



MONETARY AND MACROPRUDENTIAL POLICIES UNDER ENDOGENOUS RISK

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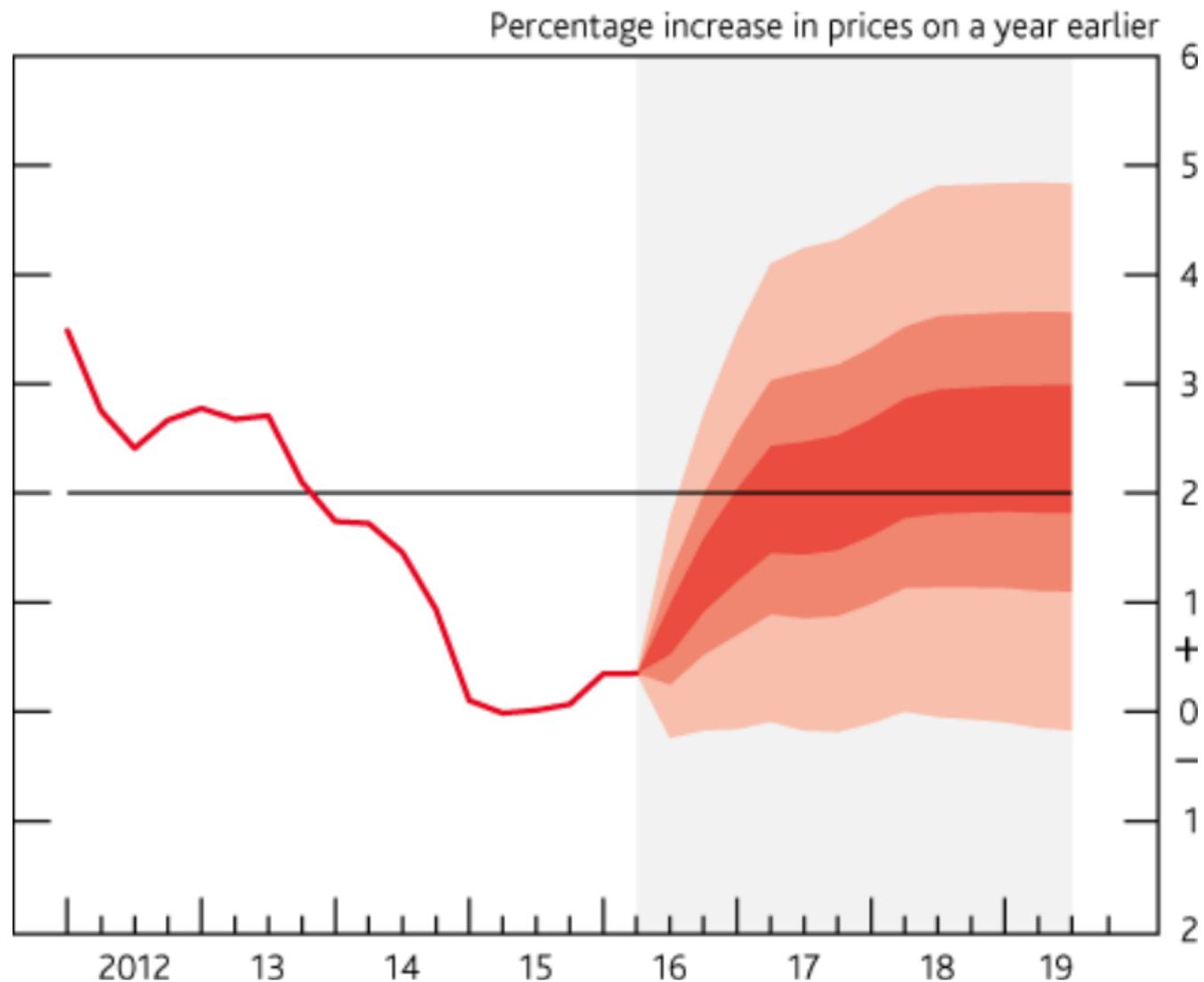
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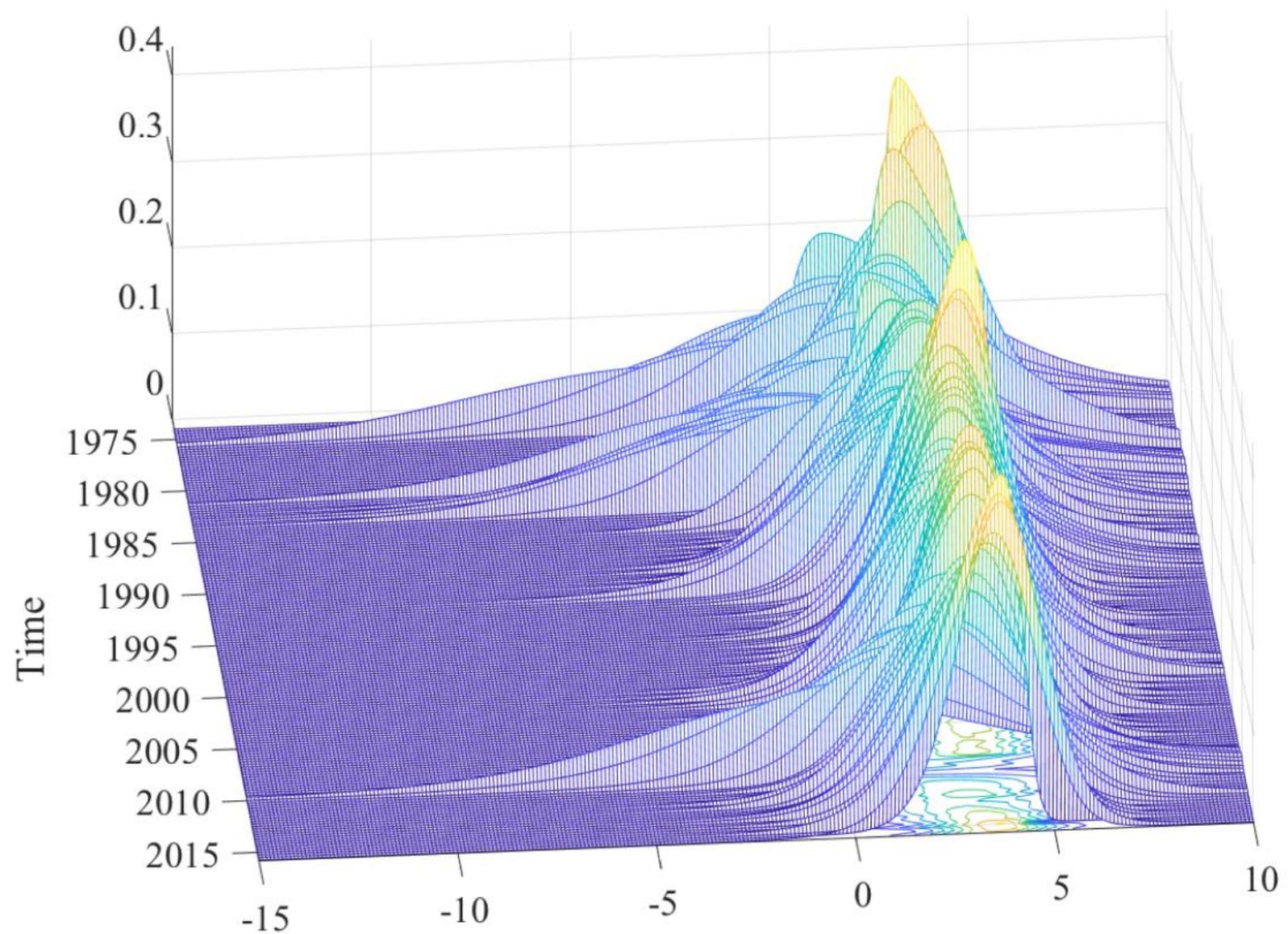
Predictive distributions

- Policy makers are clearly interested in the whole density of key state variables (Timmermann (2000))
- But the literature has not yet proposed a parsimonious structural model...



One-year-ahead distribution of GDP growth

- Adrian, Boyarchenko, Giannone (2019) document interesting regularities in the conditional distribution of GDP growth

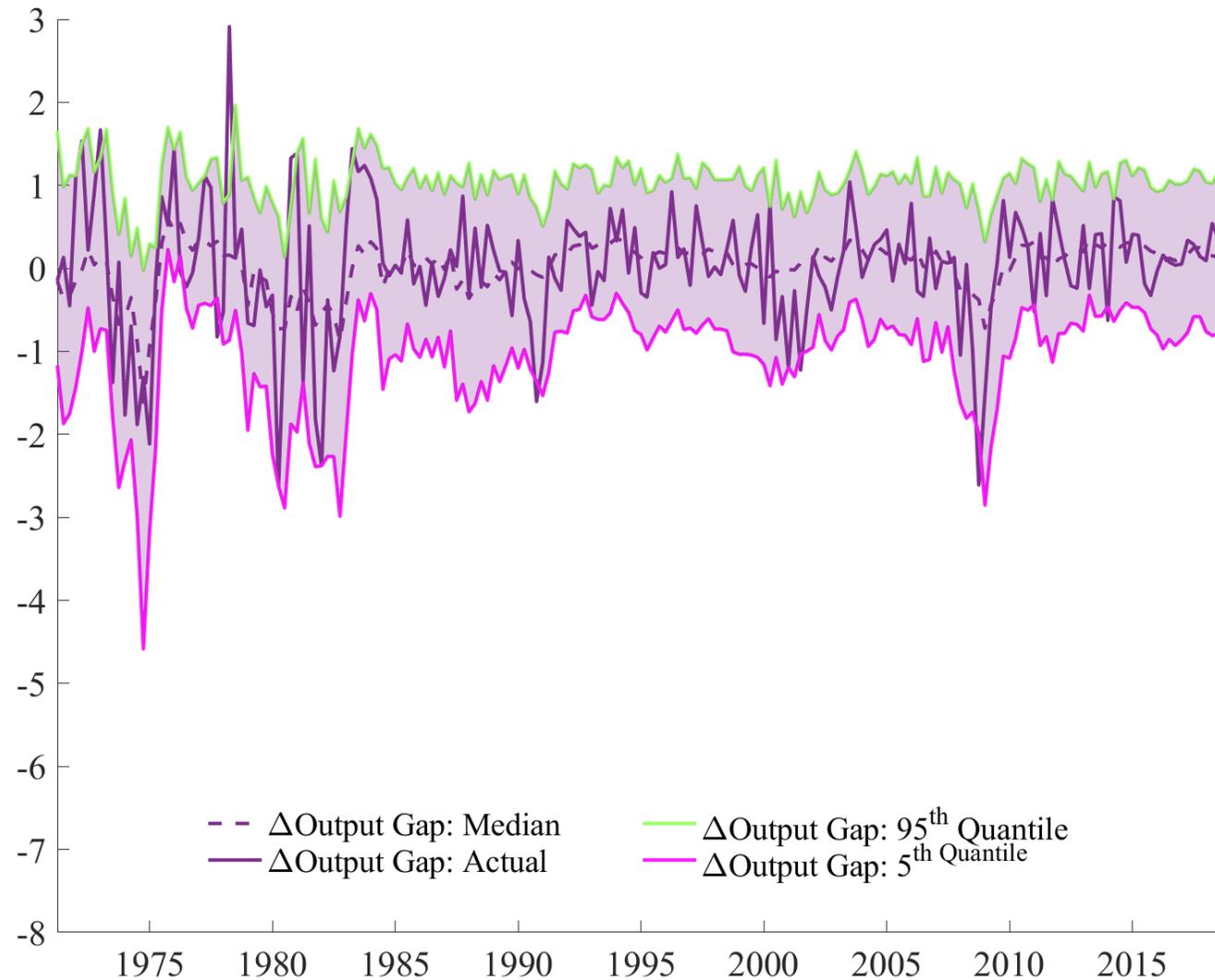


Presentation Outline

- **Stylized facts**
- Towards an NKV model
- Matching the facts
- Policy Implications
- Conclusions

