacy conditions:

$\phi > 0$

and at least one infinite sequence $k_n \subset [1, \infty)$ such that $0 \leq \mathbb{E}_t\, \mathcal{D}_{t+k} \delta_{t+k} < 1$

Case 1: Price-level targeting

Optimal Wickellian rule has the sequence of time-varying intercepts

$$\left\{\bar{\iota}_{t+j}\right\}_{j=0}^{\infty} \equiv \left\{\frac{r^n_{t+j}+\mathbb{E}_t\,\mathcal{D}_{t+j+1}\delta_{t+j+1}}{1-\mathbb{E}_t\,\mathcal{D}_{t+j+1}\delta_{t+j+1}}\right\}_{j=0}^{\infty}$$

If the CB does not update the intercept ($\bar{\iota}_t = r^n_t$), we obtain a **high-price-level bias**, which partially disconnects $\mathbb{E}\,p$ from $\overline{p} = 0$:

$$\mathbb{E}\,p = \underbrace{\frac{\mathbb{E}\,\mathcal{D}\delta}{(1-\mathbb{E}\,\mathcal{D}\delta)\,\phi}\,(1+\mathbb{E}\,r^n)}_{\text{price-level bias}} \tag{20}$$

- Bias collapses to $\overline{p} = 0$ only when $\mathbb{E}\,\mathcal{D}\delta = 0$
- If $\mathbb{E}\,r^n > -1$, the price-level bias is positive for $\mathbb{E}\,\mathcal{D}\delta < 1$
- Bias reduces with the size of ϕ

Back Calibrated/estimated period: 1999Q3-2019Q4

Parameter	Description	Value
β	time discount factor	0.989
η	disutility of labor	varies
χ	inverse of the Frisch elasticity of labor	1.0
$\overline{N}$	steady-state labor supply	1/3
k_Y	capital-to-quarterly-output ratio	18.0
γ^{NR}	fraction of non-Ricardian households	0.40
γ_τ	tax-rate elasticity to the debt level	0.108
$\overline{\delta}_{\delta_t>0}$	debt haircut in case of default	0.05
$\overline{\Pi}$	gross inflation target	1.011
δ^{TFP}	TFP loss at the impact of default	0.0238
θ	elasticity of substitution between intermediate goods	11
ϕ^C	price adjustment cost	100
ρ_τ	tax-rate autoregressive coefficient	0.862

Parameter	Description	Value
$\overline{Z}$	steady-state government transfers	$0.142\overline{Y}$
$\overline{G}$	steady-state government expenses	$0.206\overline{Y}$
$\overline{\tau}_{\tau_t<\tau_t^{\max}}$	steady-state tax rate	0.391
$\overline{Y}$	steady-state output	1.0
$\overline{B}$	steady-state debt	2.48
$\overline{P}$	steady-state price level	1.0

Parameter	Prior Dist.	CI Min	CI Max	% CI	Post. Mode	Post. Mean	Post. Std.	Post. 5%	Post. 95%
σ	gamma	1.500	3.500	99.0%	2.227	2.132	0.259	1.684	2.586
α_G	normal	-1.000	1.000	95.0%	0.551	0.542	0.108	0.376	0.717
$\gamma_{G\Psi}$	normal	-0.250	0.500	95.0%	0.160	0.163	0.028	0.117	0.208
ϕ^{π}	normal	2.000	3.500	95.0%	2.891	2.965	0.163	2.683	3.199
ϕ^{Y}	normal	0.000	1.000	95.0%	0.017	0.020	0.011	0.005	0.039
ϕ^{i}	beta	0.500	0.990	95.0%	0.787	0.783	0.037	0.714	0.834
ρ^{A}	beta	0.250	0.750	90.0%	0.934	0.933	0.014	0.909	0.955
ρ^{β}	beta	0.250	0.750	90.0%	0.971	0.966	0.012	0.944	0.984
ρ^{GY}	beta	0.250	0.750	90.0%	0.143	0.132	0.026	0.090	0.176
ρ^{GG}	beta	0.250	0.750	90.0%	0.777	0.795	0.039	0.729	0.858
$\rho^{\mathcal{M}}$	beta	0.250	0.750	90.0%	0.216	0.232	0.054	0.145	0.321
σ^{A}	inv. gamma	0.000	0.035	99.9%	0.005	0.005	$3.8e^{-4}$	0.004	0.005
σ^{β}	inv. gamma	0.000	0.020	99.9%	0.004	0.004	$3.6e^{-4}$	0.003	0.004
σ^{G}	inv. gamma	0.000	0.035	99.9%	0.013	0.013	0.001	0.011	0.015
σ^{M}	inv. gamma	0.000	0.020	99.9%	0.004	0.004	$8.6e^{-4}$	0.003	0.006
$\sigma^{me,Y}$	inv. gamma	0.000	0.040	99.9%	0.009	0.009	$6.8e^{-4}$	0.008	0.010

