A Finance-Integrated New Keynesian Model

Carolin Pflueger and Gianluca Rinaldi

Chicago Harris and Harvard

July 2020

Why do Financial Markets Move so Much?

Why do Financial Markets Move so Much?

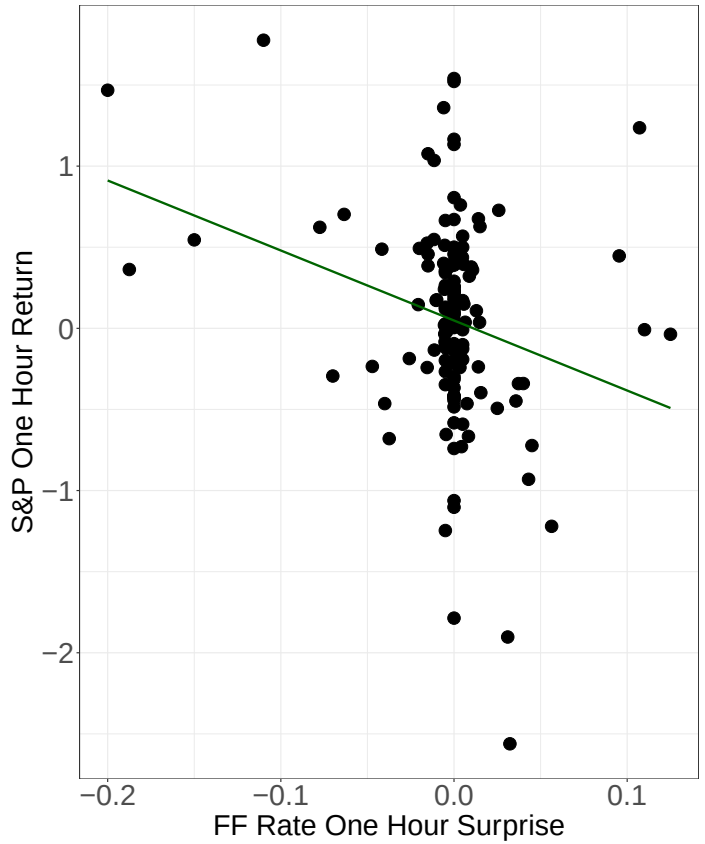
- **New integrated model:**
  1. Work-horse small-scale New Keynesian model
  2. Finance habits (Campbell and Cochrane, 1999) generate time-varying risk aversion

Why do Financial Markets Move so Much?

- **New integrated model:**
  1. Work-horse small-scale New Keynesian model
  2. Finance habits (Campbell and Cochrane, 1999) generate time-varying risk aversion
- **Contribution:** Model of monetary policy with consumption-based time-varying risk premia matching jointly
  - Classic asset pricing puzzles
  - Hump-shaped macro output responses
  - Stocks and bonds around monetary policy announcements

Application A: Fed Funds Effect

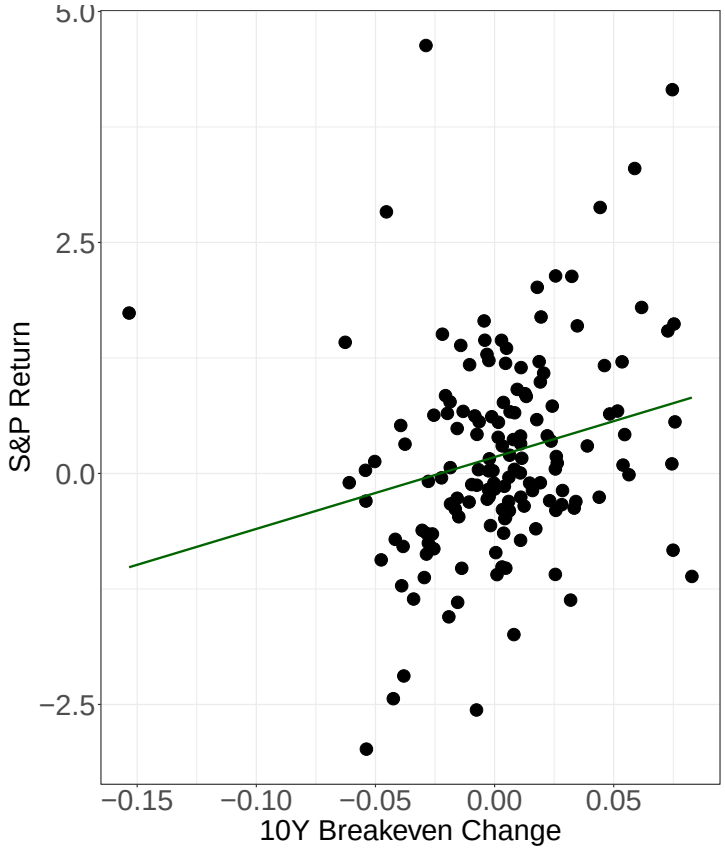
Bernanke and Kuttner (2005)