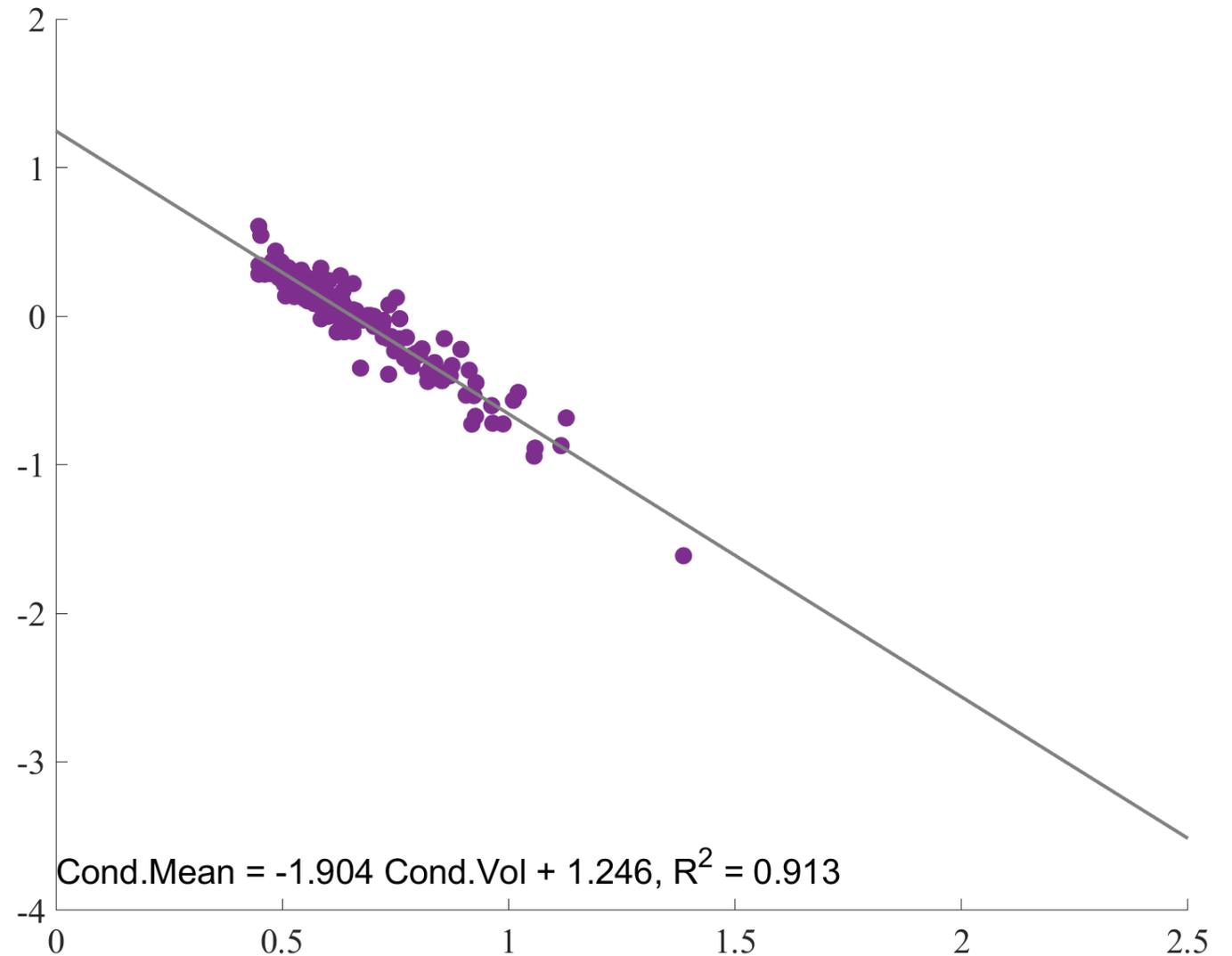
Stylized Fact I

- Financial variables predict tail of ΔY^{gap} distribution



Stylized Fact II

- Conditional mean and conditional volatility of ΔY^{gap} correlate negatively





How stylized facts I and II are connected

- For a normal distribution the formulae for the 95th and 5th conditional quantiles are given by

$$\begin{aligned}1.645\sigma_{t+1|t} + \mu_{t+1|t} &= q_{t+1|t}^{95} \\ -1.645\sigma_{t+1|t} + \mu_{t+1|t} &= q_{t+1|t}^5\end{aligned}$$

- This implies

$$\sigma_{t+1|t} = \frac{q_{t+1|t}^{95} - q_{t+1|t}^5}{2 \times 1.645} = \frac{q_{t+1|t}^{95} - q_{t+1|t}^5}{3.29}$$



How stylized facts I and II are connected (ctd)

- Exploiting this relationship in the formula for the lower quantile yields

$$-1.645 \left(\frac{q_{t+1|t}^{95} - \mu_{t+1|t}}{1.645} \right) + \mu_{t+1|t} = q_{t+1|t}^5$$

- Which implies “excess sensitivity”

$$q_{t+1|t}^5 = -q_{t+1|t}^{95} + 2\mu_{t+1|t}$$

- One reason why the lower quantile is a good measure of underlying risk



Why should policy makers care?

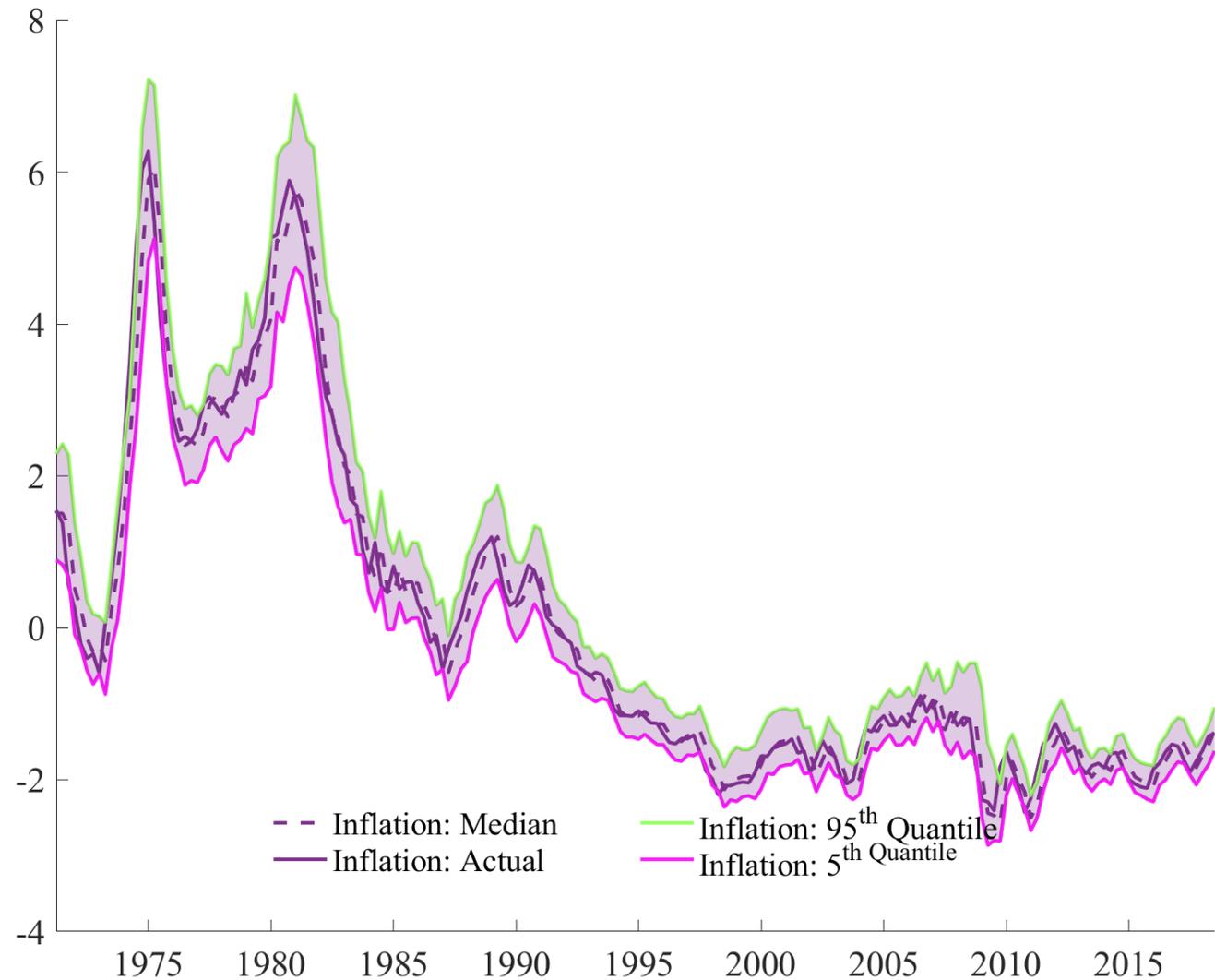
- Under flexible inflation targeting policy makers aim to affect the conditional mean of the output gap and inflation several quarters ahead

$$\sigma_{t+1|t} = \frac{q_{t+1|t}^{95}}{1.645} - \frac{1}{1.645} \mu_{t+1|t}$$

- By pushing down on its conditional mean, the central bank will simultaneously be increasing the conditional volatility of the output gap
- This trade-off, which has an intertemporal aspect, should be reflected in policy deliberations

