Monetary Policy Drivers of Bond and Equity Risks

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March 2014

Changing Risks of Treasury Bonds

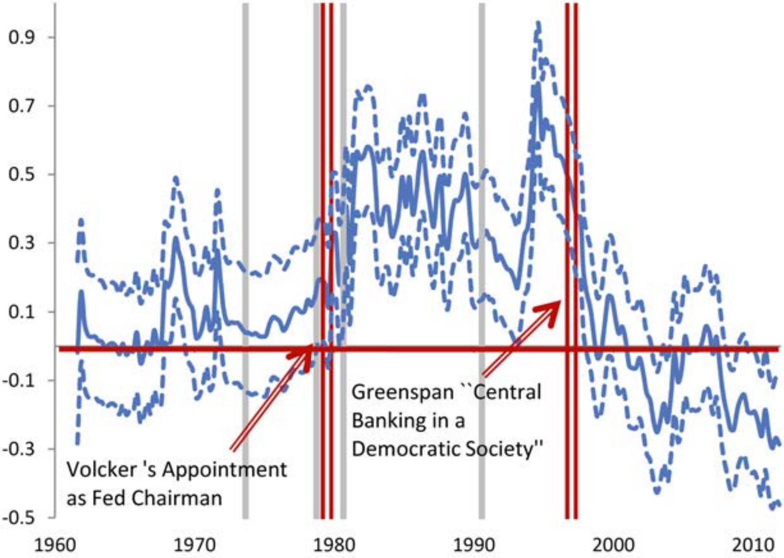
- US Treasuries are viewed differently today:
  - "Inflation risk premium" in 1980s
  - "Anchor to windward" or "safe haven" in 2000s.
- Treasuries comoved positively with stocks and the economy in the 1980s, negatively in the 2000s.
- Important implications for portfolio construction and asset pricing:
  - Bonds hedge stocks in endowment portfolios
  - Equity investing is riskier for pension funds with fixed long-term liabilities
  - Increased default risk for firms with long-term liabilities
  - Term premium and average yield spread are likely to be lower.
- What has caused this change?
  1. Changes in monetary policy?
  2. Changes in macroeconomic shocks?

Changing Risks of Treasury Bonds

Over the past decade, the correlation of stocks and bonds has remained persistently negative (causing big problems for pension funds that are essentially long stocks and short bonds)....Understanding correlations requires an understanding of the nature and causes of asset returns.

Bridgewater Associates, LP, 2013, Recent Shifts in Correlations Reflect the Drivers of Markets, *Bridgewater Daily Observations*

Changing Beta of US Treasury Bonds



This Paper

- Model output gap, inflation, and policy rate in canonical New Keynesian framework.
- Endogenize bond and stock returns to match second moments:
  - Use habit formation and stochastic volatility of macro shocks
  - Combine modeling conventions of macroeconomics and asset pricing (while trying not to create a "mutant toy" that both fields dislike.)
- Calibrate model to three monetary policy regimes.
  - Pre-Volcker (1960.Q1-1979.Q2): Accommodation of inflation
  - Volcker-Greenspan (1979.Q3-1996.Q4): Aggressive counter-inflationary policy (Clarida, Gali, and Gertler 1999)
  - Increased Transparency (1997.Q1-2011.Q4): Monetary policy persistence and continued shocks to inflation target.

Related Literature

- **Empirical time-variation in bond risks:** Baele, Bekart, and Inghelbrecht (2010), Viceira (2012), David and Veronesi (2013), Campbell, Sunderam, and Viceira (2013), Kang and Pflueger (2013).
- **Affine term structure models with macro factors:** Ang and Piazzesi (2003), Ang, Dong, and Piazzesi (2007), Rudebusch and Wu (2007).
- **Asset-pricing implications of real business cycle models:** Bansal and Shaliastovich (2010), Buraschi and Jiltsov (2005), Burkhardt and Hasseltoft (2012), Gallmeyer et al (2007), Piazzesi and Schneider (2006).
- **Term-structure implications of New Keynesian models:** Andreasen (2012), Bekaert, Cho and Moreno (2010), van Binsbergen et al. (2012), Kung (2013), Palomino (2012), Rudebusch and Wu (2008), Rudebusch and Swanson (2012).
- **Monetary policy regime shifts:** Clarida, Gali and Gertler (1999, 2000), Boivin and Giannoni (2006), Rudebusch and Wu (2007), Smith and Taylor (2009), Chib, Kang, and Ramamurthy (2010), Ang, Boivin, Dong, and Kung (2011), Bikbov and Chernov (2013).