Consumption-based risk premia amplify stock response

Application B: Nominal Fed Information Effect

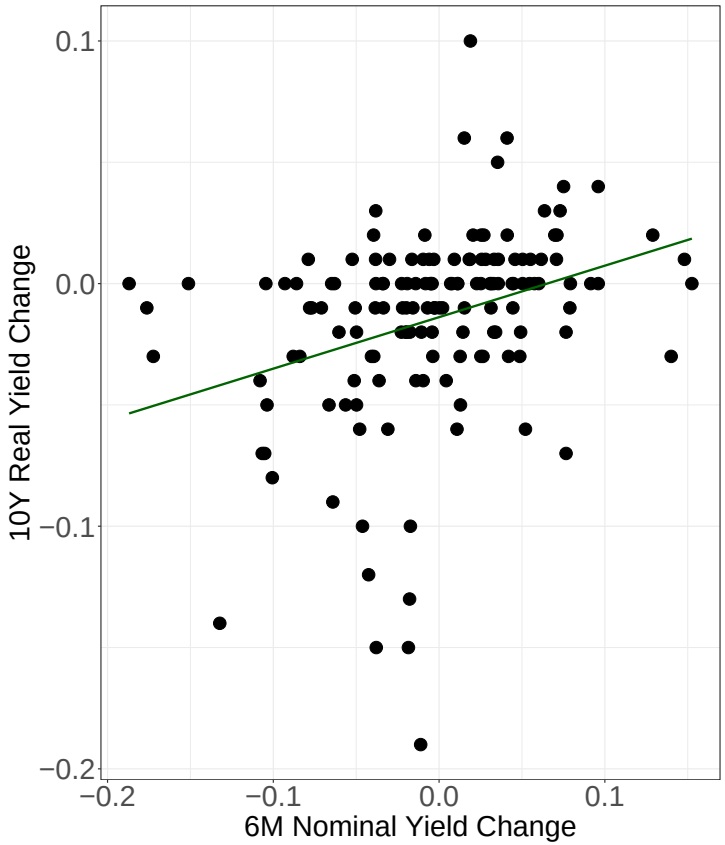
Romer and Romer (2000)



Costly disinflation drives down stocks, amplified by risk premia

Application C: Real Fed Information Effect

Nakamura and Steinsson (2018)



Learning about growth alters bond risk premium response to identified shock

Related Literature

- **Bonds and Stocks on FOMC Dates:** Bernanke and Kuttner (2005), Cochrane and Piazzesi (2002), Gurkaynak, Sack, and Swanson (2005), Hanson and Stein (2015), Nakamura and Steinsson (2018).
- **Habits and Asset Prices:** Constantinides (1990), Campbell and Cochrane (1999), Bekaert, Engstrom and Grenadier (2010), Bekaert and Engstrom (2017), Bekaert, Engstrom and Xu (2019), Campbell, Pflueger, and Viceira (2020)
- **Habits and Macro:** Lettau and Uhlig (2000), Fuhrer (2000), Boldrin, Christiano, and Fisher (2001), Christiano, Eichenbaum and Evans (2005)
- **Asset Pricing in New Keynesian Models:** Uhlig (2007), Rudebusch and Swanson (2008), Binsbergen et al. (2012), Dew-Becker (2014), Lòpez-Salido, and Francisco Vazquez-Grande (2015), Kung (2015), Kekre and Lenel (2020).