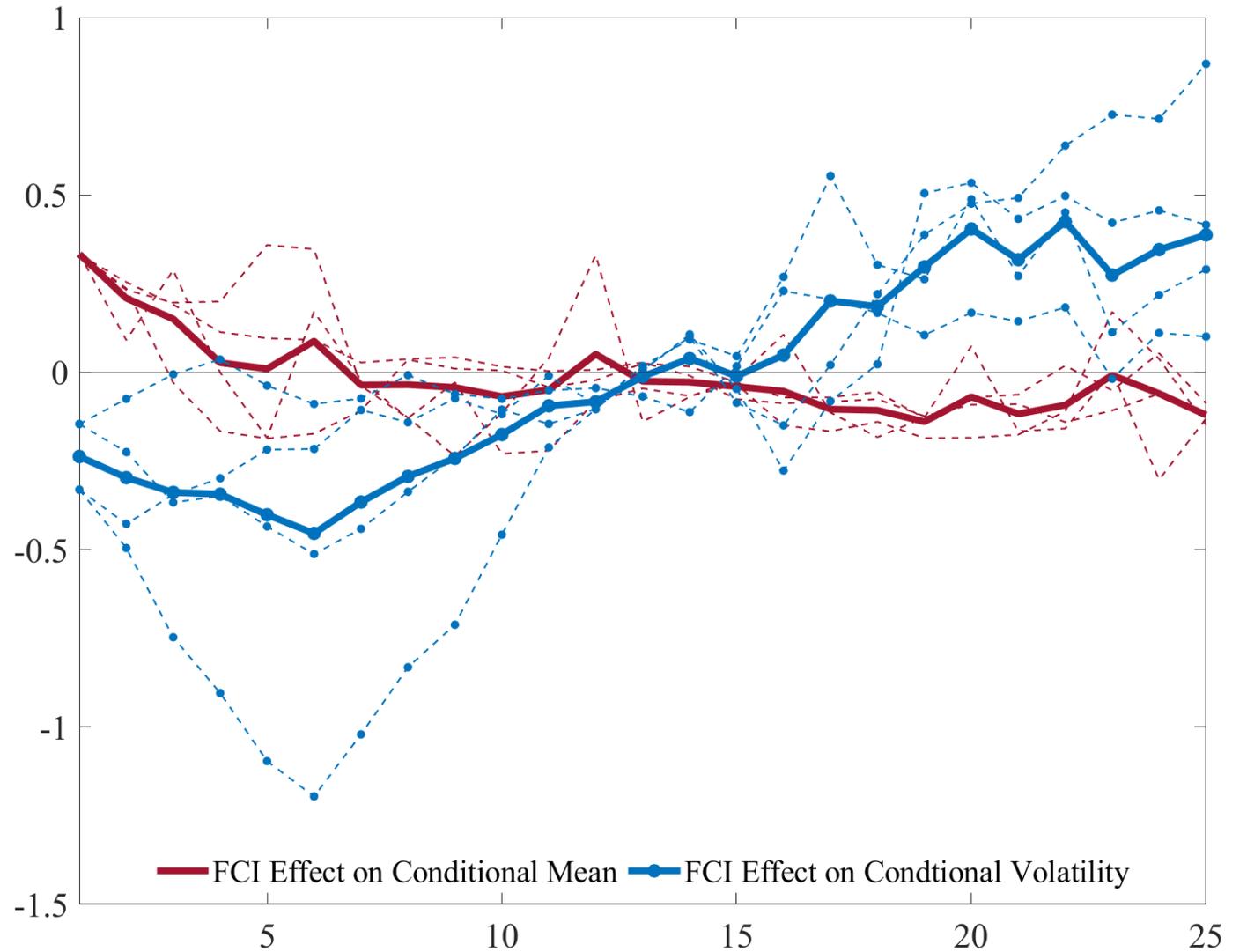
Stylized Fact III

- Financial variables do not predict tails of inflation



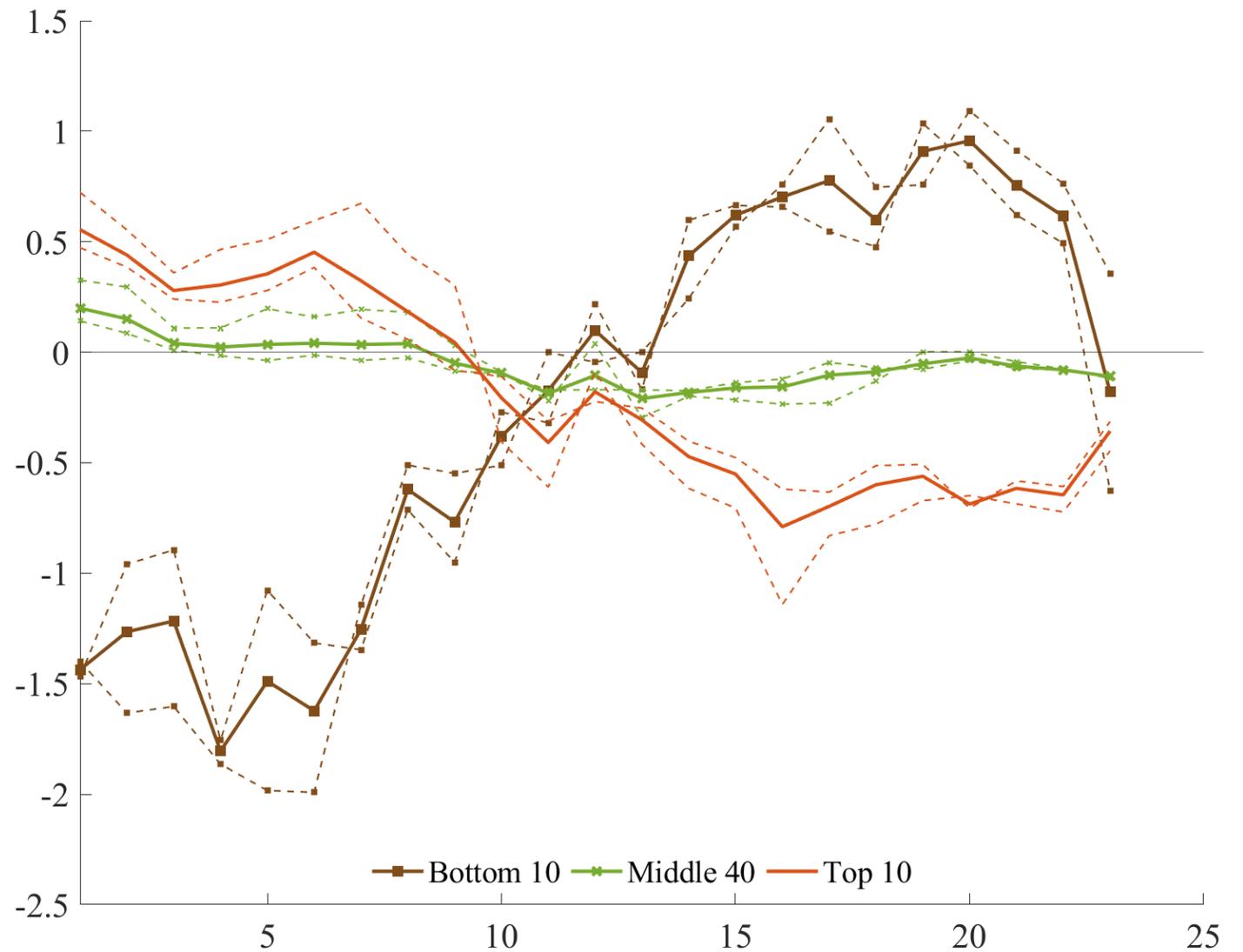
Stylized Fact IV

- The Volatility Paradox



Stylized Fact V

- Term-Structures of Growth-at-Risk cross





Stylized facts: Summary

- Desired features of a policy model:
 - Replicate the negative conditional mean / conditional volatility trade-off and the associated stability of the upper quantile of the ΔY^{gap} distribution
 - Retain a tight link between the conditional volatility of Y^{gap} / the SDF and financial conditions
 - This will also have important implications for asset pricing
 - Use the Volatility Paradox / Growth at Risk Term Structure charts as a cross-check on the inter-temporal trade-off
 - Retain the familiar NK transmission mechanism of standard shocks

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What's wrong with the standard NK model?

- Let's start with the simplest 3-equation NK model (Woodford / Gali Ch.3)

1. IS curve

$$y_t^{gap} = E_t y_{t+1}^{gap} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - r_t^{nat})$$

2. Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \left(\sigma + \frac{(\phi + \alpha)}{1 - \alpha} \right) y_t^{gap}$$

3. Policy rule

$$i_t = \phi^\pi \pi_t + \phi^y y_t^{gap}$$



What's wrong with the standard NK model? (I)

- No immediate role for financial conditions...
- Financial frictions on the borrower side give rise to a financial accelerator term in the IS curve

$$y_t^{gap} = E_t y_{t+1}^{gap} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - r_t^{nat}) - (\gamma_\eta) \eta_t$$

- Tighter financial conditions (higher eta) push down on activity / are associated with a lower output gap



What's wrong with the standard NK model? (I)

- No immediate role for financial conditions...
- Financial frictions on the borrower side give rise to a financial accelerator term in the IS curve

$$y_t^{gap} = E_t y_{t+1}^{gap} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - r_t^{nat}) - (\gamma_\eta) \eta_t + \epsilon_t^{ygap}$$

- Tighter financial conditions (higher eta) push down on activity / are associated with a lower output gap
- Financial frictions on the lender side (e.g. VaR constraint in Adrian and Duarte, 2018) give rise to an additional IS curve wedge



What's wrong with the standard NK model? (II)

