Downward Nominal Rigidities and Bond Premia

François Gourio - Phuong Ngo

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Federal Reserve Bank of Chicago - Cleveland State U.

Motivation: large, time-varying bond premium

- Long-term bond excess returns large and volatile:

	$E(R)$	$\sigma(R)$
T-bill	9bps	30bps
10-year	38bps	240bps
30-year	47bps	390bps
Stocks	77bps	430bps

- Bond premium also appears time-varying:
  - Cycle: Fama-Bliss (1987), Campbell-Shiller (1991)
  - Trend: Wright (2011)
- What are the risks of long-term bonds?
- Why do they vary over time?

What we do

- Simple macro-finance model that generates secular and cyclical variation in bond premia

- Bond premium lower when π lower

- Two key ingredients:

  1. (Standard) New Keynesian model and supply shocks:
     $\Longrightarrow$ Bonds are risky because of fear of stagflation

  2. (New) Downward nominal rigidities:
     $\Longrightarrow$ nominal rigidities are larger when π is low
     $\Longrightarrow$ effect of supply shocks is muted when π is low

Outline

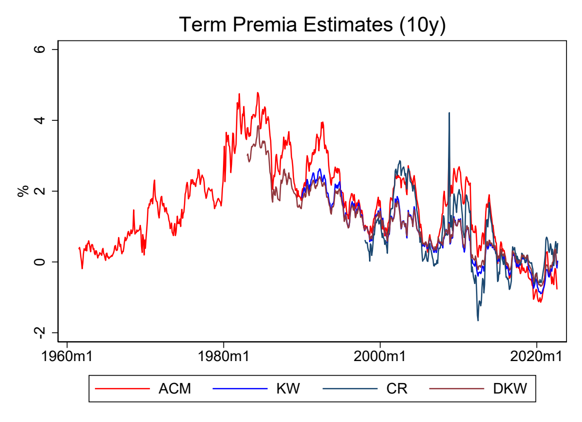
1. Motivating Evidence
2. Model
3. Mechanism and implications
4. Some more direct evidence

Related literature

- Inflation and Asset Prices
  - Fama & Schwert '77, Modigliani & Cohn '79, Piazzesi & Schneider '06, Bansal & Shaliastovich '13, David & Veronesi '13, Song '17, Roussainov & '22, etc.
- Asset prices in NK models
  - Rudebusch & Swanson '08, '12, Palomino '15, Campbell et al. '20, Gourio & Ngo '20, etc.
- Downward nominal rigidities
  - Kim & Ruge-Murcia '09, Benigno & Ricci '11, Daly & Hobijn '15, Schmitt-Grohe & Uribe '16, Dupraz et al. '21, Jo & Zubairy '22, etc.
  - Peltzman '00, Nakamura & Steinsson '08, Hazell & Taska '18, Grigsby et al. '21, etc.

MOTIVATING EVIDENCE

10y-Term Premia Estimates



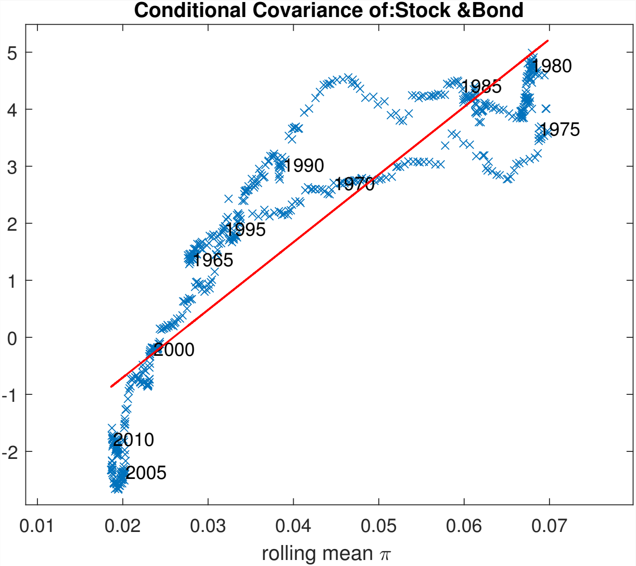
$$tp_t^{(n)} = y_t^{(n)} - \frac{1}{n} E_t \sum_{k=0}^{n-1} y_{t+k}^{(1)}$$

Association of term premium and level of inflation

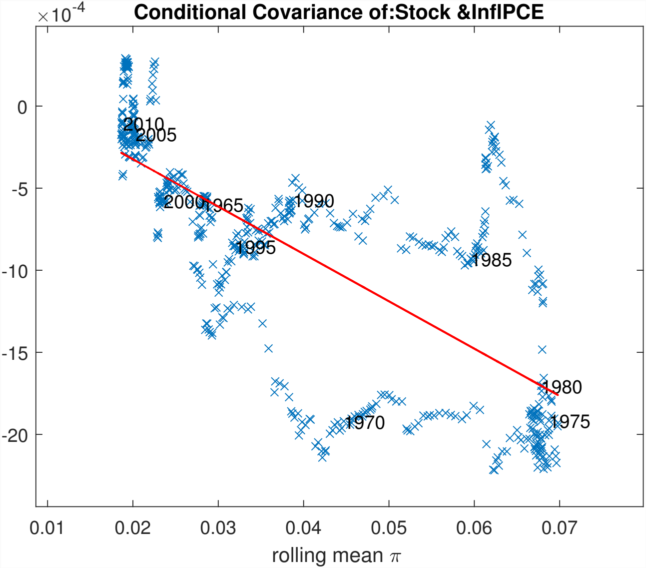
$$TP_t = \beta_0 + \beta_1 \pi_t + \beta_2 t + \varepsilon_t.$$

Regressors	(1)	(2)	(3)	(4)
Core CPI inflation	0.164***		0.173***	
	(0.055)		(0.054)	
CPI inflation		0.107**		0.105**
		(0.049)		(0.053)
Trend			0.000	-0.000
			(0.000)	(0.000)
Observations	716	716	716	716