- **Our contribution:** Integrate Campbell and Cochrane (1999) finance-habits with work-horse New Keynesian model.

Model Overview

- **Exact Euler equation:** $x_t = f^x E_t x_{t+1} + \rho^x x_{t-1} - \psi(r_t - r_t^a) + v_{x,t}$
- **Log-linear Phillips curve:** $\pi_t = f^\pi E_t \pi_{t+1} + \rho^\pi \pi_{t-1} + \kappa x_t + v_{\pi,t}$
- **Interest rate rule:** see applications

x_t = output gap, r_t = real rate, r_t^a = real rate associated with expected growth, π_t = inflation

Model Overview

- **Exact Euler equation:** $x_t = f^x E_t x_{t+1} + \rho^x x_{t-1} - \psi(r_t - r_t^a) + v_{x,t}$
- **Log-linear Phillips curve:** $\pi_t = f^\pi E_t \pi_{t+1} + \rho^\pi \pi_{t-1} + \kappa x_t + v_{\pi,t}$
- **Interest rate rule:** see applications

x_t = output gap, r_t = real rate, r_t^a = real rate associated with expected growth, π_t = inflation

- **New:** Euler equation and Phillips curve consistent with finance habits

Model Overview

- **Exact Euler equation:** $x_t = f^x E_t x_{t+1} + \rho^x x_{t-1} - \psi(r_t - r_t^a) + v_{x,t}$
- **Log-linear Phillips curve:** $\pi_t = f^\pi E_t \pi_{t+1} + \rho^\pi \pi_{t-1} + \kappa x_t + v_{\pi,t}$
- **Interest rate rule:** see applications

x_t = output gap, r_t = real rate, r_t^a = real rate associated with expected growth, π_t = inflation

- **New:** Euler equation and Phillips curve consistent with finance habits
- Homoskedastic shocks; time-varying risk premia only from preferences

Review: Difference Habit

- Difference habit utility (Campbell and Cochrane, 1999)

$$U_t = \frac{(C_t - H_t)^{1-\gamma} - 1}{1-\gamma}$$

- Surplus consumption ratio

$$S_t = \frac{C_t - H_t}{C_t}$$

- Log surplus consumption ratio $s_t = \log S_t$

Investors risk-averse when consumption falls close to habit.

Implicit Model of Habit Dynamics

$$s_{t+1} = (1-\theta_0)\bar{s} + \theta_0 s_t + \theta_1 x_t + \theta_2 x_{t-1} + \lambda(s_t)\varepsilon_{c,t+1}$$

x_t= output gap = consumption minus potential

- Implied habit $\approx$ distributed lag of consumption (Campbell and Cochrane, 1999)
- $\theta_1 < 0$ and $\theta_2 > 0$: Macro Euler equation with forward- and backward-looking terms (Campbell, Pflueger, and Viceira, 2020)
  - Habit increases more with most recent consumption lag
  - Hump-shaped output responses to interest rates (Boldrin, Christiano, and Fisher, 2001, Christiano, Eichenbaum, and Evans (2005))

Implicit Model of Habit Dynamics

$$
\begin{aligned}
s_{t+1} &= (1-\theta_0)\bar{s} + \theta_0 s_t + \theta_1 x_t + \theta_2 x_{t-1} + \lambda(s_t)\varepsilon_{c,t+1}, \\
\varepsilon_{c,t+1} &= c_{t+1} - E_t c_{t+1}
\end{aligned}
$$

- Non-linear $\lambda(s_t)$ decreasing in s_t (Campbell and Cochrane, 1999)

Implicit Model of Habit Dynamics

$$
\begin{aligned}
s_{t+1} &= (1-\theta_0)\bar{s} + \theta_0 s_t + \theta_1 x_t + \theta_2 x_{t-1} + \lambda(s_t)\varepsilon_{c,t+1}, \\
\varepsilon_{c,t+1} &= c_{t+1} - E_t c_{t+1}
\end{aligned}
$$