- In any linear, homoscedastic model it will be the case that

$$X_t = AX_{t-1} + B\epsilon_t$$

- It immediately follows that

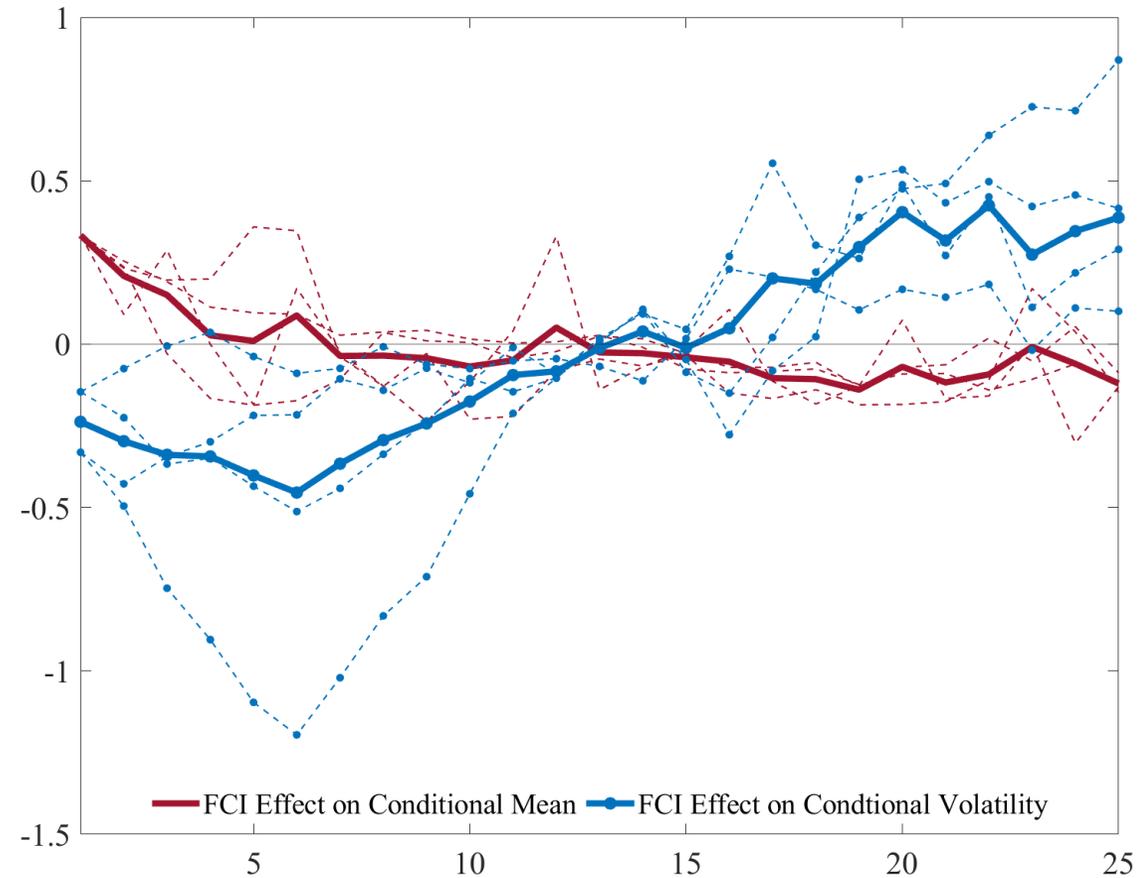
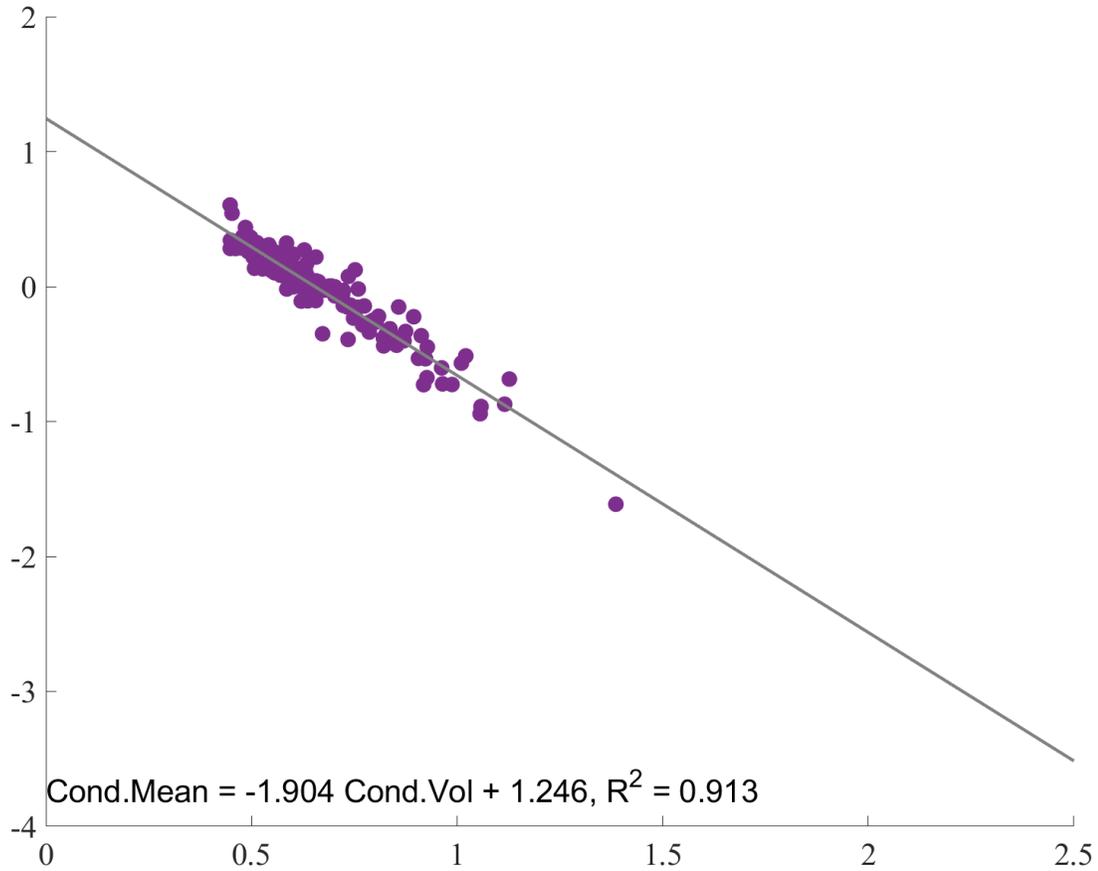
$$\mathcal{P}(X_{t+1}|\mathcal{F}_t) = \mathcal{N}(AX_t, B\Sigma\epsilon B')$$

- I.e. crucially: conditional volatility would be constant!



TRADE-OFF WOULD BE VERTICAL

& CONDITIONAL VOLATILITY FLAT





What's wrong with the standard NK model? (ctd)

- Assumption of financial conditions being driven purely by exogenous shocks appears hard to square with empirical evidence
- The “great moderation” and “great recession” were, arguably, related!
- How can we modify this setup to generate “financial vulnerability” endogenously?



Generating “endogenous vulnerability”

- Instead of specifying ETA as

$$\eta_t = \lambda_\eta \eta_{t-1} + \epsilon_t^\eta$$

we opted for

$$\eta_t = (\lambda_\eta) \eta_{t-1} - (\theta_y) y_t^{gap} - (\theta_\eta) E_t y_{t+1}^{gap}$$

- Intuition: financial conditions are both persistent and affected by current and expected real-economy developments...



How to get state-dependent conditional volatility?

- Constant conditional volatility is a side-effect of “certainty equivalence”, which holds under a linear (homoscedastic) approximation around the SS
- This immediately implies three different ways forward:
 1. Using a non-linear model
 2. Using a linear, heteroskedastic model
 3. Approximating away from the deterministic steady state
- We have experimented with all three approaches: #2 proved most tractable and can help build a simple non-linear extension as well!



How to specify heteroscedasticity?

- To fix attention, we switch off productivity and monetary policy shocks, focusing instead purely on i.i.d. fluctuations driven by the IS-curve wedge
 - This approach is inspired by Adrian and Duarte (2018)
 - We constrain our exercise by assuming textbook values for all NK parameters
 - IRFs to (homoscedastic) monetary policy and productivity shocks would be exactly equal to those in the NK model (sans financial accelerator)
- This still leaves us a lot of freedom in specifying

$$\epsilon_t^{ygap} = f(\cdot) \epsilon_t^{ygap}$$

- Free to choose both the arguments of f and its functional form
- How can we discipline these choices?



How to specify heteroscedasticity? (ctd)

- Assuming an analytically convenient exponential doesn't work well...

$$f(\eta_{t-1}) = \frac{1}{2} \exp(\eta_{t-1})$$

- Adding other variables can help replicate the trade-off slope but R2 typically goes down and 95th conditional quantile ends up counterfactually volatile
- Simple alternative idea. Consider:

$$X_t = AX_{t-1} + B$$

| | | | |
|--------------|-----|----------|-----|
| $f(X_{t-1})$ | 0 | \vdots | 0 |
| 0 | 1 | \vdots | 0 |
| ... | ... | \ddots | ... |
| 0 | 0 | \vdots | 1 |

$\underbrace{\hspace{15em}}_{F(X_{t-1})}$

| |
|------------------------|
| ε_t^{ygap} |
| ε_t^1 |
| ... |
| ε_t^k |



How to specify heteroscedasticity? (ctd)

- The model variables are then conditionally distributed as

$$\mathcal{P}(X_t|\mathcal{F}_{t-1}) = \mathcal{N}(AX_{t-1}, BF(X_{t-1})\Sigma^\varepsilon F(X_{t-1})'B')$$

- Where the conditional variances are given by

$$\text{diag}(BF(X_t)\Sigma^\varepsilon F(X_t)'B') = \text{sum}((B \circ B)(F(X_t) \circ F(X_t))\Sigma^\varepsilon, 2)$$

with \circ denoting the Hadamard product

- Accordingly the conditional volatility of the first element of X is given by

$$\text{vol}(X_t^1|\mathcal{F}_{t-1}) = \sqrt{b_{11}^2 f^2(X_{t-1}) \sigma_{\text{ygap}}^2 + \sum_{i=1}^k b_{1i+1}^2 \sigma_{1i}^2}$$

- Because of certainty equivalence the b 's do not depend on how $f()$ is specified



How to specify heteroskedasticity? (ctd)

- Conditional normality gives us

$$Q^{95}(X_t^1 | \mathcal{F}_{t-1}) = A(1, :)X_{t-1} + \Phi^{-1}(0.95) \text{vol}(X_t^1 | \mathcal{F}_{t-1})$$

- And so, to ensure that the conditional 95th quantile of the first element of X is constant, we can combine these results and set f() equal to

$$f(X_{t-1}) = \sqrt{\frac{\left(\frac{Q^{95}(X_t^1 | \mathcal{F}_{t-1}) - A(1, :)X_{t-1}}{\Phi^{-1}(0.95)} \right)^2 - \sum_{i=1}^k b_{1i+1}^2 \sigma_{1i}^2}{b_{11}^2 \sigma^{2, \text{ygap}}}}$$