Table: Summary of parameters estimation

Back **The NK model with endogenous capital and smoothing in the Taylor rule**

Model is log-linearized around the deterministic steady state ($\overline{\pi} = 0$, $\overline{y} = 1$)
For any variable X, $\hat{X} \equiv \frac{X_t - \overline{X}}{\overline{X}}$, with exception of $\hat{i}_t \equiv i_t - \overline{i}$ and $\hat{r}_t \equiv r_t - \overline{r}$

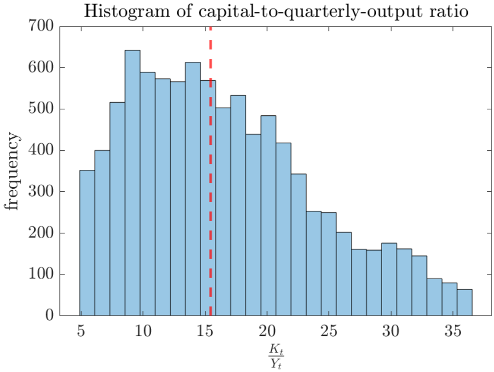
After some algebra, we obtain a reduced system with only 4 equations:

$$\left.\begin{aligned}
-\hat{c} &= -\mathbb{E}_t\,\hat{c}_{t+1} + \rho^i \hat{i}_{t-1} + \left(1-\rho^i\right)\nu\pi_t - \mathbb{E}_t\,\pi_{t+1} + \xi_t^m && (21)\\
-\hat{c} &= -\mathbb{E}_t\,\hat{c}_{t+1} + \mathbb{E}_t\,\hat{g}_{t+1} + r\,\mathbb{E}_t\left(\hat{c}_{t+1} + \frac{1+\eta}{1-\alpha}\hat{y}_{t+1} - \frac{1+\alpha\eta}{1-\alpha}\hat{k}_{t+1}\right) && (22)\\
\pi_t &= \Psi\left(\frac{\eta+\alpha}{1-\alpha}\hat{y}_t - \alpha\frac{1+\eta}{1-\alpha}\hat{k}_t + \hat{c}_t\right) + \beta\,\mathbb{E}_t\,\pi_{t+1} && (23)\\
\hat{y}_t &= \frac{\overline{c}}{\overline{y}}\hat{c}_t + \frac{\overline{k}}{\overline{y}}\hat{k}_{t+1} - (1-\delta)\frac{\overline{k}}{\overline{y}}\hat{k}_t && (24)
\end{aligned}\right\}$$

where $\Psi \equiv \chi\frac{(1-\theta)(1-\theta\beta)}{\theta}$, such that when prices are flexible, $\Psi \to \infty$

$G_{t+1} \equiv \frac{q_{t+1}}{q_t}$ is the capital gain, so $\hat{g}_t = \hat{q}_t - \hat{q}_{t-1} = \overline{\kappa}\left(\hat{k}_{t+1} - \hat{k}_t\right) - \overline{\kappa}\left(\hat{k}_t - \hat{k}_{t-1}\right)$,
where $\overline{\kappa} = \kappa\overline{k}$.

Back **Realistic capital-to-output ratio**



Calculated with annual data from the Penn World Table 10.0 (Feenstra, Inklaar and Timmer (2015)) for 183 countries from 1950 to 2019

The red-dashed line marks the median of the full distribution
Values below percentile 5 and above percentile 95 are censored in the graph