Road Map

- A New Keynesian asset pricing model
- Data
- Estimating monetary policy rules in three regimes
- Model calibration to three monetary regimes
- Counterfactual analysis of bond and equity risks

Model Overview

- "A standard New Keynesian model has emerged" (Blanchard and Gali 2007):
    - Euler equation is New Keynesian equivalent of Investment and Savings (IS) curve
    - Phillips Curve (PC) with both forward-looking and backward-looking components captures nominal rigidities and productivity shocks
    - Monetary Policy (MP) rule follows a Taylor (1993) rule with time-varying inflation target.
- Stochastic discount factor (SDF) with habit formation generates Euler equation and prices stocks and bonds:
    - Risk premia increase during recessions, consistent with the empirical evidence on stock and bond return predictability (Fama and French 1989).

SDF Implies Euler Equation

- For SDF M_{t+1} and gross real one-period asset return $(1 + R_{t+1})$,

$$1 = \mathrm{E}_t \left[M_{t+1}(1 + R_{t+1}) \right].$$

- Household optimization:

$$M_{t+1} = \frac{\beta U'_{t+1}}{U'_t}.$$

- Assuming no risk premia on short-term nominal interest rates:

$$i_t = r_t + \mathrm{E}_t \pi_{t+1}.$$

- Euler equation for nominal T-bill (ignoring constants):

$$lnU'_t = (i_t - \mathrm{E}_t \pi_{t+1}) + \ln \mathrm{E}_t U'_{t+1}.$$

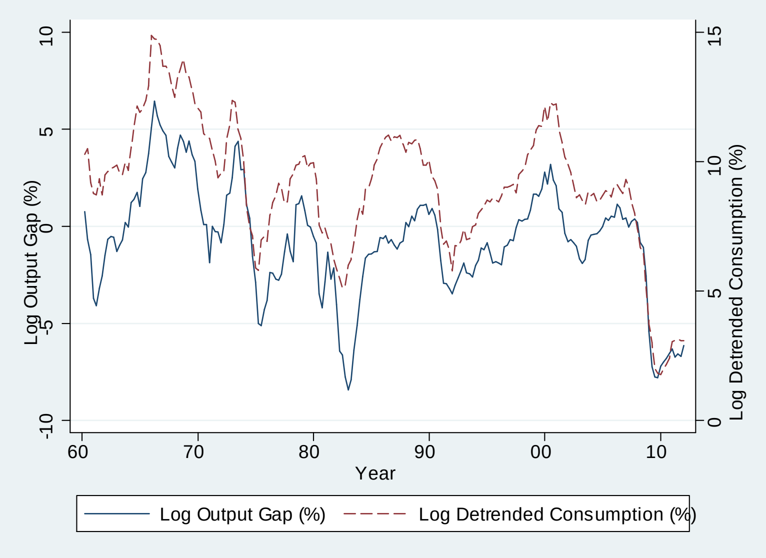
Modeling Marginal Utility

- For preference parameter α and heteroskedasticity parameter $b > 0$, assume analytically tractable form:

$$\begin{aligned} \ln U_t' &= -\alpha(x_t - \theta x_{t-1} - v_t) \\ \mathrm{Var}_t(\ln U_t') &= \alpha^2 \bar{\sigma}^2 (1 - b x_t) \end{aligned} \tag{1}$$