- With a single heteroskedastic shock we obtain an affine relationship

$$f(X_{t-1}) = \frac{Q^{95}(X_t^1 | \mathcal{F}_{t-1})}{\Phi^{-1}(0.95) b_{11} \sigma^{\text{ygap}}} - \frac{A(1, :)}{\Phi^{-1}(0.95) b_{11} \sigma^{\text{ygap}}} X_{t-1}$$



Interpretation of the regression coefficients

- Can then obtain the following relationship

$$vol(X_t^1 | \mathcal{F}_{t-1}) = \frac{Q^{0.95}(X_t^1 | \mathcal{F}_{t-1})}{\Phi^{-1}(0.95)} - \frac{1}{\Phi^{-1}(0.95)} E(X_t^1 | \mathcal{F}_{t-1})$$

- The estimated coefficients of the conditional mean variance relationship tell us which quantile we're fixing and at what value. Say we've estimated

$$vol(X_t^1 | \mathcal{F}_{t-1}) = \alpha - \beta E(X_t^1 | \mathcal{F}_{t-1})$$

- Then we could solve for x and Q^x from

$$\beta = \frac{1}{\Phi^{-1}(x)} \quad \alpha = \frac{Q^x(X_t^1 | \mathcal{F}_{t-1})}{\Phi^{-1}(x)}$$

Where α and β are the estimated regression coefficients

Conditional volatility and financial conditions

- We know that

$$f(X_{t-1}) = \frac{Q^{95}(X_t^1 | \mathcal{F}_{t-1})}{\Phi^{-1}(0.95)b_{11}\sigma^{ygap}} - \frac{A(1, :)}{\Phi^{-1}(0.95)b_{11}\sigma^{ygap}} X_{t-1}$$

- Conditional volatility is an affine function of the state
- In our specification the only state variable will be financial conditions ETA
 - This allows for a direct link between financial conditions and conditional volatility



Towards a New Keynesian model with vulnerability

- Can our New Keynesian model with vulnerability (NKV) generate the stylized facts I – V?
- No. Why?
- Fundamentally, a consequence of the dynamic properties of the core NK model that we're extending...



Endogenous propagation in the NK model

- RBC model lacks endogenous propagation in the sense of Frisch (1933)
 - Watson (1993) spectral power of RBC model is low at business cycle frequencies (2 - 8 years)
 - Cogley and Nason (1995) find that the dynamic properties of the shocks determine the dynamic properties of output, with the model contributing almost nothing
- NK model inherits many properties of the RBC model – including absence of a meaningful shock propagation mechanism
 - If we fed the NK model N.i.d. shocks, in line with the continuous time specification of Adrian and Duarte (2018), we would get N.i.d. processes for the output gap and inflation...



Endogenous propagation in the NKV model

- The NKV model improves on the NK model but the parsimonious setup means that dynamics of endogenous variables will be at most as complicated as the dynamics of the state
- Since in equilibrium ETA would be an AR(1) process, therefore all other variables would also be AR(1)
- Problem: lack of “overshooting” (Dornbusch, 1976) leads to counterfactual Volatility Paradox and Growth at Risk Term Structure
- Two potential solutions:
 - Increase the dimensionality of the state (e.g. habits, interest rate smoothing, accelerationist Phillips curve); however, in the spirit of Ascari, Fagiolo and Roventini (2015), we found this doesn’t necessarily improve fit
 - Enrich shock propagation by allowing for richer dynamics of ETA



Endogenous vulnerability

- To allow for overshooting, we end up with

$$\eta_t = (\lambda_\eta)\eta_{t-1} + (\lambda_{\eta\eta})\eta_{t-2} - (\theta_y)y_t^{gap} - (\theta_\eta)E_t y_{t+1}^{gap}$$

- Number of reasons to introduce a second lag term:
 - AR(2) dynamics frequently used as forecasting benchmark
 - Initially extended the results of Bordalo, Gennaioli and Shleifer (2018) to the case of an AR(2) underlying state process
 - Turned out that the extra degrees of freedom were not necessary to generate an empirically relevant overshooting
 - The model endogenously generates cyclical behavior
 - Somewhat in the spirit of Kalecki's (35 ECTA & 54 monograph)

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Final NKV model specification

- Just one i.i.d. shock, one extra equation, 5 new free parameters:

- IS curve

$$y_t^{gap} = E_t y_{t+1}^{gap} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - r_t^{nat}) - (\gamma_\eta) \eta_t + (\sigma_{ygap}) f(\cdot) \varepsilon_t^{ygap}$$

- Evolution of financial conditions

$$\eta_t = (\lambda_\eta) \eta_{t-1} + (\lambda_{\eta\eta}) \eta_{t-2} - (\theta_y) y_t^{gap} - (\theta_\eta) E_t y_{t+1}^{gap}$$

- Phillips curve

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \left(\sigma + \frac{(\phi + \alpha)}{1 - \alpha} \right) y_t^{gap}$$

- Policy rule

$$i_t = \phi^\pi \pi_t + \phi^y y_t^{gap}$$



How we calibrated (ctd)

- Our chosen parameter values were

| | | | | | | | | | | | | | |
|---------------|---------|------------|---------------|----------------|----------------------|--------|------------|----------|----------|----------|---------------|------------|-----------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| α | β | ϵ | γ_η | λ_η | $\lambda_{\eta\eta}$ | ϕ | ϕ_π | ϕ_y | σ | θ | θ_η | θ_y | σ_{ygap} |
| $\frac{1}{3}$ | 0.99 | 6 | 0.01 | 1.97 | -1.01 | 1 | 1.5 | 0.5/4 | 1 | 2/3 | 0.3 | 0.08 | -0.17 |

- All NK parameters set to values from Gali (2015) Ch. 3
- The five remaining parameters (4,5,6,12 and 13) selected to match autocorrelation of ΔY^{gap} and its cross-correlation with ETA
- Helpful result (verified numerically): cross- and auto-correlations in the heteroscedastic model match those in the homoscedastic specification



How we calibrated (ctd)

- Can do more meaningful analytics conditional on the *Dynare* solution
- Denote reduced form by

$$\eta_t = F_2\eta_{t-1} + F_3\eta_{t-2} + F_1\epsilon_t$$

$$y_t^{gap} = P_2\eta_{t-1} + P_3\eta_{t-2} + P_1\epsilon_t$$

- Then

$$y_t^{gap} = F_2y_{t-1}^{gap} + F_3y_{t-2}^{gap} + P_1\epsilon_t + (F_1P_2 - F_2P_1)\epsilon_{t-1} + (F_1P_3 - F_3P_1)\epsilon_{t-2}$$

$$E_t y_{t+1}^{gap} = F_2 E_{t-1} y_t^{gap} + F_3 E_{t-2} y_{t-1}^{gap} + F_1 P_2 \epsilon_t + F_1 P_3 \epsilon_{t-1}$$

$$dy_t^{gap} = F_2 dy_{t-1}^{gap} + F_3 dy_{t-2}^{gap} + P_1 \epsilon_t + (F_1 P_2 - (F_2 + 1) P_1) \epsilon_{t-1} + (F_1 P_3 - F_3 P_1 - F_1 P_2 + F_2 P_1) \epsilon_{t-2} - (F_1 P_3 - F_3 P_1) \epsilon_{t-3}$$

$$E_t dy_{t+1}^{gap} = F_2 E_{t-1} dy_t^{gap} + F_3 E_{t-2} dy_{t-1}^{gap} + (P_1 - F_1) \epsilon_t + (F_1 P_2 - F_2 P_1 - F_1) \epsilon_{t-1} + (F_1 P_3 - F_3 P_1) \epsilon_{t-2}$$

- This makes it easy to get closed form results for auto- and cross-correlations



Targeted and non-targeted moments

- Unrestricted specification

AUTO-CORRELATIONS

| | |
|---|--|
| Target auto-correlation of level of output gap | 0.9341305; actual correlation 0.694070 |
| Target auto-correlation of conditional mean of output gap level | 0.9373728; actual correlation 0.757629 |
| Target auto-correlation of change of output gap | 0.2989659; actual correlation 0.281678 |
| Target auto-correlation of conditional mean of change of output gap | 0.7717568; actual correlation 0.725652 |

CROSS CORRELATIONS WITH ETA

| | |
|--|--|
| Target cross-correlation of level of output gap | -0.0373087; actual correlation -0.051117 |
| Target cross-correlation of conditional mean of output gap level | -0.0179207; actual correlation -0.634668 |
| Target cross-correlation of change of output gap | -0.4259927; actual correlation -0.434040 |
| Target cross-correlation of conditional mean of change of output gap | -0.8151644; actual correlation -0.811455 |