Realistic capital-to-output ratio

Huge heterogeneity across time and countries

Year	Country	Annual GDP	Capital Stock	$\frac{K}{Y}$
1960	Brazil	US$ 285,613	US$ 1,095,861	15.3
2019	Brazil	US$ 3,042,119	US$ 13,716,488	18.0
1960	Canada	US$ 310,435	US$ 1,198,070	15.4
2019	Canada	US$ 1,874,187	US$ 8,757,840	18.7
1960	China	US$ 689,787	US$ 1,739,456	10.1
2019	China	US$ 20,572,606	US$ 81,726,344	15.9
1960	Germany	US$ 1,092,642	US$ 4,206,044	15.4
2019	Germany	US$ 4,314,068	US$ 20,957,202	19.4
1960	France	US$ 592,031	US$ 3,638,362	24.6
2019	France	US$ 2,965,339	US$ 18,013,436	24.3
1960	United Kingdom	US$ 782,240	US$ 3,447,930	17.6
2019	United Kingdom	US$ 3,016,695	US$ 15,374,464	20.4
1960	Japan	US$ 609,690	US$ 1,707,238	11.2
2019	Japan	US$ 5,099,254	US$ 26,138,818	20.5
1960	Mexico	US$ 274,372	US$ 1,012,672	14.8
2019	Mexico	US$ 2,406,410	US$ 10,934,025	18.2
1960	United States	US$ 3,510,945	US$ 14,711,919	16.8
2019	United States	US$ 20,563,592	US$ 69,059,072	13.4
1960	South Africa	US$ 134,600	US$ 417,390	12.4
2019	South Africa	US$ 732,852	US$ 2,892,806	15.8

Realistic capital-to-output ratio

The model requires significant capital adjustment costs to fulfill local determinacy conditions

	$\rho^i = 0$	ρ^i =0.1	ρ^i =0.2	ρ^i =0.3	ρ^i =0.4	ρ^i =0.5	ρ^i =0.6	ρ^i =0.7	ρ^i =0.8	ρ^i =0.9
$\rho^m = 0$									+	+
ρ^m =0.1									+	+
ρ^m =0.2									+	+
ρ^m =0.3									-	+
ρ^m =0.4									-	+
ρ^m =0.5									-	-
ρ^m =0.6									-	-
ρ^m =0.7									-	-
ρ^m =0.8									-	-
ρ^m =0.9									-	-

Table: Parameter sweep with $\overline{K} = 15.4\overline{Y}$, $\delta = 0.025$, and $\kappa = 0$

	$\rho^i = 0$	ρ^i =0.1	ρ^i =0.2	ρ^i =0.3	ρ^i =0.4	ρ^i =0.5	ρ^i =0.6	ρ^i =0.7	ρ^i =0.8	ρ^i =0.9
$\rho^m = 0$								+	+	+
ρ^m =0.1								+	+	+
ρ^m =0.2								+	+	+
ρ^m =0.3								+	+	+
ρ^m =0.4								+	+	+
ρ^m =0.5								+	+	+
ρ^m =0.6								+	+	+
ρ^m =0.7								+	+	+
ρ^m =0.8								+	+	+
ρ^m =0.9								+	+	+

Table: Parameter sweep with $\overline{K} = 15.4\overline{Y}$, $\delta = 0.025$, and $\kappa = 0.1$

Back **The mechanics**

Assume for the set of coefficients $\{a_0, a_1, a_2, b_0, b_1, b_2, d_0, d_1, d_2, f_0, f_1, f_2\}$

$$\hat{c}_t = a_0\hat{k}_t + a_1\xi^m_t + a_2\hat{i}_{t-1}; \qquad \hat{k}_{t+1} = f_0\hat{k}_t + f_1\xi^m_t + f_2\hat{i}_{t-1};$$

$$\pi_t = b_0\hat{k}_t + b_1\xi^m_t + b_2\hat{i}_{t-1}; \qquad \hat{y}_t = d_0\hat{k}_t + d_1\xi^m_t + d_2\hat{i}_{t-1}$$

With $\hat{R}_t = \hat{i}_t - \mathbb{E}_t\,\pi_{t+1}$ and the Euler equation (21) we can write:

$$\hat{R}_t = \mathbb{E}_t\,\hat{c}_{t+1} - \hat{c}_t$$

$$= \underbrace{\left(a_0 f_0 - a_0 + a_2\left(1-\rho^i\right)\nu b_0\right)\hat{k}_t + \left(a_0 f_2 - a_2 + a_2\rho^i + a_2\left(1-\rho^i\right)\nu b_2\right)\hat{i}_{t-1}}_{=0 \text{ at the shock}}$$

$$+ \left(\underbrace{\rho^m a_1 - a_1 + a_2\left(1-\rho^i\right)\nu b_1 + a_2}_{\text{indirect effect of capital}} \quad \underbrace{+a_0 f_1}_{\text{direct effect of capital}}\right)\xi^m_t$$

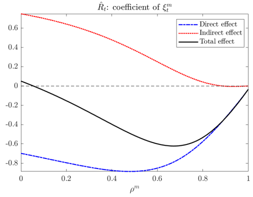
System is non-linear in the coefficients, so multiple solutions may exist. We solve numerically imposing sign restrictions: $a_0 > 0$, $d_0 > 0$, $a_2 \leq 0$, $b_2 \leq 0$, and $d_2 \leq 0$