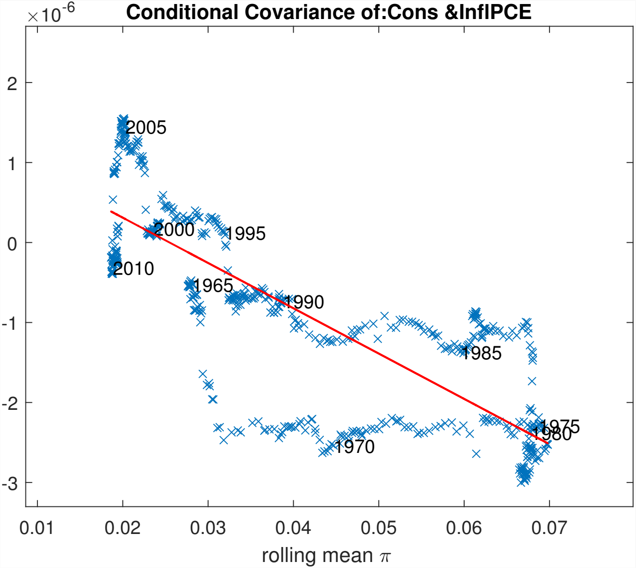
Another measure of risk: $Cov(R_s, R_b)$ vs. π



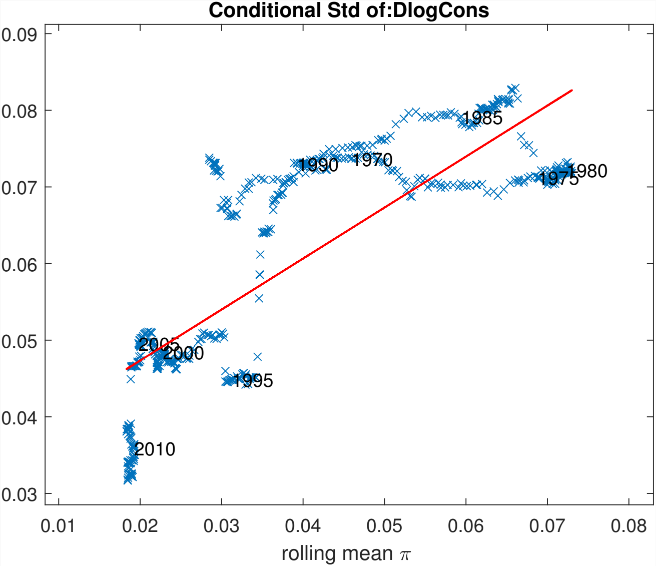
CAPM beta of inflation: $Cov(R_s, \pi)$ vs. π



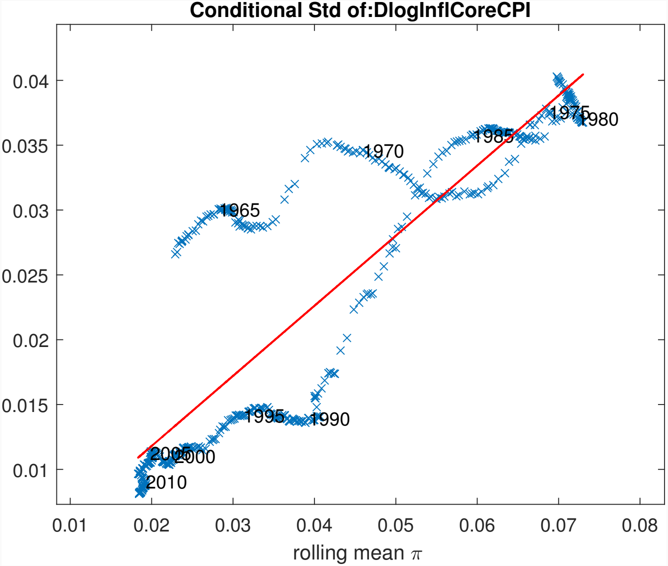
CCAPM beta of inflation: $Cov(\pi, \Delta \log c)$ vs. π



Great moderation: $\sigma(\Delta \log c)$ vs. π



High π is volatile π: $\sigma(\pi)$ vs. π



Summing up

Suggestive association between the **level** of π
and proxies for riskiness of bonds
or riskiness of inflation

But why would the **level** of π matter?

MODEL

Model overview

3-equation (non-linear) New Keynesian model

Two modifications:

1. recursive utility (high risk aversion)
2. downward nominal rigidities

Extensions: demand shocks, wage stickiness & asymmetry

Household problem

- Epstein-Zin

$$V_t = (1-\beta)\left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{\chi N_t^{1+\nu}}{1+\nu}\right) + \beta E_t \left(V_{t+1}^{1-\alpha}\right)^{\frac{1}{1-\alpha}}$$

- Euler equation

$$E_t\left[R_t^{\$} M_{t,t+1}^{\$}\right] = 1$$

- Labor supply

$$\frac{W_t}{P_t} = \chi C_t^{\sigma} N_t^{\upsilon}$$

Phillips curve

- Production function: $Y_{it} = Z_t N_{it}$
- Dixit-Stiglitz demand: $Y_{it} = Y_t \left(P_{it}/P_t\right)^{-\varepsilon}$
- Rotemberg adjustment cost of price change:

$$AC_{it} = G\left(\frac{P_{it}}{P_{it-1}}\right) Y_t$$

- Phillips curve

$$J\left(\Pi_t\right) = 1 - \varepsilon + \varepsilon \frac{W_t}{Z_t} + E_t\left[M_{t+1} J\left(\Pi_{t+1}\right)\frac{Y_{t+1}}{Y_t}\right].$$

$$J(x) = xG'(x)$$

Downward nominal price rigidities

- G is a linex function (Kim and Ruge-Murcia '09) asymmetric, but nests quadratic:

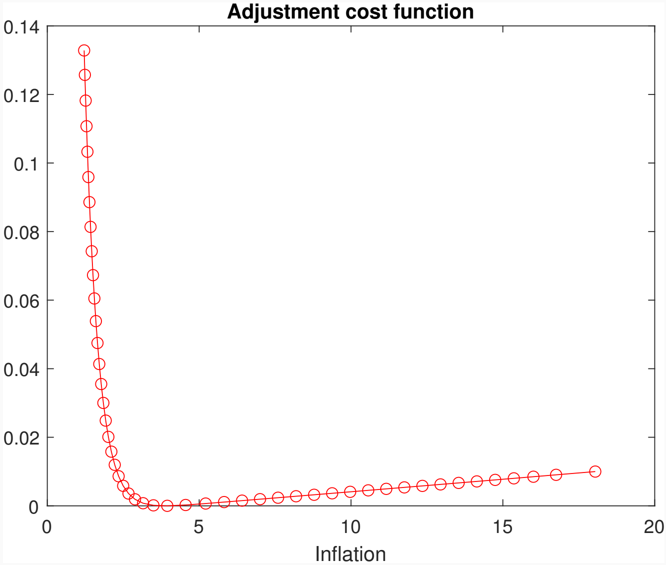
$$G(x) = \frac{\phi}{\psi^2}\left(e^{-\psi\left(x-\overline{\Pi}\right)} + \psi\left(x - \overline{\Pi}\right) - 1\right)$$

$\phi =$ scale, $\psi =$ asymmetry; $\psi \to 0$: quadratic

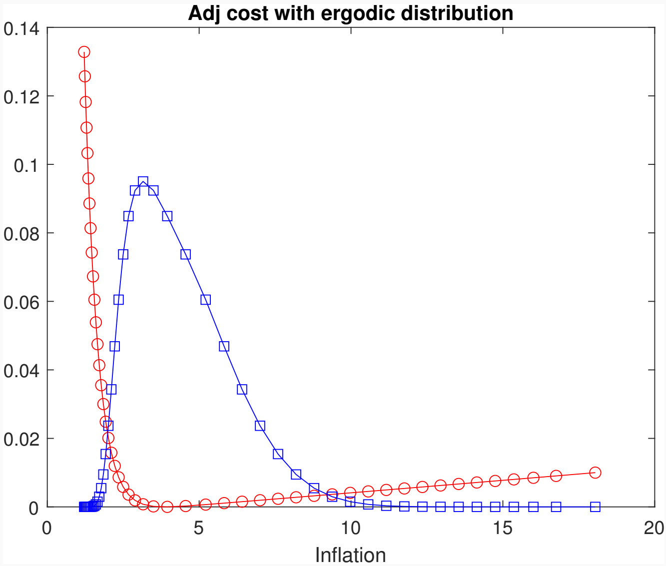
- Taylor approximation:

$$G(x) \approx \frac{\phi}{2}\left(\left(x - \overline{\Pi}\right)^2 - \frac{\psi}{3}\left(x - \overline{\Pi}\right)^3\right)$$

Adjustment cost function



... and inflation stationary distribution



Intuition: linearized Phillips Curve

$$\pi_t = \kappa \widehat{MC}_t + \frac{\beta J(\Pi^*)}{J'(\Pi^*)} E_t \left(\widehat{M}_{t+1} + \widehat{Y}_{t+1} - \widehat{Y}_t \right) + \beta E_t(\pi_{t+1})$$

$$\kappa = \frac{\varepsilon - 1 + J(\Pi^*)(1-\beta)}{J'(\Pi^*)}$$

- If G quadratic and $\Pi^* = 1$: $\kappa = (\varepsilon - 1)/\phi$, $J(\Pi^*) = 0$
- Middle term: $\Pi^* \neq 1$ (Ascari & Sbordone)
- New feature: NKPC slope κ increasing in Π^*

Monetary Policy and Shocks

- Taylor Rule:

$$\log R_t^{\$} = \log R^* + \phi_\pi \left(\pi_t - \pi^*\right) + \phi_y \left(y_t - y^*\right)$$

- TFP shock:

$$\log Z_t = \rho_z \log Z_{t-1} + \sigma_z \varepsilon_{z,t}$$

$$\varepsilon_{z,t} \rightarrow N(0,1)$$

MECHANISMS AND QUANTITATIVE MATCH

Calibration

	Data	Model
$\sigma(\Delta \log Y)$	3.03	3.03
$E(\pi)$	3.14	3.12
$\sigma(\pi)$	1.97	1.91
$Skewness(\pi)$	1.55	1.48
$Prob(\pi < 1\%)$	1.74	1.73
$E(Y^{\$(1)})$	5.63	5.71
$E(Y^{\$(40)})$	7.36	7.43

Data (1979q4-2008q4) and model moments

- Choose G to match skewness and $Prob(\pi < 1\%)$
- Choose risk aversion to match slope of yield curve

Parameters

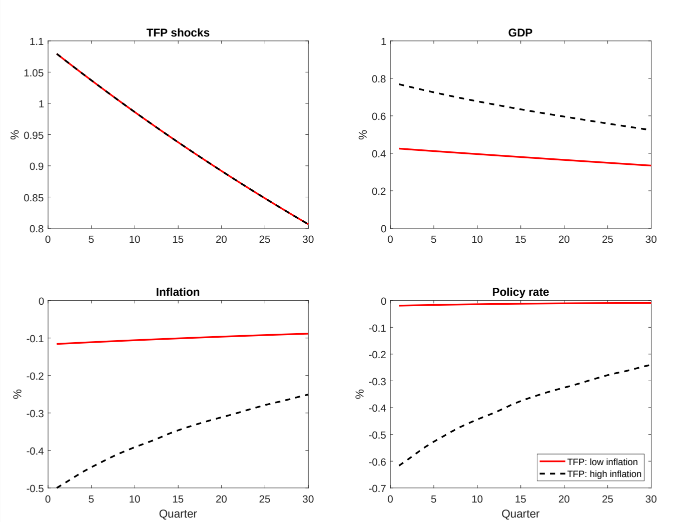
Parameter	Description	Value
β	discount factor	0.99
α	Curvature (note: CRRA=79)	-62
R^*	Intercept of Taylor Rule	1.01
$\overline{\Pi}$	Zero-cost inflation, 3.04% per year	1.0076
ϕ	Adjustment cost	258
ψ	Asymmetry	912
ρ_z	Persistence of Z	0.99
σ_z	SD innovation Z(%)	1.07

Model parameters.