Targeted and non-targeted moments

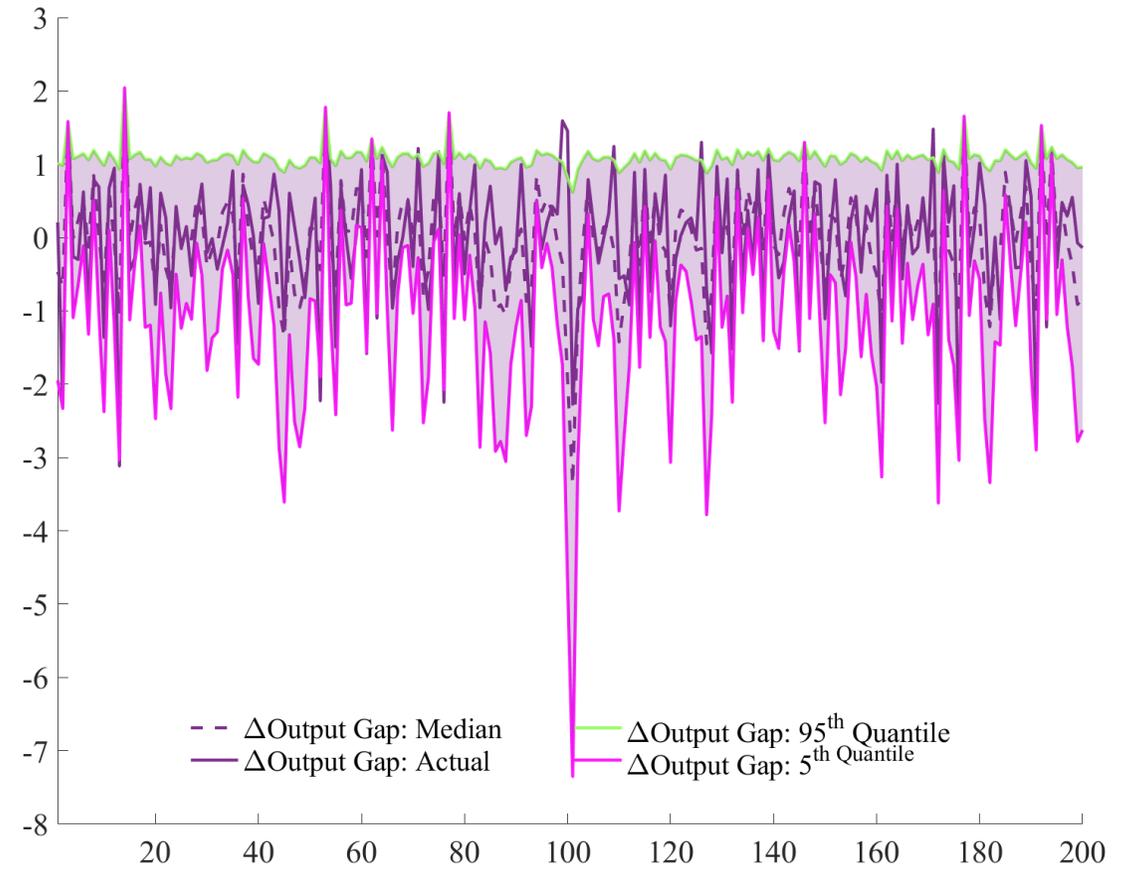
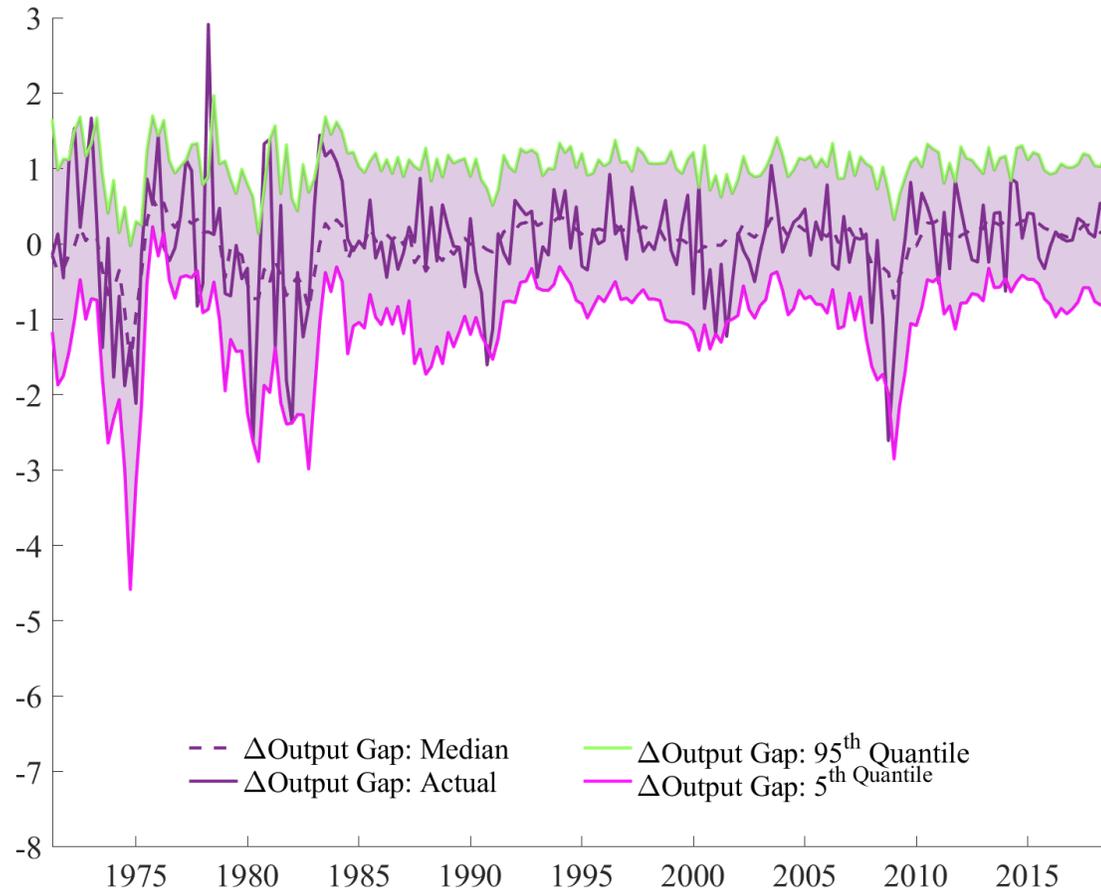
- Restricted specification

| AUTO-CORRELATIONS | |
|--|--|
| Target correlation of level of output gap | 0.9341305; actual correlation 0.974546 |
| Target correlation of conditional mean of output gap level | 0.9373728; actual correlation 0.984742 |
| Target correlation of change of output gap | 0.2989659; actual correlation 0.380395 |
| Target correlation of conditional mean of change of output gap | 0.7717568; actual correlation 0.732440 |

| CROSS CORRELATIONS WITH ETA | |
|--|--|
| Target cross-correlation of level of output gap | -0.0373087; actual correlation -0.866495 |
| Target cross-correlation of conditional mean of output gap level | -0.0179207; actual correlation -0.943194 |
| Target cross-correlation of change of output gap | -0.4259927; actual correlation -0.435475 |
| Target cross-correlation of conditional mean of change of output gap | -0.8151644; actual correlation -0.356513 |