- Non-linear $\lambda(s_t)$ decreasing in s_t (Campbell and Cochrane, 1999)
  - Shocks amplified when close to subsistence
  - Risk premia have business cycle pattern (Fama and French, 1989)
    - Risk premium for one-period consumption claim

$$Cov_t(-m_{t+1}, c_{t+1}) = \gamma(1+\lambda(s_t))\sigma_c^2$$

    - Opposite sign for safe assets that pay out in high SDF states $\Rightarrow$ flight-to-safety

Implicit Model of Habit Dynamics

$$
\begin{aligned}
s_{t+1} &= (1-\theta_0)\bar{s} + \theta_0 s_t + \theta_1 x_t + \theta_2 x_{t-1} + \lambda(s_t)\varepsilon_{c,t+1}, \\
\varepsilon_{c,t+1} &= c_{t+1} - E_t c_{t+1}
\end{aligned}
$$

- Non-linear $\lambda(s_t)$ decreasing in s_t (Campbell and Cochrane, 1999)
  - Shocks amplified when close to subsistence
  - Risk premia have business cycle pattern (Fama and French, 1989)
    - Risk premium for one-period consumption claim

      $$Cov_t(-m_{t+1}, c_{t+1}) = \gamma(1+\lambda(s_t))\sigma_c^2$$

    - Opposite sign for safe assets that pay out in high SDF states $\Rightarrow$ flight-to-safety
  - Non-linear $\lambda(s_t)$ keeps macro dynamics log-linear

Firm Problem

- Non-market hours used for home production (Greenwood, Hercowitz, and Huffman (1988))
    - Separate wages from habit (Lettau and Uhlig (2000))
- Expected productivity growth Δa_{t+1} and learning-by-doing (Lucas (1988))
- Optimal Calvo (1983) price-setting with indexation

Interest Rate Rule

$$\begin{aligned} i_t &= \text{smoothed Taylor rule} + v_t^* + v_{ST,t} \\ v_t^* &= v_{t-1}^* + v_{LT,t} \end{aligned}$$

- $v_{ST,t}$: traditional short-term shock to monetary policy
- $v_{LT,t}$: nominal "Fed information effect"
- ρ_a: real "Fed information effect" (Nakamura and Steinsson (2018)):

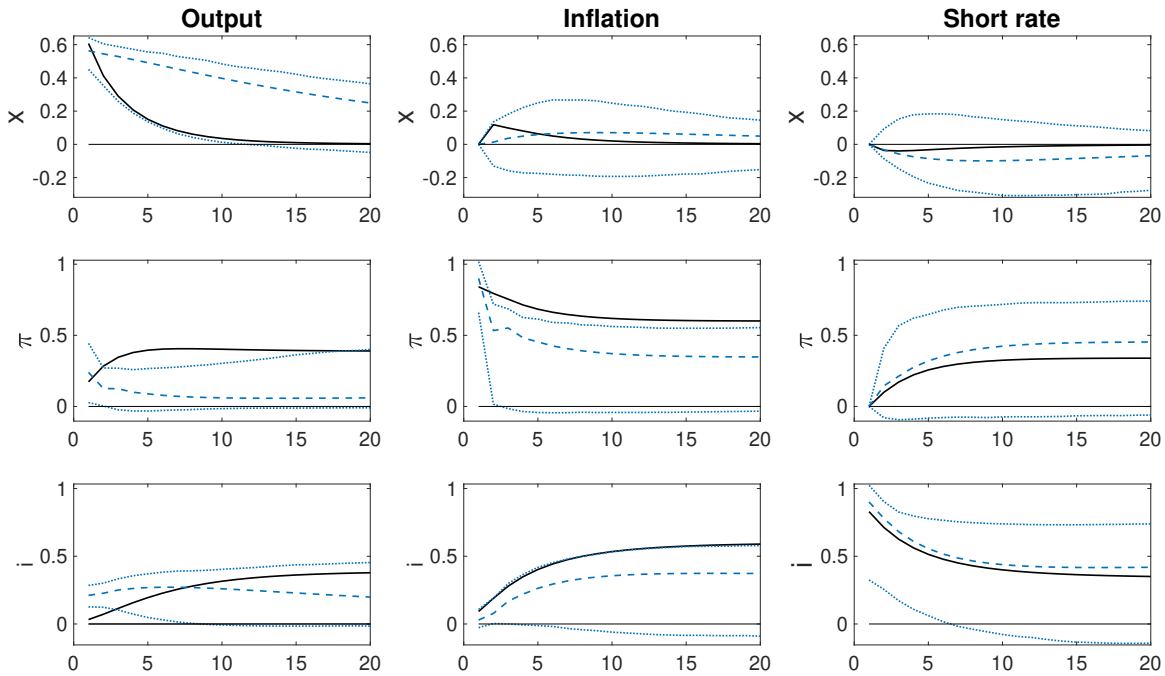
$$\rho_a r_t = \gamma \Delta a_{t+1} =: r_t^a$$