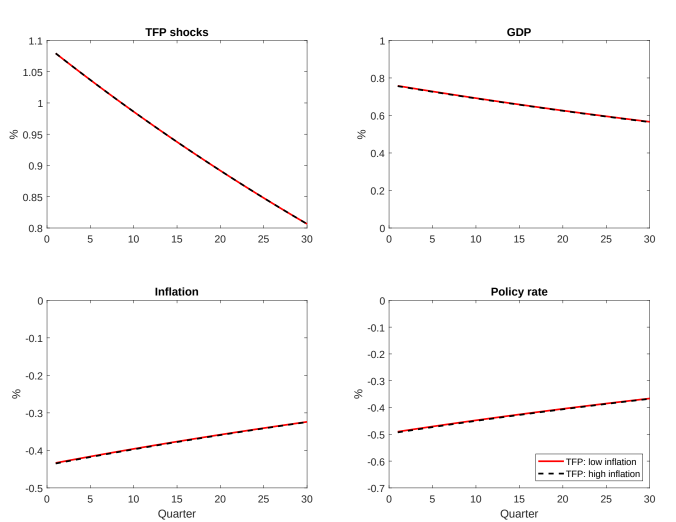
Mechanisms

1. Response to TFP shock when π is high vs. low
2. Average term premia and other moments
3. Effect of trend inflation on TP, covs, ...
4. Bond return predictability
5. Role of monetary policy
6. Term spread and GDP growth

1. Response to TFP shock at low vs. high inflation



1. No state-dependent IRF if symmetric stickiness



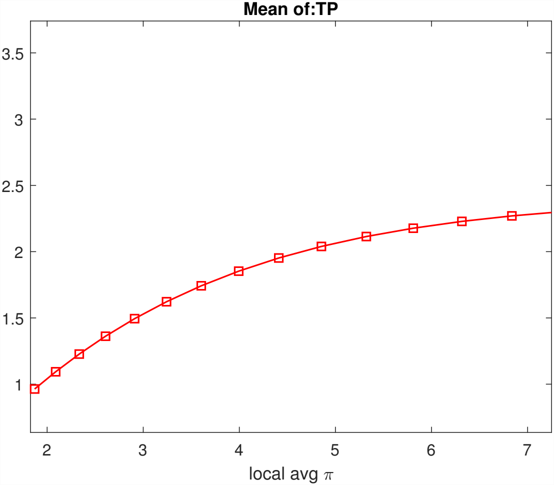
2. Moments

	Data		Full sample	
	Mean	Sd	Mean	Sd
$D.lnY$	0.00	3.03	-0.00	3.03
π	3.14	1.97	3.12	1.91
$y^{n(1)}$	5.63	3.20	5.71	2.05
$y^{n(40)}$	7.36	2.97	7.43	2.09
$y^{r(1)}$	NaN	NaN	2.55	0.44
$y^{r(40)}$	NaN	NaN	2.68	0.25
Real term premium	NaN	NaN	0.10	0.19
Nominal term premium	NaN	NaN	1.58	0.60

3. Effect of lower trend Inflation

- Experiment: change in inflation target Π^*
- Key assumption: reference rigidity $\overline{\Pi}$ remains fixed
- How do term premia & other moments change?

3. Term premia vs. avg π



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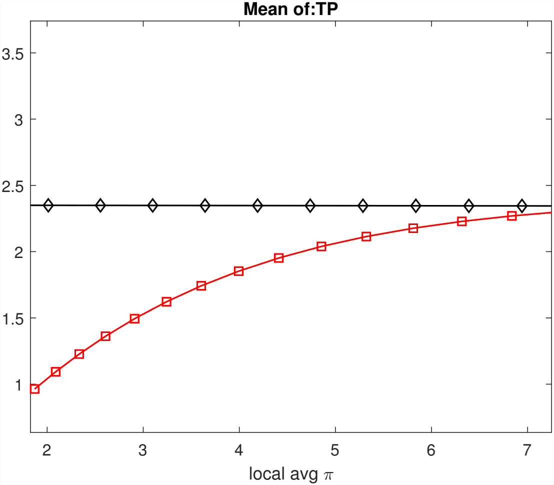

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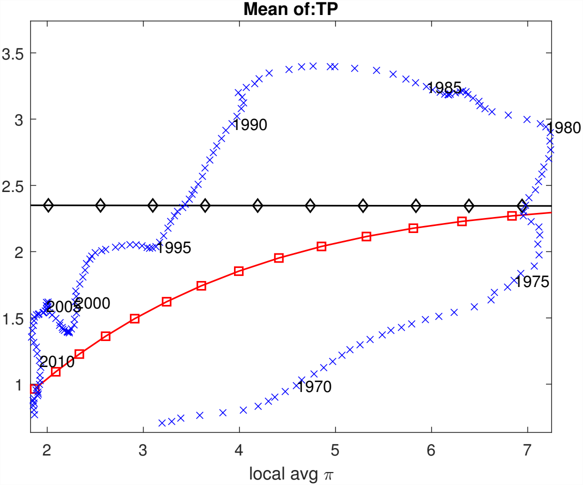
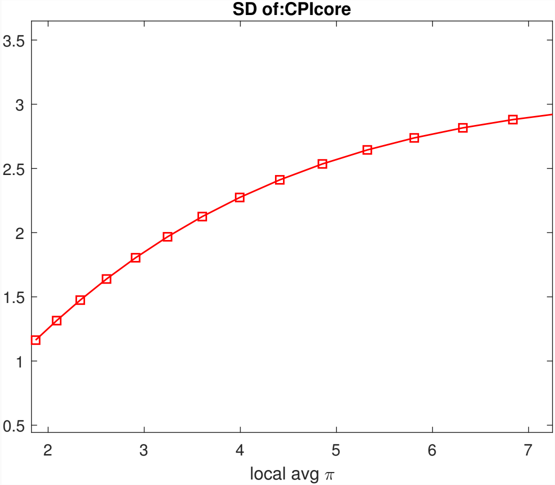