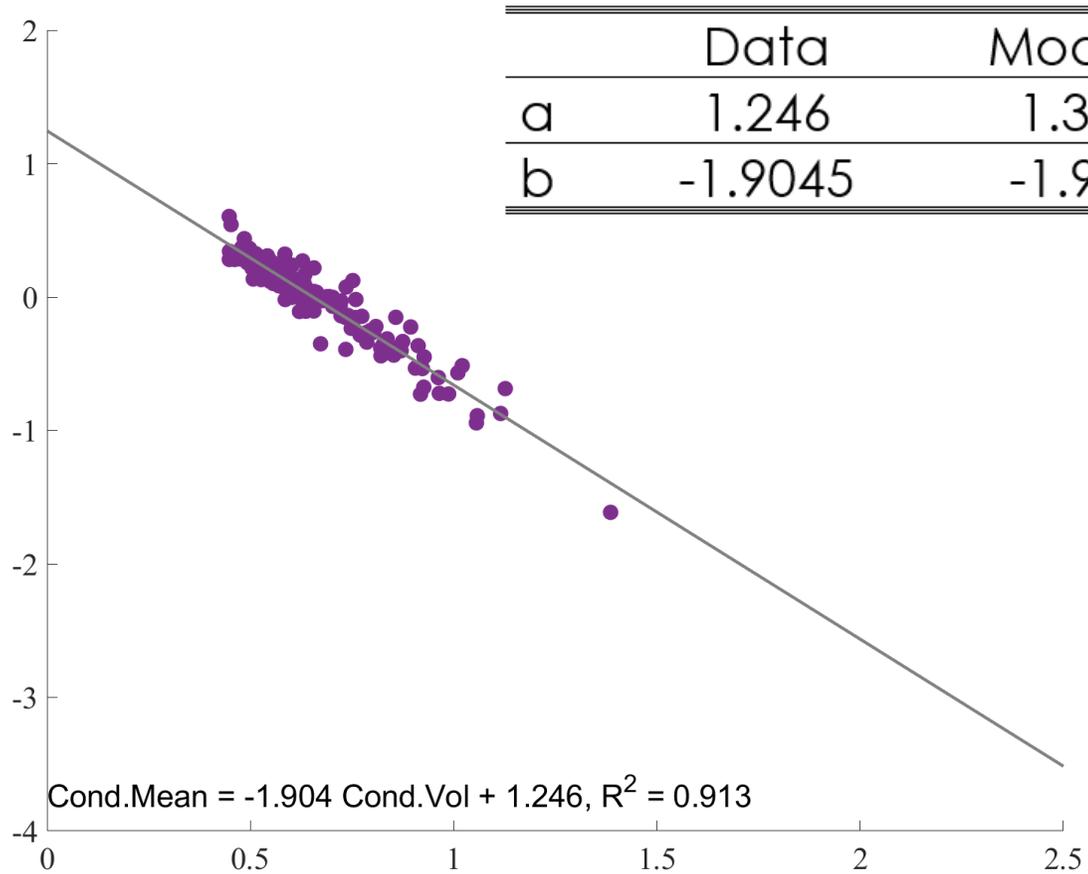


Stylized Fact I

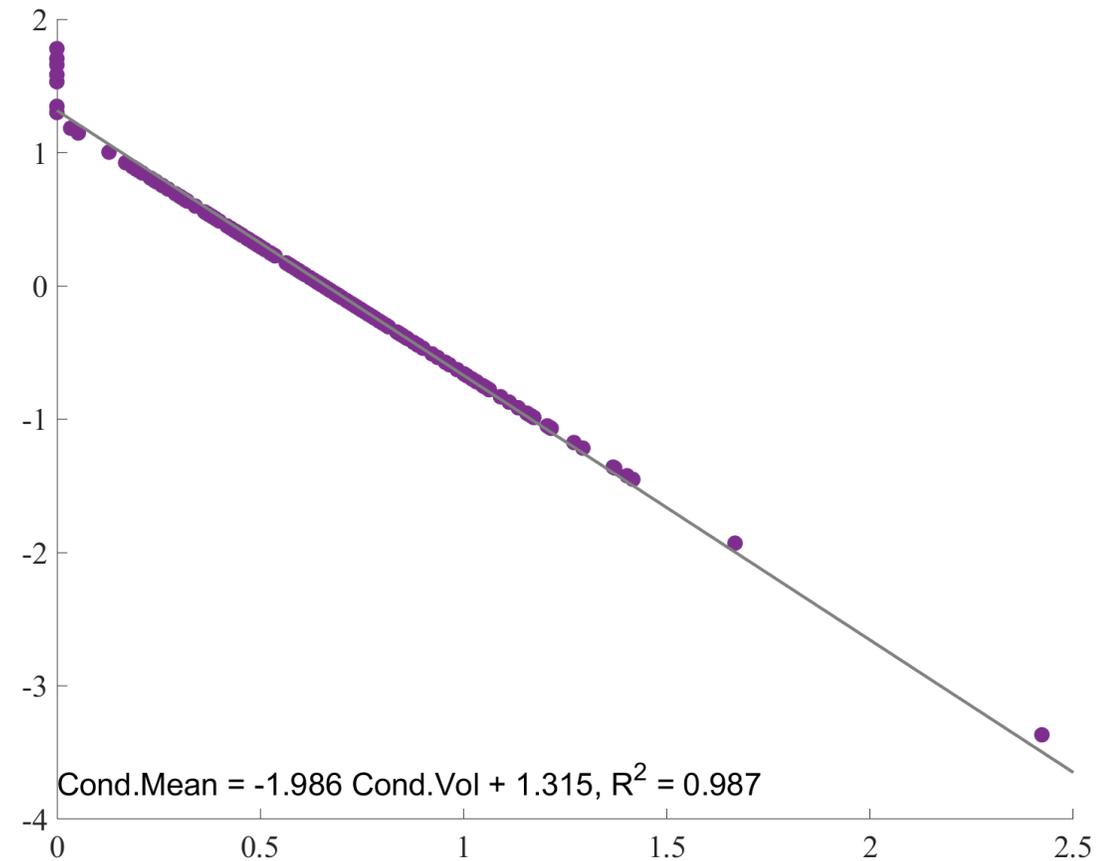




Stylized Fact II



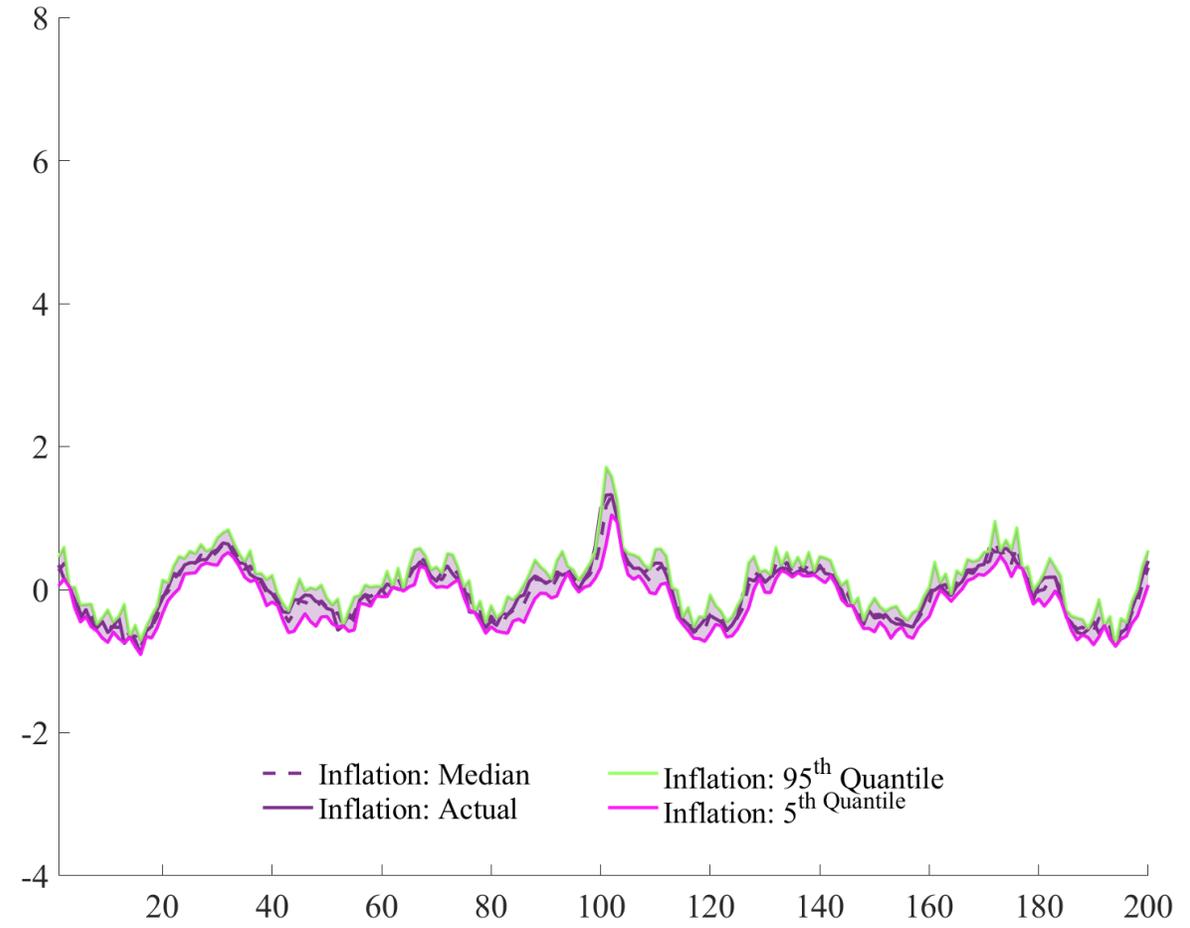
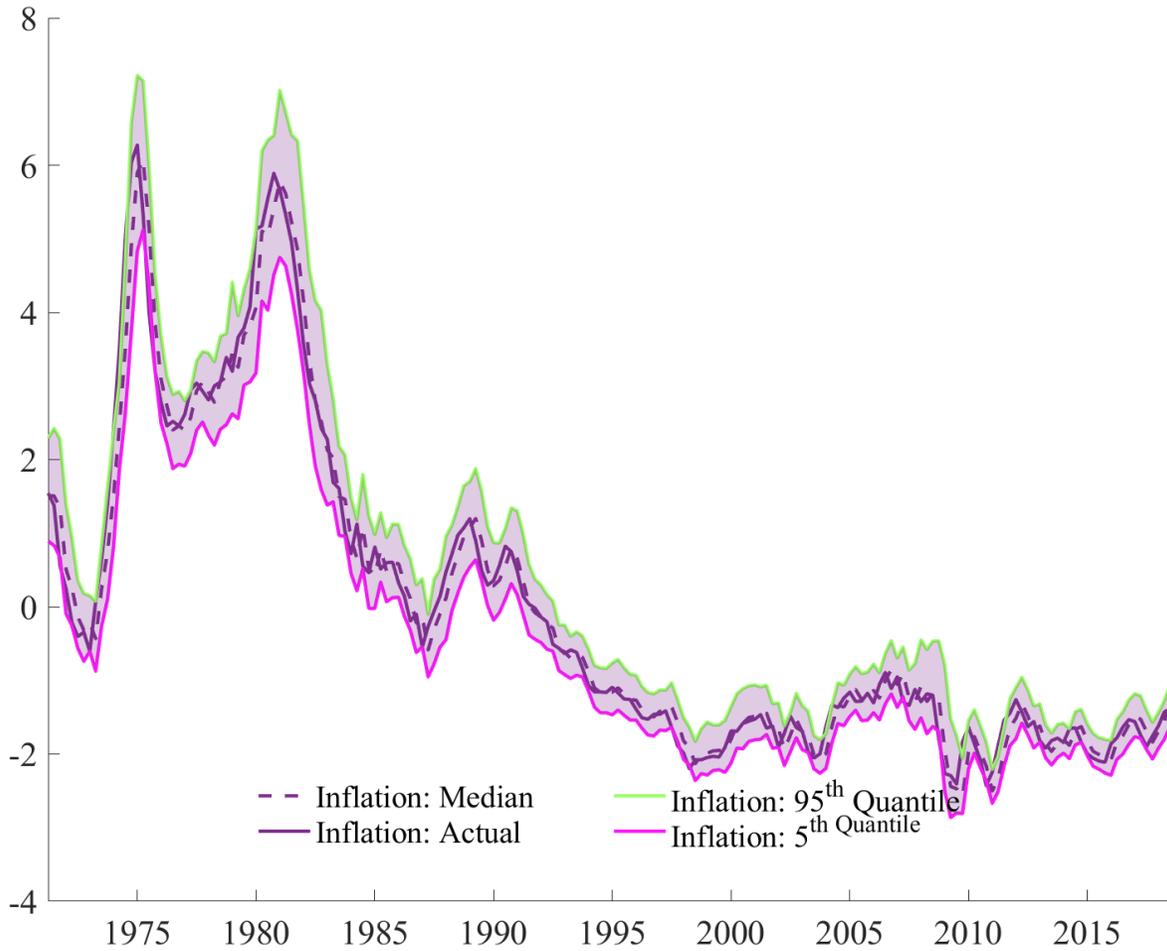
| | Data | Model |
|---|---------|-------|
| a | 1.246 | 1.31 |
| b | -1.9045 | -1.99 |