- Current and lagged output gap affect level of surplus consumption:
  - Habit formation preferences of Campbell and Cochrane (1999) produce desired properties for SDF.
  - Empirically plausible: Stochastically detrended log consumption and the log output gap 90% correlated.
- Output gap negatively affects volatility of surplus consumption and hence marginal utility:
  - Countercyclical volatility of asset returns
  - Countercyclical risk premia
  - Campbell and Hentschel (1992), Calvet and Fisher (2007), Campbell and Beeler (2012), Bansal, Kiku and Yaron (2011), Bansal, Kiku, Shaliastovich, and Yaron (2014)

Output Gap and De-Trended Consumption



Forward- and Backward-Looking Euler Equation

$$x_t = \rho^{x-} x_{t-1} + \rho^{x+} E_t x_{t+1} - \psi \left(i_t - E_t \pi_{t+1} \right) + u_t^{IS}.$$

- Forward- and backward-looking Euler equation captures the hump-shaped output gap response to shocks (Fuhrer 2000, Christiano, Eichenbaum, and Evans 2005).
- Here $\rho^{x-} = \frac{\theta}{1+\theta^*}$, $\rho^{x+} = \frac{1}{1+\theta^*}$, $\psi = \frac{1}{\alpha(1+\theta^*)}$, $\theta^* = \theta - \alpha b \sigma^2 / 2 < \theta$.
- Marginal utility shocks drive IS shocks: $u_t^{IS} = \frac{1}{1+\theta^*} v_t$.
- Countercyclical shock volatility ($b > 0$) implies that $\rho^{x+} + \rho^{x-} > 1$.

Forward- and Backward-Looking Phillips Curve

$$\pi_t = \rho^{\pi}\pi_{t-1} + (1-\rho^{\pi})E_t\pi_{t+1} + \lambda x_t + u_t^{PC}$$

- Calvo (1983) model of monopolistically competitive firms and staggered price setting implies a forward-looking Phillips curve.
- Infrequent information updating can give rise to backward-looking Phillips curve (Mankiw and Reis 2002).
- PC shock u_t^{PC} reflects productivity or cost-push shocks.

Monetary Policy Rule

$$\begin{aligned} i_t &= \rho^i (i_{t-1} - \pi^*_{t-1}) + (1-\rho^i)\left[\gamma^x x_t + \gamma^\pi (\pi_t - \pi^*_t)\right] + \pi^*_t + u^{MP}_t \\ \pi^*_t &= \pi^*_{t-1} + u^*_t \end{aligned}$$

- Taylor (1993) rule with the Fed funds rate as policy instrument (Clarida, Gali, Gertler 1999, Rudebusch and Wu 2007).
- Fed funds rate adjusts gradually to target.
- Fed funds target increases in the output gap x_t and the inflation gap $\pi_t - \pi^*_t$.
- Changes in central bank inflation target π^*_t are unpredictable:
  - Dynamics of π^*_t consistent with persistent component in inflation and nominal interest rates (Ball and Cecchetti 1990, Stock and Watson 2007).
  - Persistent inflation target shifts term structure similar to a level factor (Rudebusch and Wu 2007, 2008).

Summary of the Macro Model

$$
\begin{aligned}
x_t &= \rho^{x-} x_{t-1} + \rho^{x+} E_{t-} x_{t+1} - \psi(E_{t-} i_t - E_{t-} \pi_{t+1}) + u_t^{IS} \\
\pi_t &= \rho^{\pi} \pi_{t-1} + (1 - \rho^{\pi}) E_{t-} \pi_{t+1} + \lambda x_t + u_t^{PC} \\
i_t &= \rho^{i} (i_{t-1} - \pi^*_{t-1}) + (1 - \rho^{i}) \left[\gamma^{x} x_t + \gamma^{\pi} (\pi_t - \pi^*_t) \right] + \pi^*_t + u_t^{MP} \\
\pi^*_t &= \pi^*_{t-1} + u^*_t
\end{aligned}
$$

Stochastic Volatility for All Shocks

- Independently and conditionally normal vector of shocks:

$$u_t = [u_t^{IS}, u_t^{PC}, u_t^{MP}, u_t^{*}]'$$

- Conditional variance-covariance matrix:

$$\Sigma_u (1 - bx_{t-1}) = \begin{bmatrix} (\sigma^{IS})^2 & 0 & 0 & 0 \\ 0 & (\sigma^{PC})^2 & 0 & 0 \\ 0 & 0 & (\sigma^{MP})^2 & 0 \\ 0 & 0 & 0 & (\sigma^{*})^2 \end{bmatrix} (1 - bx_{t-1}) .$$

- Common stochastic volatility for all shocks makes model tractable and generates time-varying risk premia.