i_t=nominal rate, r_t = real rate, r_t^a = real rate associated with expected growth

Parameter Values (Table 1)

Panel A: Calibrated Parameters		
Consumption Growth Rate	g	1.89
Utility Curvature	γ	2.00
Steady-State Riskfree Rate	$\bar{r}$	0.94
Persistence Surplus Consumption Ratio	θ_0	0.87
Dependence Output	θ_1	-0.67
Dependence Lagged Output	θ_2	0.60
Smoothing Parameter Consumption	ϕ	0.93
Leverage	δ	0.40
Price Stickiness	α	0.67
Capital Share of Production	τ	0.33
Cross-Goods Substitutability	θ	6.00
Frisch Elasticity	$\chi \frac{\bar{L}}{1-\bar{L}}$	1.00
MP Coefficient Output	γ^x	0.50
MP Coefficient Inflation	γ^π	1.50
MP Persistence	ρ^i	0.90
Growth Rate Dependence	ρ^a	0.68

Macro Moments (2001Q2-2019Q2)



Blue = data (95% bootstrapped CI), Black = model

- Orthogonalized impulse responses from VAR in output gap, change in inflation, and Fed Funds minus inflation
- Additional moment: Std(10 Year - 10 Year Breakeven) =0.26%

Parameter Values (Table 1)

Panel B: Estimated Parameters		
Std. Demand Shock (%)	σ_x	0.37
Std. PC Shock (%)	σ_π	0.49
Std. Short-Term MP (%)	σ_{ST}	0.37
Std. Long-Term MP (%)	σ_{LT}	0.22

Asset Prices

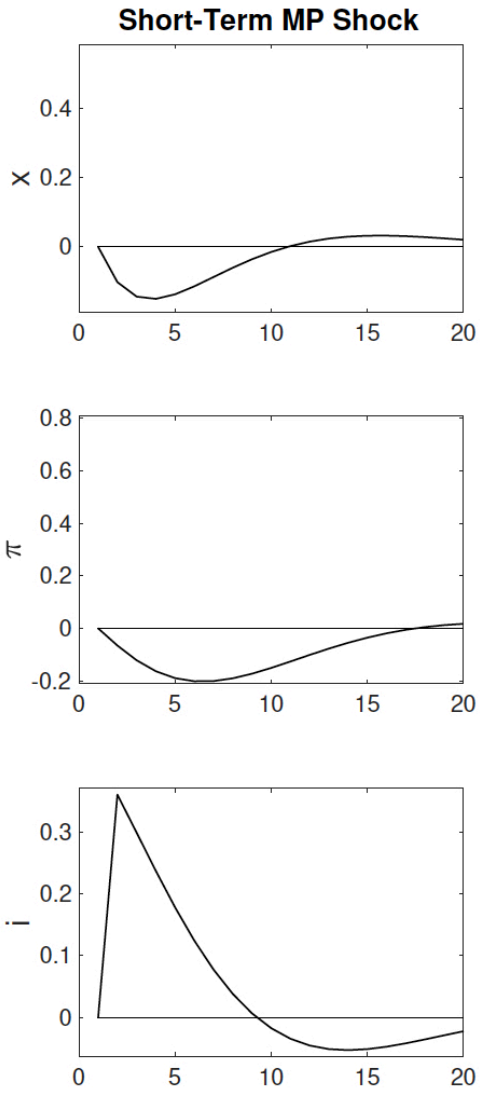
		Model	Data
Stocks (Levered Consumption Claim)			
	Equity Premium	6.82	7.41
	Volatility	13.55	16.96
	Sharpe Ratio	0.50	0.44
10 YR Breakeven (Nominal - Real Bonds)			
	Volatility	5.10	7.01
	Breakeven-Stock Beta	-0.13	-0.23
10 YR Real Bonds			
	Volatility	1.56	6.83
	Real Bond-Stock Beta	0.03	-0.08