3. SD(π) vs. avg π



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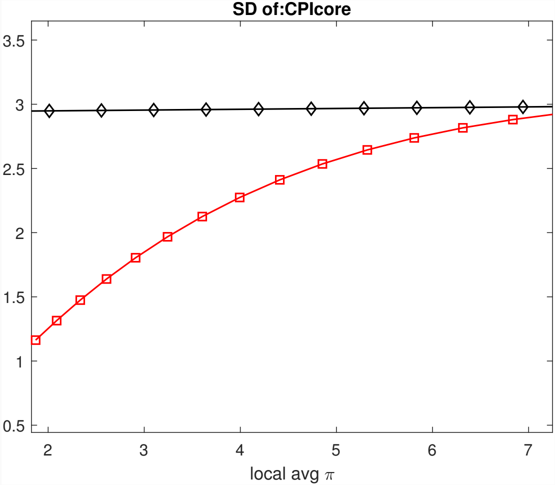

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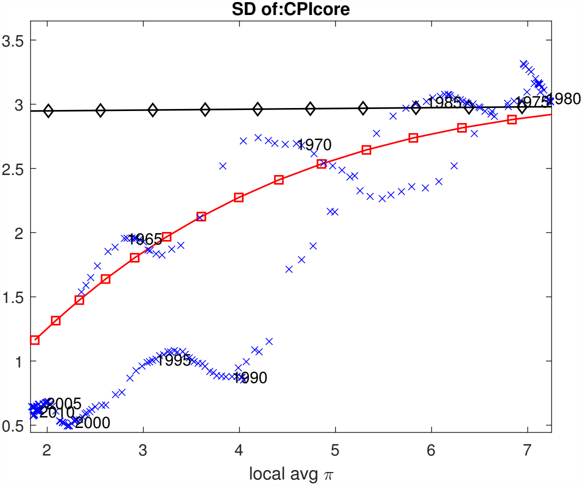
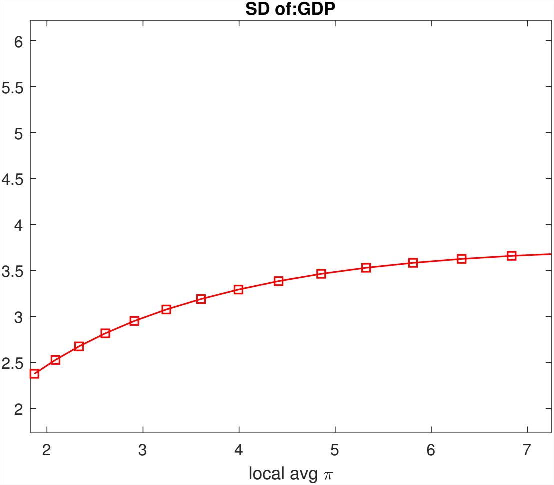


3. SD(GDP) vs. avg π



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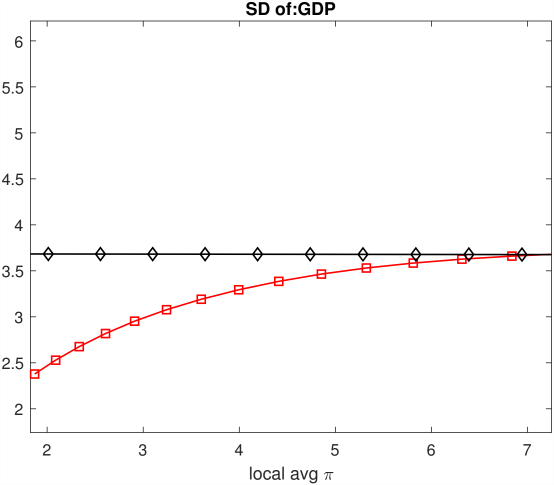

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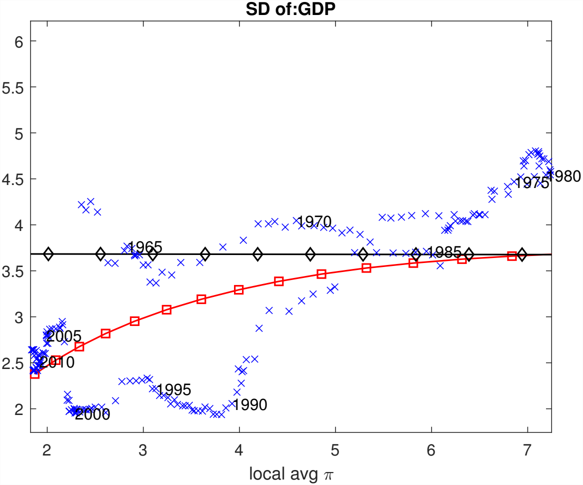

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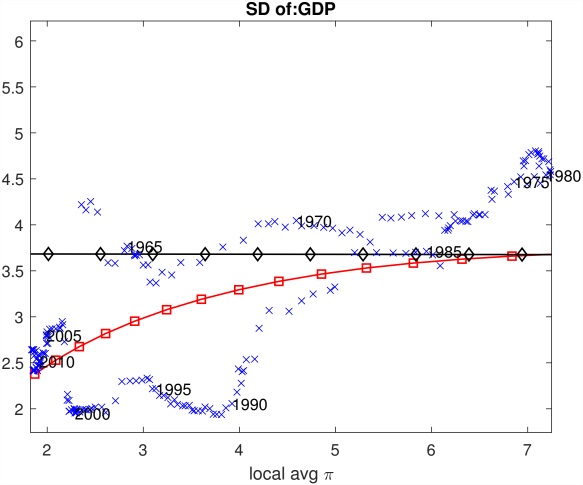
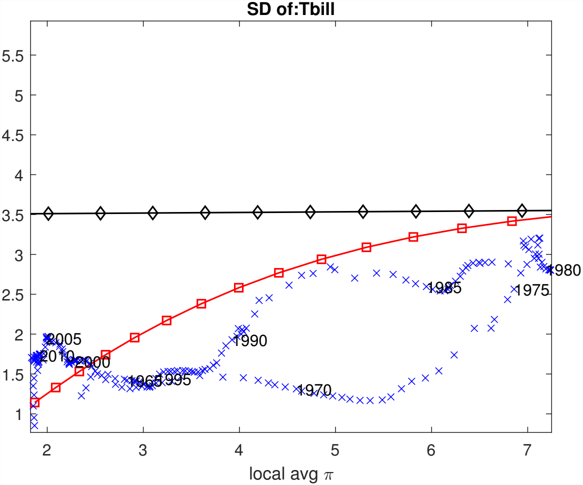
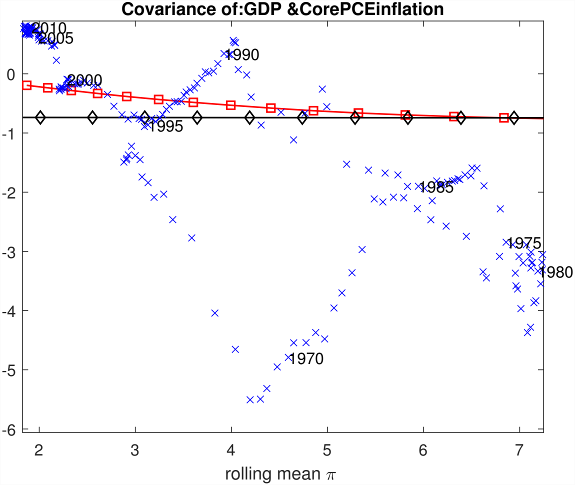