Modeling Bonds and Stocks

- Solve for nominal bond returns using Campbell and Ammer (1993) exact loglinear return decomposition

$$r^{\$}_{n-1,t+1} - E_t r^{\$}_{n-1,t+1} = A^{\$,n} u_{t+1}.$$

- Model stocks as levered claim on log output gap (Abel 1990, Campbell 1986, 2003): $d_t = \delta x_t$.
- Solve for equity returns using Campbell and Shiller (1988) loglinear approximation

$$r^e_{t+1} - E_t r^e_{t+1} = A^e u_{t+1}.$$

- Solve for the nominal bond CAPM beta, and the volatilities of stock and bond excess returns.
  - The model is ready to drive!

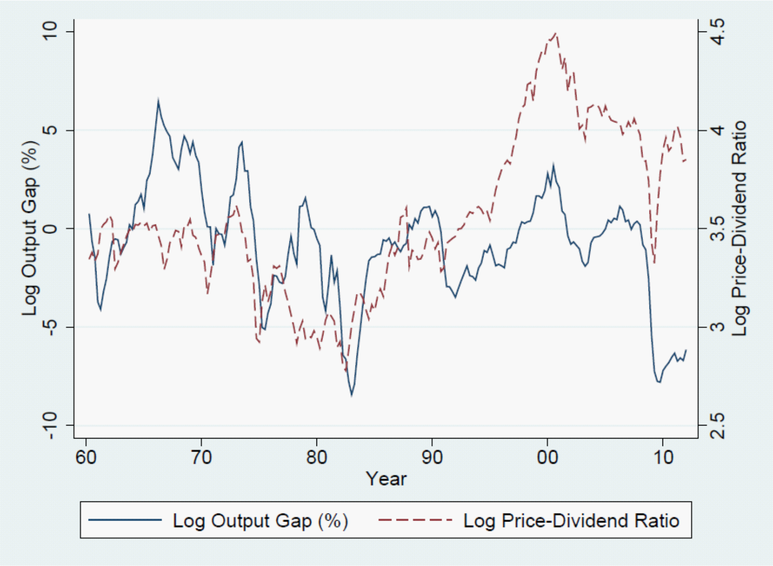
Monetary Policy Regimes

- Divide sample in three subperiods:
  1. Pre-Volcker [1960.Q1-1979.Q2]
  2. Volcker - pre-1997 Greenspan [1979.Q3-1996.Q4]
  3. Post-1996 Greenspan - Bernanke [1997.Q1-2011.Q4]
- Subperiods 1 and 2 identical to Clarida, Gali, and Gertler (1999)
  - Post-Volcker Federal Reserve counteracts inflation
- Superiod 3 is newly identified in this paper
  - Increased transparency and gradualism
  - Publication of FOMC transcripts
  - Not a single dissenting vote at FOMC meetings since 1997
  - Greenspan and Bernanke argue for cautious monetary policy in light of increased uncertainty about the effects of monetary policy
  - Characterized by negative bond beta

Data

- GDP in 2005 chained dollars and GDP deflator from Bureau of Economic Analysis.
- Potential output from Congressional Budget Office.
- Federal funds rate from Federal Reserve H.15 publication.
- Five-year bond yield from CRSP Fama-Bliss data base.
- Value-weighted NYSE/AMEX/Nasdaq stock return from CRSP.
- S&P 500 dividend-price ratio from Robert Shiller's web site.
- Real consumption expenditures data for nondurables and services from the Bureau of Economic Analysis.