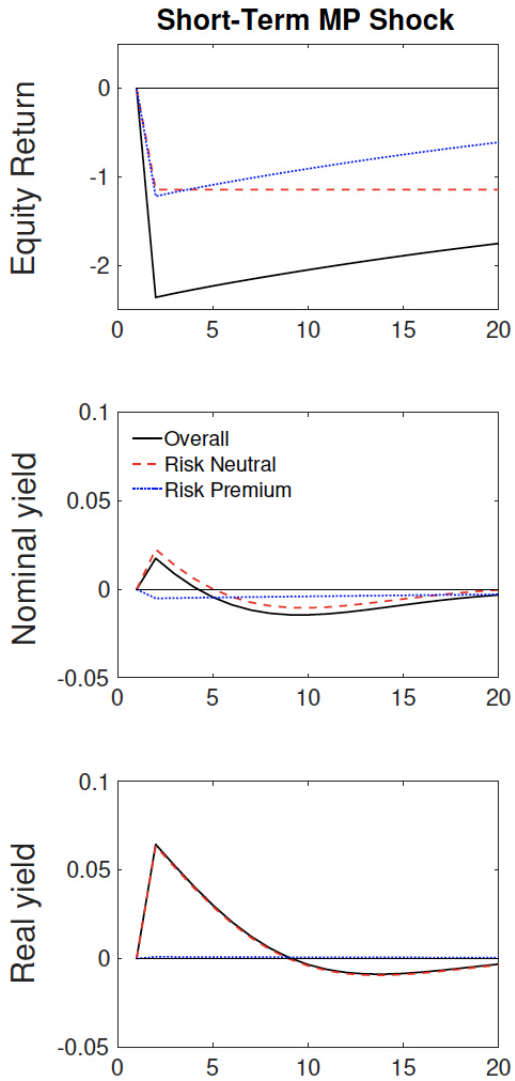
Application A: Fed Funds Effect (Table 3)

	Data	Model	Short Term
Slope(Equity Returns, Fed Funds)	-4.32	-6.03	-6.24
	(1.65)		
Risk Premia		-2.89	-3.14

- Model matches large empirical response
- Half due to risk premia, similarly to Bernanke and Kuttner (2005)