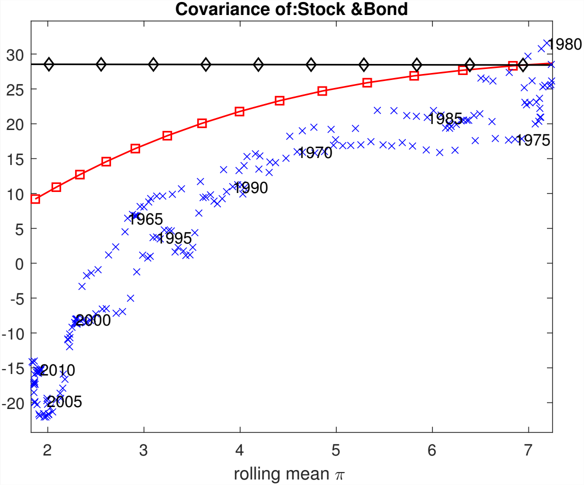
3. SD(T-Bill yield) vs. avg π



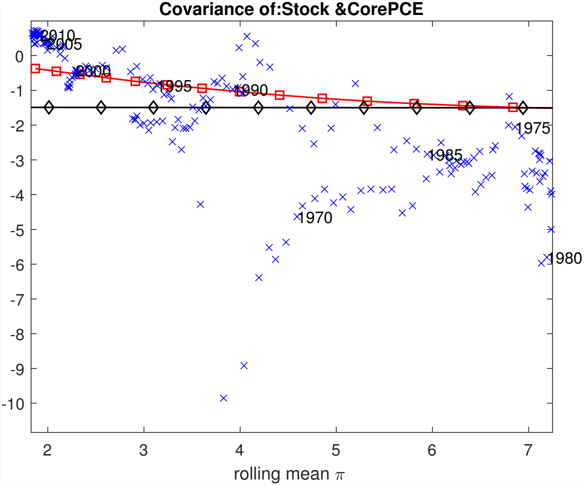
3. Output-Inflation covariance



3. Stock-Bond covariance



3. Stock-Inflation covariance



4. Bond Return Predictability: data

Fama-Bliss, Campbell-Shiller: bond returns are predictable

$$rx_{t+1}^{(n)\$} = \alpha + \beta(f_t^{(n)\$} - y_t^{(1)\$}) + \varepsilon_t,$$

	β	std	R^2
Data	1.384	0.443	0.029
Benchmark	0.643	0.009	0.018
Symetric	0.191	0.010	0.001

Intuition: low TFP $\Longrightarrow$ high π $\Longrightarrow$ higher bond premium, and simultaneously steeper yield curve

5. Role of monetary policy

	Benchmark $\phi_\pi = 1.74$		Varying ϕ_π $\phi_\pi = 5$	
	Mean	Std	Mean	Std
D.lnY	-0.00	3.03	-0.00	3.39
π	3.12	1.91	2.09	0.46
$y^{n(1)}$	5.71	2.05	4.40	0.84
$y^{n(40)}$	7.43	2.09	5.05	0.73
$y^{r(1)}$	2.55	0.44	2.31	0.45
$y^{r(40)}$	2.68	0.25	2.58	0.33
Real TP	0.10	0.19	0.26	0.08
Nominal TP	1.58	0.60	0.61	0.11

A more aggressive MP rule (higher ϕ_π) stabilizes π, reducing bond premia

6. The term spread forecasts growth

$$\log \frac{Y_{t+4}}{Y_t} = \alpha + \beta TS_t^{2y-Tbill} + \varepsilon_t$$

	Data	Model
GDP	1.55	1.22
	(0.34)	(0.17)
	[4.6]	[7.2]

SOME MORE DIRECT EVIDENCE

TFP propagation stronger when π high

$$y_{t+4} = \alpha + \sum_{i=1}^{L} \beta_i y_{t-i} + \beta_z Z_t + \beta_\pi \pi_t + \gamma Z_t \pi_t + \varepsilon_t$$

- y is log GDP or log (core) PCE index
- Z_t is util.-adj. (Fernald) TFP growth:

$$Z_t = \log(TFP_t / TFP_{t-4})$$

- π_t is inflation over past 2 years
- include a quadratic time trend
- US data, 1953q1:2019q4

TFP propagation stronger when π high

$$y_{t+4} = \alpha + \sum_{i=1}^{L} \beta_i y_{t-i} + \beta_z Z_t + \beta_\pi \pi_t + \gamma Z_t \pi_t + \varepsilon_t$$

	GDP	Inflation
β_z	0.100	-0.028
	(0.029)	(0.023)
	[3.4]	[1.2]
γ	**0.024**	**-0.021**
	0.010	0.008
	[2.4]	[2.8]

Conclusion

- Simple model where bond premia & other macro-finance moments are related to level of inflation due to downward nominal rigidities

- Current context: risk that if inflation becomes entrenched, bond premia will rise, with associated costs

- Next step: model these costs, i.e. feedback of bond premium into the economy:
    - Cost of borrowing e.g. mortgages , ...
    - Risk-taking by banks, ...