Output Gap and Price-Dividend Ratio



Estimating Monetary Policy Rules

$$i_t = c^0 + c^x x_t + c^\pi \pi_t + c^i i_{t-1} + \epsilon_t$$

$$\hat{\rho}^i = \hat{c}^i, \quad \hat{\gamma}^x = \hat{c}^x/(1-\hat{c}^i), \quad \hat{\gamma}^\pi = \hat{c}^\pi/(1-\hat{c}^i).$$

- Post-1979
  - $\hat{\gamma}^\pi \uparrow \hat{\gamma}^x \downarrow$
  - Stronger inflation response
  - Weaker output response
- Post-1997
  - $\hat{\rho}^i \uparrow$
  - Stronger persistence

Estimating Monetary Policy Rules

Fed Funds i_t	60.Q1-11.Q4	60.Q1-79.Q2	79.Q3-96.Q4	97.Q1-11.Q4
Output Gap x_t	0.06	0.18**	-0.04	0.05
	(0.04)	(0.06)	(0.13)	(0.04)
Inflation π_t	0.21	0.30**	0.83**	0.21**
	(0.11)	(0.07)	(0.21)	(0.07)
Lagged Fed Funds i_{t-1}	0.81**	0.56**	0.43*	0.89**
	(0.05)	(0.10)	(0.17)	(0.06)
Constant	0.42	0.91*	1.75	-0.12
	(0.26)	(0.38)	(0.92)	(0.29)
R^2	0.79	0.75	0.69	0.91
Implied $\hat{\gamma}^x$	0.32	0.42**	-0.07	0.44
	(0.21)	(0.13)	(0.22)	(0.21)
Implied $\hat{\gamma}^\pi$	1.08**	0.69**	1.44**	1.92*
	(0.43)	(0.16)	(0.19)	(1.26)
Implied $\hat{\rho}^i$	0.81**	0.56**	0.43**	0.89**
	(0.05)	(0.10)	(0.17)	(0.06)

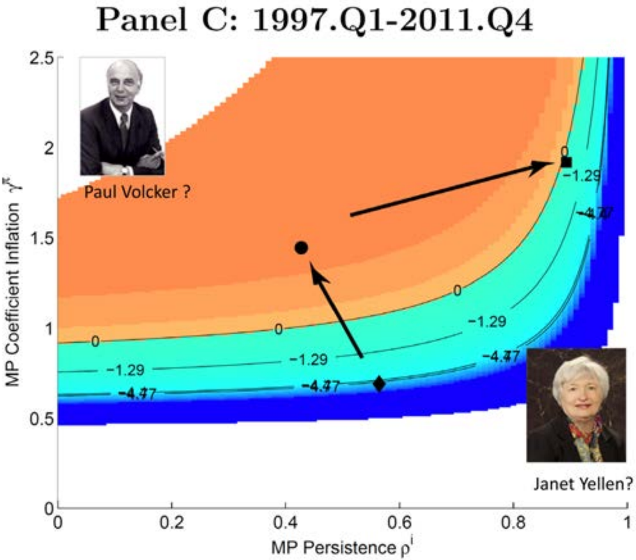
Calibration Procedure

- Specify time-invariant vs. time-varying parameters to isolate effects of changing monetary policy and macroeconomic shocks (Smets and Wouters, 2007):
  - Time-varying parameters: Monetary policy rule parameters and volatilities of shocks.
  - Time-invariant parameters: ρ, δ, α, ρ^{π}, ρ^{x+}, ρ^{x-}, λ.
- Set monetary policy parameters to estimated values.
- Phillips curve parameters follow the literature: $\lambda = 0.3$ (Clarida, Gali, and Gertler, 1999) and $\rho^{\pi} = 0.8$ (Fuhrer, 1997).
- Set leverage $\delta = 2.43$ to match relative volatility of real dividend growth and real output gap growth, and utility curvature $\alpha = 30$ to match equity volatility.
- Choose remaining parameters to minimize distance between model and empirical moments:
  - Slope coefficients and residual volatilities for a VAR(1) in log output gap, inflation, Fed funds rate, and five-year nominal yield; volatilities of bond and stock returns; and beta of bonds with stocks.