Structural Impulse Reponses - ST Monetary Policy Shock



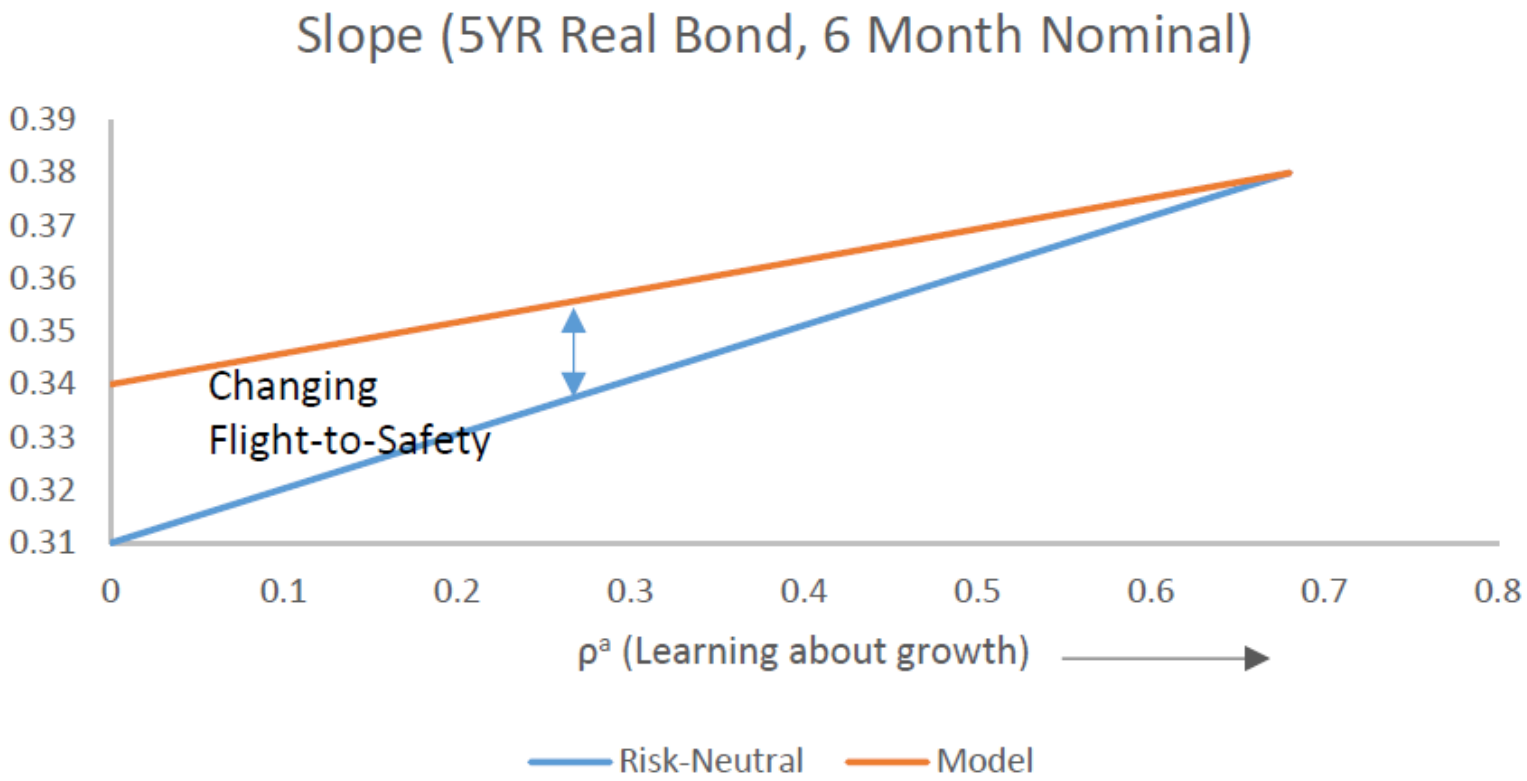


Application B: Nominal Fed Information Effect (Table 3)

	Data	Model	Short Term	Long Term
Slope(Equity Returns, 10Y Breakeven)	7.77	6.81	49.37	6.03
	(4.25)			
Risk Neutral		3.68	28.39	3.18

- Long-term monetary policy shock generates costly disinflation
- Stock response amplified by risk premia

Application C: Real Fed Information Effect



- Learning about growth increases real bond yields in response to ST monetary policy shock
- Risk premia go the other way, making empirical finding more striking

Application C: Real Fed Information Effect (Continued)

- Whether real bonds benefit from flight-to-safety depends on macroeconomic regime
- $Corr(r_t, growth) > 0 \Rightarrow$ real bonds do well in bad states $\Rightarrow$ safer
- Learning about growth implies that bonds benefit more from flight-to-safety after identified monetary policy shock

Conclusion

- Make consumption-based finance habits applicable to macroeconomic models
- Parsimonious model matches both macro and asset pricing moments
- Interpret bond and stock movements around monetary policy news