BACKUP

Term structure concepts

- zero-coupon nominal bond of maturity n, with price $P_t^{(n)}$ or yield $Y_t^{(n)}$:

$$P_t^{(n)} = \frac{1}{\left(1 + Y_t^{(n)}\right)^n}$$

- Yield = avg return per year *if hold to maturity*.
- Holding period return is return if hold for one period:

$$\log R_{t+1}^{(n)} = \log P_{t+1}^{(n-1)} - \log P_t^{(n)}$$

Bond riskiness

Long-term bond riskiness depends on investor horizon:

1. No uncertainty about return *til maturity*
   since (nominal) payoff certain
   but *holding period return* is risky as price varies.

2. Conversely, if investor has long horizon,
   short-term bonds are risky
   since future short-term rates unknown.

Bond riskiness

How to measure bond riskiness?

1. Using holding period return:
    - CCAPM β,
    - CAPM β, etc.
2. Using yields:
    - Term premium: expected avg return per year if buy bond n & hold to maturity, over the return from rolling over short-term bonds:

$$tp_t^{(n)} = y_t^{(n)} - \frac{1}{n} E_t \sum_{k=0}^{n-1} y_{t+k}^{(1)}$$

    - $tp_t^{(n)}$ is not the *slope* of yield curve
    - but on average they are equal

Inflation compensation and inflation premia

- Now add real bonds
- Inflation compensation (breakeven):

$$IC_t^{(n)} = y_t^{(n)\$} - y_t^{(n)}$$

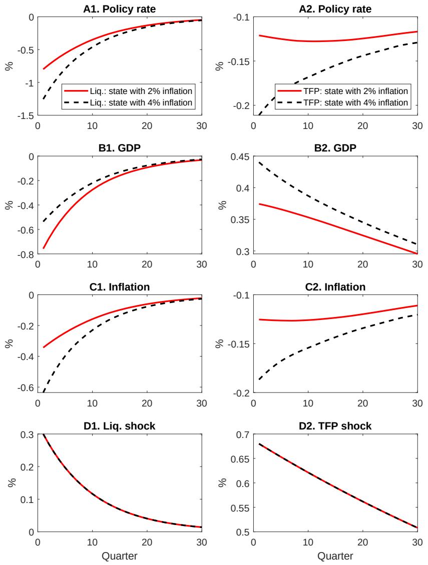
- Inflation term premium:

$$itp_t^{(n)\$} = tp_t^{(n)\$} - tp_t^{(n)}$$

Extension: adding demand shocks

- Modeled as shock to EE for (all) bonds
- Demand shock make bonds hedges $\implies$ lower TP
- But, effect of Π^* on TP ambiguous: higher π vol, lower GDP vol.

IRF demand shocks



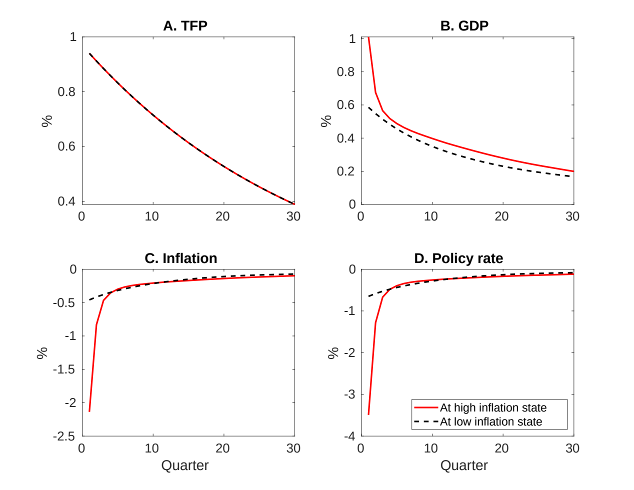
Demand shocks

	Data		Full sample		$\pi \leq 2\%$	π
	Mean	Sd	Mean	Sd	Mean	
$D.lnY$	0.00	3.03	0.00	3.06	-0.48	
π	3.14	1.97	3.14	1.85	1.36	
$y^{n(1)}$	5.63	3.20	5.64	3.04	2.87	
$y^{n(40)}$	7.36	2.97	7.39	1.41	5.85	
$y^{r(1)}$	NaN	NaN	2.41	1.46	1.37	
$y^{r(40)}$	NaN	NaN	2.59	0.43	2.17	
Real term premium	NaN	NaN	0.09	0.06	0.02	
Nominal term premium	NaN	NaN	1.55	0.13	1.39	

Extension: price and wage asymmetries

- Linex adjustment cost for nominal wages
- Wage stickiness and asymmetry plus *some* price asymmetry can generate similar effects without needing as much asymmetry

IRF wage

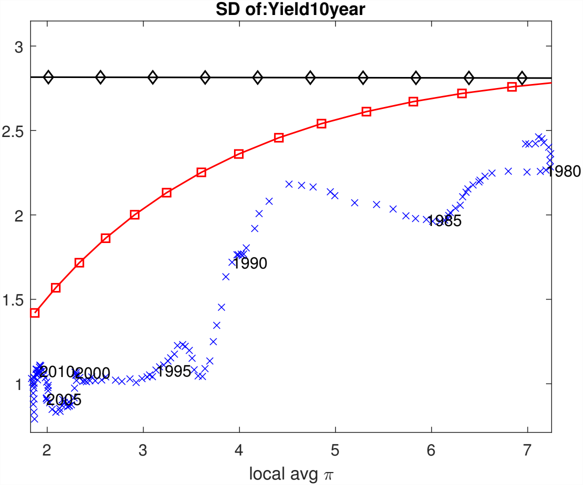


A. TFP
B. GDP
C. Inflation
D. Policy rate
%
Quarter
At high inflation state
At low inflation state

Wage rigidities

	Data		Full sample		$\pi \leq 2\%$	π
	Mean	Sd	Mean	Sd	Mean	
$D.lnY$	0.00	3.03	0.00	3.15	0.89	
π	3.14	1.97	2.97	1.73	1.36	
$y^{n(1)}$	5.63	3.20	5.68	2.46	3.48	
$y^{n(40)}$	7.36	2.97	7.25	1.05	6.19	
$y^{r(1)}$	NaN	NaN	2.56	1.11	1.91	
$y^{r(40)}$	NaN	NaN	3.16	0.29	2.87	
Real term premium	NaN	NaN	0.59	0.11	0.47	
Nominal term premium	NaN	NaN	1.52	0.23	1.28	