Model and Empirical Moments

	60.Q1-79.Q2		79.Q3-96.Q4		97.Q1-11.Q4	
Std. VAR(1) Residuals	Empirical	Model	Empirical	Model	Empirical	Model
Output Gap	0.92	0.81	0.75	0.77	0.65	0.51
Inflation	1.12	1.22	0.89	0.92	0.80	1.02
Fed Funds Rate	1.22	1.15	2.07	2.17	0.66	0.55
Log Nominal Yield	0.48	0.41	0.85	0.72	0.55	0.70
Std. Asset Returns						
Std. Eq. Ret.	17.62	18.82	15.34	17.50	20.08	17.95
Std. Nom. Bond Ret.	4.85	3.91	9.11	7.09	5.55	5.83
Nominal Bond Beta	0.06*	0.07	0.20*	0.22	-0.17**	-0.15

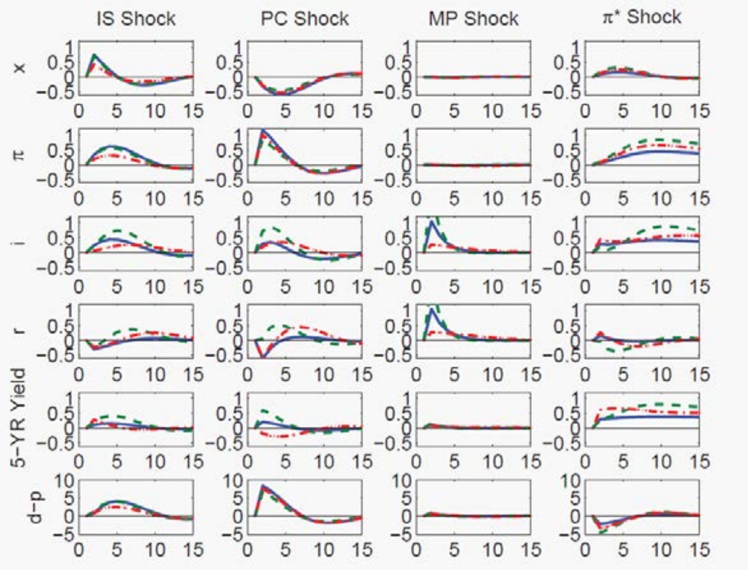
Counterfactuals: MP Inflation Response and Persistence



Impulse Response Functions

- Impulse responses are to one-standard deviation shocks
- Units for the output gap and dividend-price ratio are in percent deviations from the steady state.
- Units for other variables are annualized percentage points.
- 60.Q1-79.Q2= blue solid, 79.Q3-96.Q4=green dash, 97.Q4-11.Q4=red dash-dot.

Impulse Response Functions



Impulse Response Functions

- MP shocks and IS shocks contribute essentially zero to bond beta
- PC shock lowers output and raises inflation:
  - Stock prices fall
  - Effect on bond yields depends on monetary policy regime
  - Creates a positive bond beta in the first two regimes, a negative one in the third.
- Inflation target shocks raise inflation and nominal interest rates
  - Inflation below new target.
  - Central bank lowers real rates, creating a boom.
  - Bond prices fall and stock prices rise, creating a negative bond beta
  - When monetary policy is persistent, central bank does not lower real interest rates immediately but only with a long lag. Stronger effect on bond yields and bond betas.

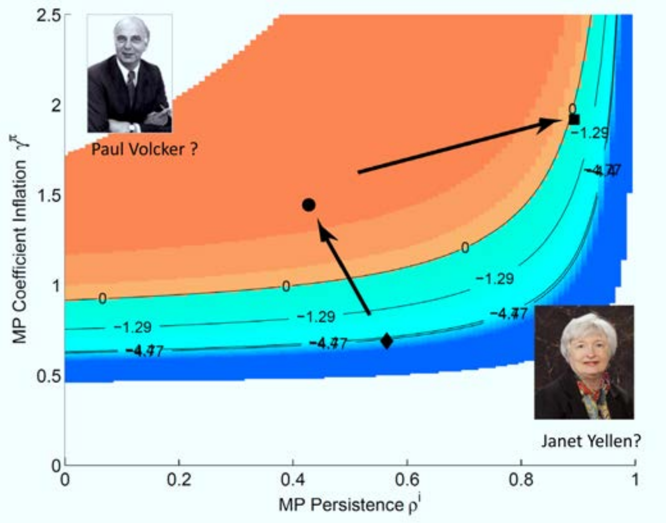
Why Changes not Driven by Volatilities?