If $\rho^i = 0$, $a_2 = 0$, $f_2 = 0$, $b_2 = 0$, and $d_2 = 0$, then we are back to Rupert and Šustek (2019)

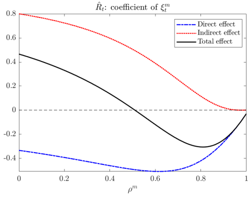
The mechanics

Benchmark: **direct** < 0 for all possible values of ρ^m, while **indirect** is mostly positive
Capital adjustment costs shift **total** up, while smoothing increases **indirect**

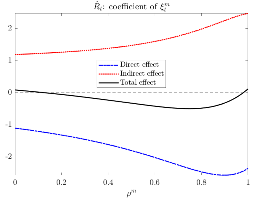
$\overline{K} = 5.5$, $\rho^i = 0$ and $\kappa = 0$



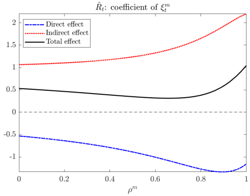
$\overline{K} = 5.5$, $\rho^i = 0$ and $\kappa = 0.1$



$\overline{K} = 5.5$, $\rho^i = 0.5$ and $\kappa = 0$



$\overline{K} = 5.5$, $\rho^i = 0.5$ and $\kappa = 0.1$



Battistini, Niccolò, Giovanni Callegari, and Luca Zavalloni. 2019. "Dynamic fiscal limits and monetary-fiscal policy interactions."

Baxter, Marianne, and Robert G King. 1999. "Measuring business cycles: approximate band-pass filters for economic time series." *Review of economics and statistics*, 81(4): 575–593.

Beers, David, Elliot Jones, and John Walsh. 2020. "BoC–BoE Sovereign Default Database: Methodology, Assumptions and Sources." Bank of Canada.

Bi, Huixin. 2012. "Sovereign default risk premia, fiscal limits, and fiscal policy." *European Economic Review*, 56(3): 389–410.

Bi, Huixin. 2017. "Fiscal Sustainability: A Cross-Country Analysis." *Economic Review (Kansas City)*, 102(4): 5–36.

Bi, Huixin, Eric M Leeper, and Campbell Leith. 2018. "Sovereign default and monetary policy tradeoffs." *International Journal of Central Banking*, 14(3): 289–324.

Bi, Huixin, Wenyi Shen, and Shu-Chun Susan Yang. 2020. "Fiscal Implications of Interest Rate Normalization in the United States." *Federal Reserve Bank of Kansas City Working Paper*, , (20-12).

Bi, Huixin, Wenyi Shen, and Shu-Chun S Yang. 2016. "Fiscal limits in developing countries: A DSGE Approach." *Journal of Macroeconomics*, 49: 119–130.

Blanchard, Olivier. 2004. "Fiscal dominance and inflation targeting: lessons from Brazil." National Bureau of Economic Research.

Blanchard, Olivier Jean, and Charles M Kahn. 1980. "The solution of linear difference models under rational expectations." *Econometrica: Journal of the Econometric Society*, 1305–1311.

Bonam, Dennis, and Jasper Lukkezen. 2019. "Fiscal and monetary policy coordination, macroeconomic stability, and sovereign risk premia." *Journal of Money, Credit and Banking*, 51(2-3): 581–616.

Brault, Joshua, and Hashmat Khan. 2019. "The Real Interest Rate Channel is Structural in Contemporary New-Keynesian Models." Carleton University, Department of Economics.

Chang, Yoosoon, Junior Maih, and Fei Tan. 2019. "Origins of monetary policy shifts: A new approach to regime switching in dsge models."

Christiano, Lawrence J, and Terry J Fitzgerald. 2003. "The band pass filter." *international economic review*, 44(2): 435–465.

Coibion, Olivier, and Yuriy Gorodnichenko. 2012. "Why are target interest rate changes so persistent?" *American Economic Journal: Macroeconomics*, 4(4): 126–62.

Davig, Troy, Eric M Leeper, and Todd B Walker. 2010. ""Unfunded liabilities" and uncertain fiscal financing." *Journal of Monetary Economics*, 57(5): 600–619.

Davig, Troy, Eric M Leeper, and Todd B Walker. 2011. "Inflation and the fiscal limit." *European Economic Review*, 55(1): 31–47.

Duffie, Darrell, and Kenneth J Singleton. 1999. "Modeling term structures of defaultable bonds." *The review of financial studies*, 12(4): 687–720.

Du, Wenxin, and Jesse Schreger. 2016. "Local currency sovereign risk." *The Journal of Finance*, 71(3): 1027–1070.