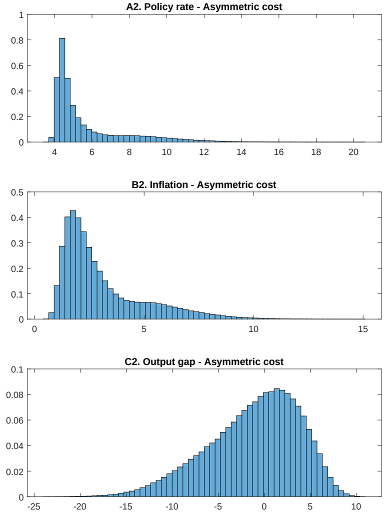
3. SD(10-year yield) vs. avg π



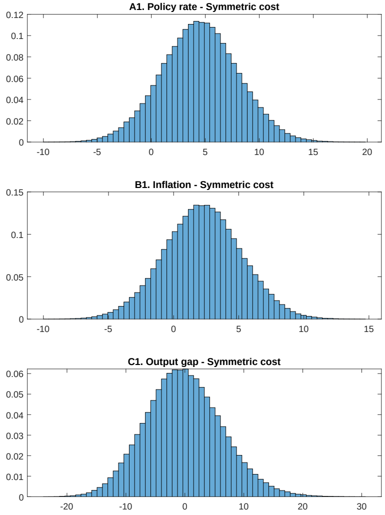
5. Risk aversion

	Benchmark $\alpha = -62$		Varying α $\alpha = 0$	
	Mean	Std	Mean	Std
D.lnY	-0.00	3.03	-0.00	3.48
π	3.12	1.91	4.57	2.84
$y^{n(1)}$	5.71	2.05	8.43	3.41
$y^{n(40)}$	7.43	2.09	8.57	2.56
$y^{r(1)}$	2.55	0.44	3.93	0.75
$y^{r(40)}$	2.68	0.25	3.97	0.43
Real TP	0.10	0.19	0.01	0.01
Nominal TP	1.58	0.60	-0.05	0.02

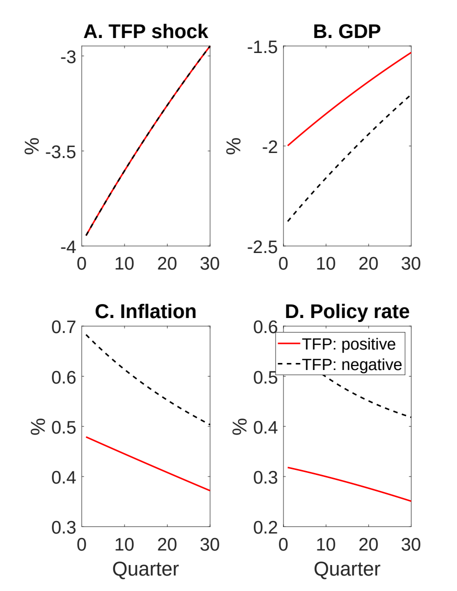
7. Skewness of macro variables ...



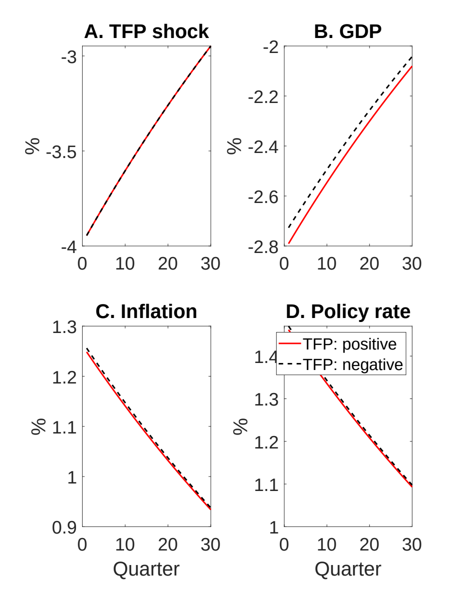
7. No skewness if symmetric stickiness



8. Asymmetric responses to shocks



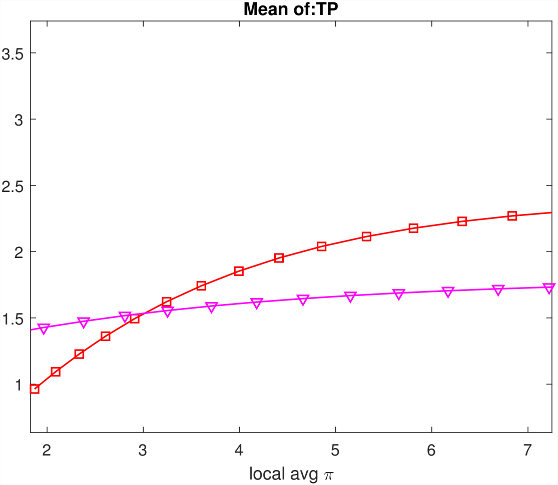
8. No asymmetry if symmetric stickiness



3. Effect of change in inflation target

	Benchmark $\pi^* = 2\%$		Varying π^* $\pi^* = 6.4\%$	
	Mean	Std	Mean	Std
D.lnY	-0.00	3.03	-0.00	3.74
π	3.12	1.91	10.12	3.07
$y^{n(1)}$	5.71	2.05	12.19	3.57
$y^{n(40)}$	7.43	2.09	14.61	2.86
$y^{r(1)}$	2.55	0.44	2.09	0.72
$y^{r(40)}$	2.68	0.25	2.47	0.44
Real TP	0.10	0.19	0.37	0.03
Nominal TP	1.58	0.60	2.38	0.08

TP with demand shocks



3. SD(π) vs. avg π