- Partial derivatives reveal that:
  - Model equity return volatility driven by PC shocks.
  - Model bond return volatility driven by inflation target shocks and PC shocks.
- Empirical volatility of equity and bond returns changed little across regimes.
  - Model matches this with near-constant PC and inflation target shock volatilities.
  - Changes in the volatility of shocks cannot explain changes in bond beta.
  - Point estimates even have opposite sign.

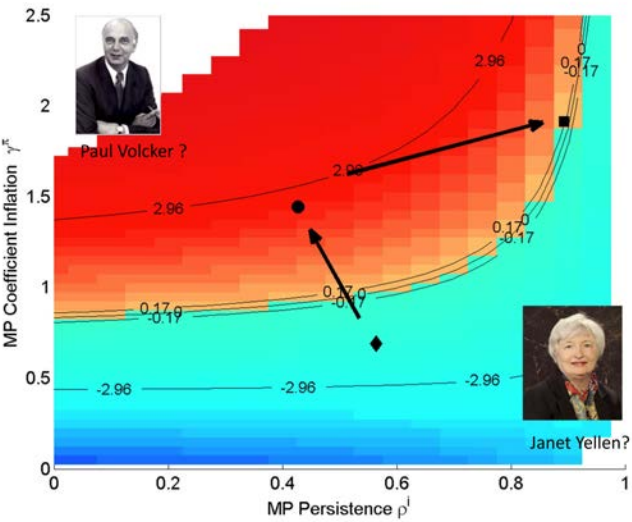
Important Amplification Channel: Risk Premia

- Key role of time-varying volatility: higher risk premia during recessions.
- Nominal bonds are hedges during third subperiod.
  - Bond hedging value especially valuable during recessions, when equity risk premia are high.
  - As a result, see negative bond yield response in response to PC shock.
- Time-varying volatility also generates time-varying Jensen's inequality (JI) effect.
  - But JI term mostly level effect.
  - Generate plausible bond return volatility, so JI term unlikely to be too large.
  - Do implications change if we ignore JI terms?

Counterfactuals: MP Inflation Response and Persistence



Risk Premia Only - No Jensen's Inequality Terms



Conclusion

- Fed anti-inflationary stance after 1979 increased nominal bond beta:
  - Large increase in Fed funds rate in response to inflation shock
  - Increase in Fed Funds rate depresses output, stock prices, and bond prices.
- Persistent monetary policy (gradualism) and shocks to inflation target generate negative nominal bond beta since mid 1990s:
  - Inflation target shock decreases bond prices
  - Real rates fall in response to inflation target shock, driving up output and equity prices.
  - Changes in official central bank inflation target or central bank credibility?
- Phillips Curve (supply) shocks increase nominal bond beta, but modest variation across regimes.
- Changing risk premia offer important amplification mechanism.

Unconditional Variances

- Unconditional variance equals conditional variance at zero output gap

$$
\begin{aligned}
Var(r^e_{t+1} - E_t r^e_{t+1}) &= E\left[A^e \Sigma_u A^{e\prime}(1 - bx_t)\right] \\
&= A^e \Sigma_u A^{e\prime}.
\end{aligned}
$$

- Investors in our model use this analytic unconditional variance to price bonds and stocks.
    - Report analytic unconditional variances and covariances.
- Conditional variances can and do turn negative in calibration.
    - Model-implied unconditional variances lower than in a model where conditional variances truncated below at zero.
    - Similar results for alternative calibration in which conditional variances almost never go negative.