Feenstra, Robert C, Robert Inklaar, and Marcel P Timmer. 2015. "The next generation of the Penn World Table." *American economic review*, 105(10): 3150–82.

Ferreira, Alex Luiz, and Miguel A León-Ledesma. 2007. "Does the real interest parity hypothesis hold? Evidence for developed and emerging markets." *Journal of International Money and Finance*, 26(3): 364–382.

Galí, Jordi. 2015. *Monetary policy, inflation, and the business cycle: an introduction to the new Keynesian framework and its applications.* . 2^{nd} ed., Princeton, USA:Princeton University Press.

Hodrick, Robert J, and Edward C Prescott. 1997. "Postwar US business cycles: an empirical investigation." *Journal of Money, credit, and Banking*, 1–16.

Kimball, Miles. 1995. "The Quantitative Analytics of the Basic Neomonetarist Model." *Journal of Money, Credit and Banking*, 27(4): 1241–77.

Leeper, Eric M. 1991. "Equilibria under 'active'and 'passive'monetary and fiscal policies." *Journal of monetary Economics*, 27(1): 129–147.

Loyo, Eduardo. 1999. "Tight money paradox on the loose: a fiscalist hyperinflation." *manuscript, Harvard University*.

Maih, Junior. 2015. "Efficient perturbation methods for solving regime-switching DSGE models."

Miller, Max, James D Paron, and Jessica A Wachter. 2020. "Sovereign default and the decline in interest rates." *Available at SSRN*.

Mishkin, Frederic S. 1984. "Are real interest rates equal across countries? An empirical investigation of international parity conditions." *The Journal of Finance*, 39(5): 1345–1357.

Orphanides, Athanasios, and John C Williams. 2002. "Robust monetary policy rules with unknown natural rates." *Brookings Papers on Economic Activity*, 2002(2): 63–145.

Orphanides, Athanasios, and John C Williams. 2008. "Learning, expectations formation, and the pitfalls of optimal control monetary policy." *Journal of Monetary Economics*, 55: S80–S96.

Pallara, Kevin, and Jean-Paul Renne. 2019. "Fiscal Limits and Sovereign Credit Spreads." *Available at SSRN 3475425*.

Reinhart, Carmen M, and Kenneth S Rogoff. 2009. *This Time Is Different: Eight Centuries of Financial Folly.* Princeton University Press.

Reis, Ricardo. 2018. "Discussion of "Sovereign Default and Monetary Policy Tradeoffs"." *International Journal of Central Banking*.

Rupert, Peter, and Roman Šustek. 2019. "On the mechanics of New-Keynesian models." *Journal of Monetary Economics*, 102: 53–69.

Sack, Brian, and Volker Wieland. 2000. "Interest-rate smoothing and optimal monetary policy: a review of recent empirical evidence." *Journal of Economics and Business*, 52(1-2): 205–228.

Sargent, Thomas, and N Wallace. 1981. "Some Unpleasant Monetarist Arithmetic." *Federal Reserve Bank of Minneapolis Quarterly Review*, 5(3): 1–17.

Schabert, Andreas, and Sweder JG Van Wijnbergen. 2014. "Sovereign default and the stability of inflation-targeting regimes." *IMF Economic Review*, 62(2): 261–287.

Sims, Christopher A. 1994. "A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy." *Economic theory*, 4(3): 381–399.

Smets, Frank, and Rafael Wouters. 2003. "An estimated dynamic stochastic general equilibrium model of the Euro Area." *Journal of the European Economic Association*, 1(5): 1123–1175.

Smets, Frank, and Rafael Wouters. 2007. "Shocks and frictions in US business cycles: A Bayesian DSGE approach." *American economic review*, 97(3): 586–606.

Uribe, Martin. 2006. "A fiscal theory of sovereign risk." *Journal of Monetary Economics*, 53(8): 1857–1875.

Wicksell, Knut. 1898. *Interest and Prices: A Study of the Causes Regulating the Value of Money.* Originally published as Geldzins und Güterpreise in 1898. Translated to English in 1936 for the Royal Economic Society. Republished by Read Books Ltd. in 2013.

Woodford, Michael. 1994. "Monetary policy and price level determinacy in a cash-in-advance economy." *Economic theory*, 4(3): 345–380.

Woodford, Michael. 2003*a*. *Interest and Prices: Foundations of a Theory of Monetary Policy.* . 1st ed., Princeton, USA:Princeton University Press.

Woodford, Michael. 2003*b*. "Optimal interest-rate smoothing." *The Review of Economic Studies*, 70(4): 861–886.