$$E_t [y_{t+1}] = a + bVol_t [y_{t+1}] + \varepsilon_t$$

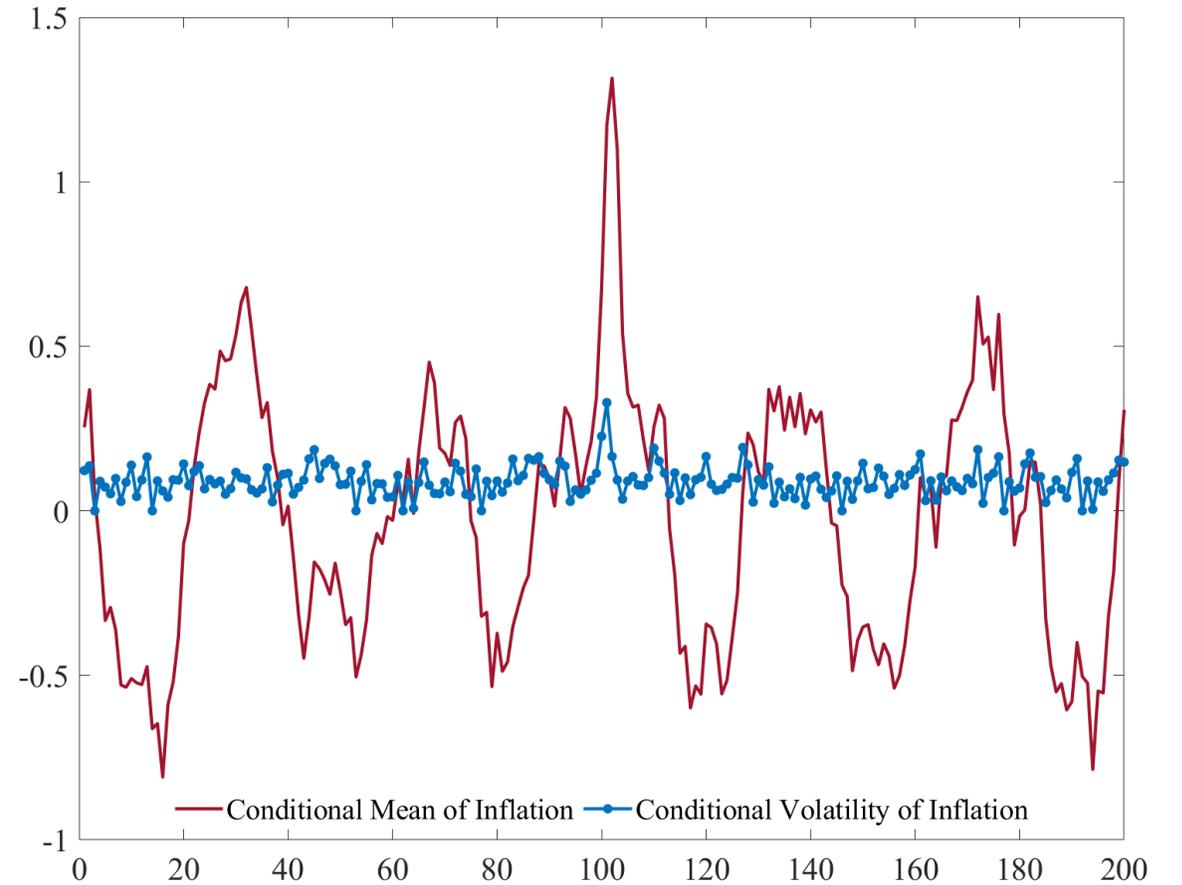
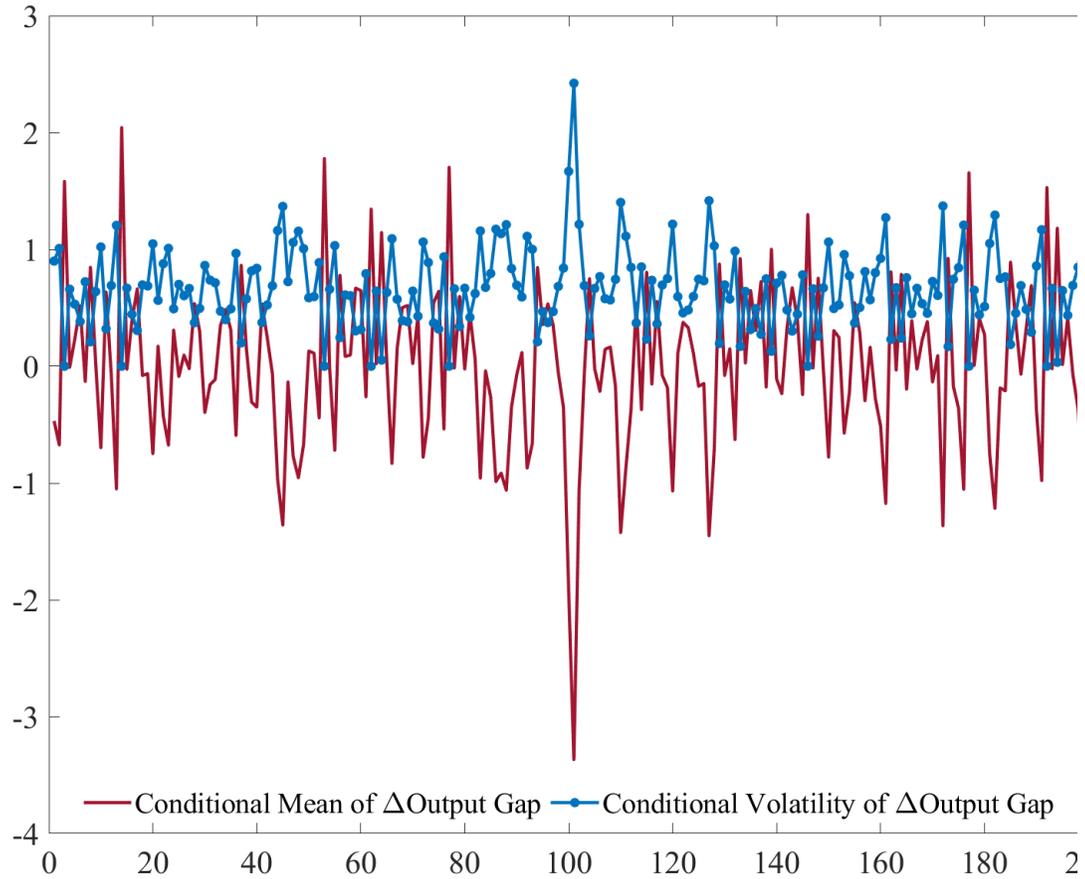


Stylized Fact III



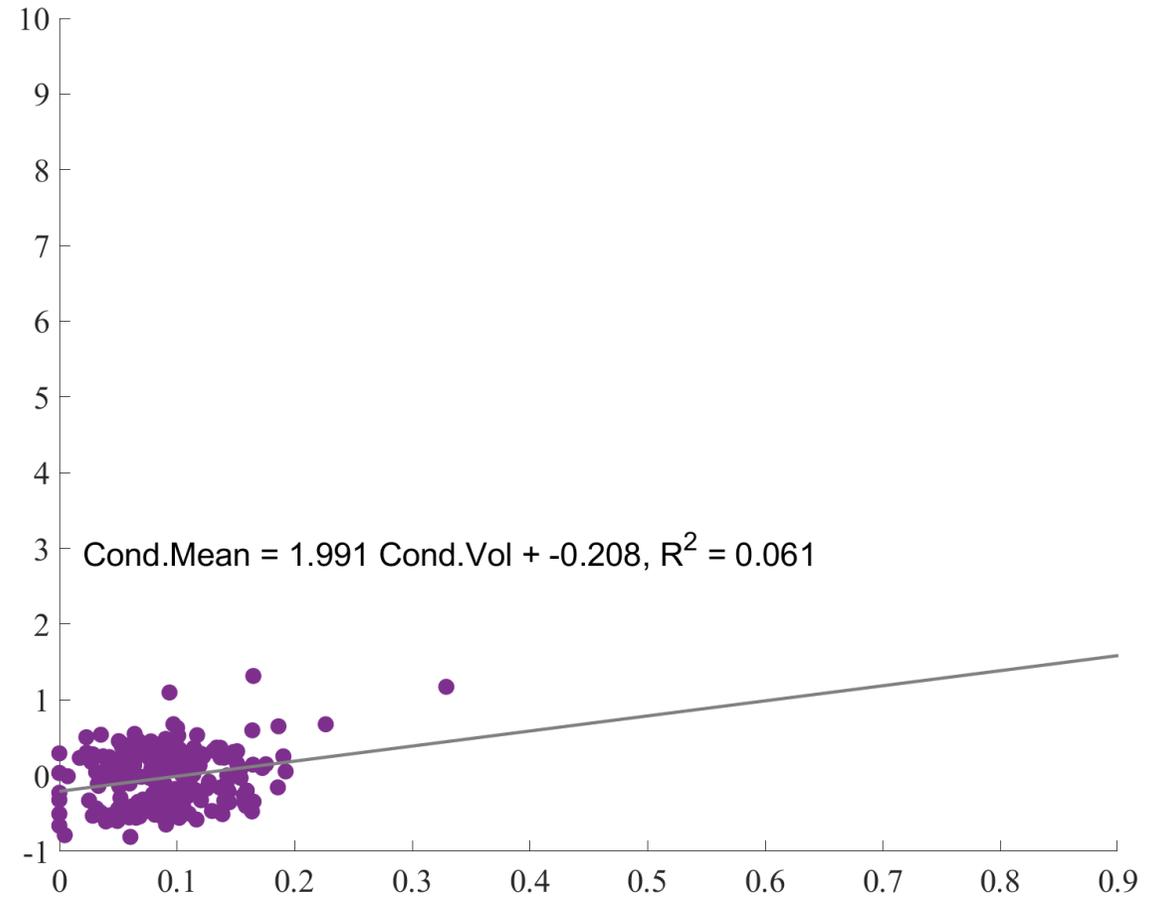
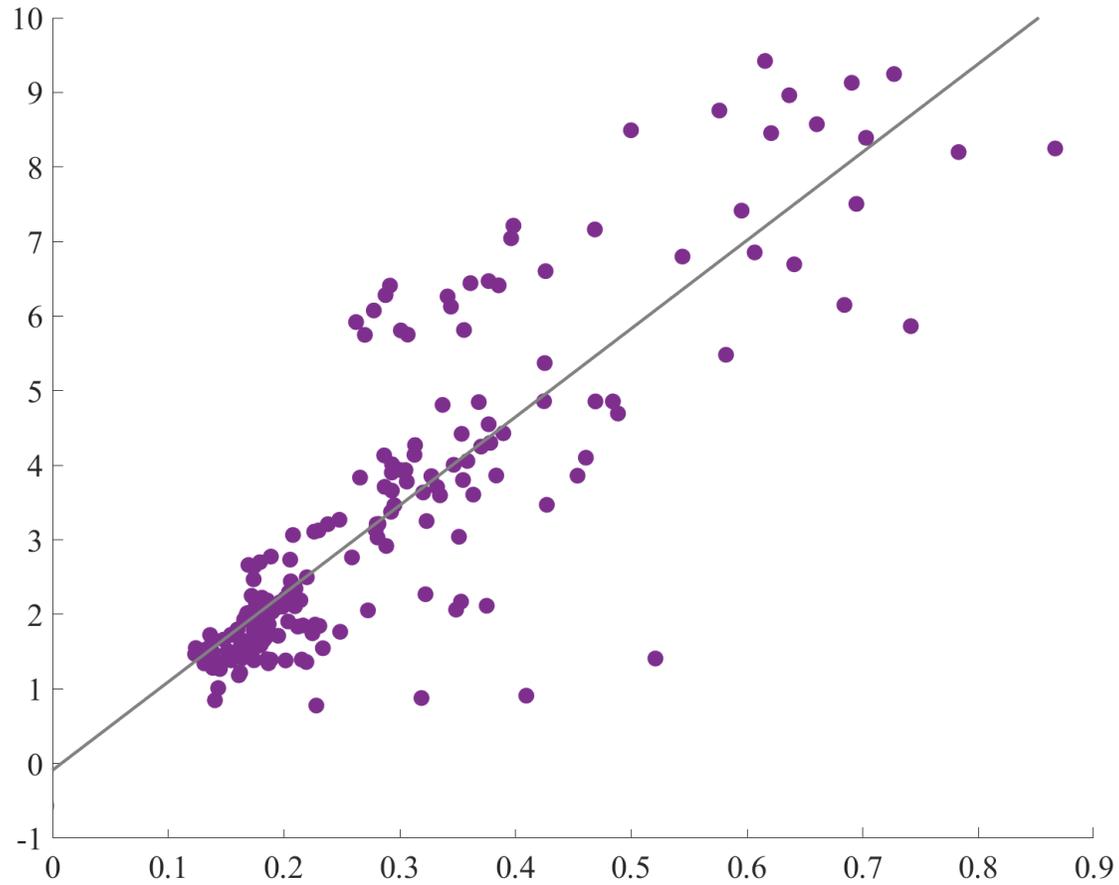


Stylized Fact III (ctd)



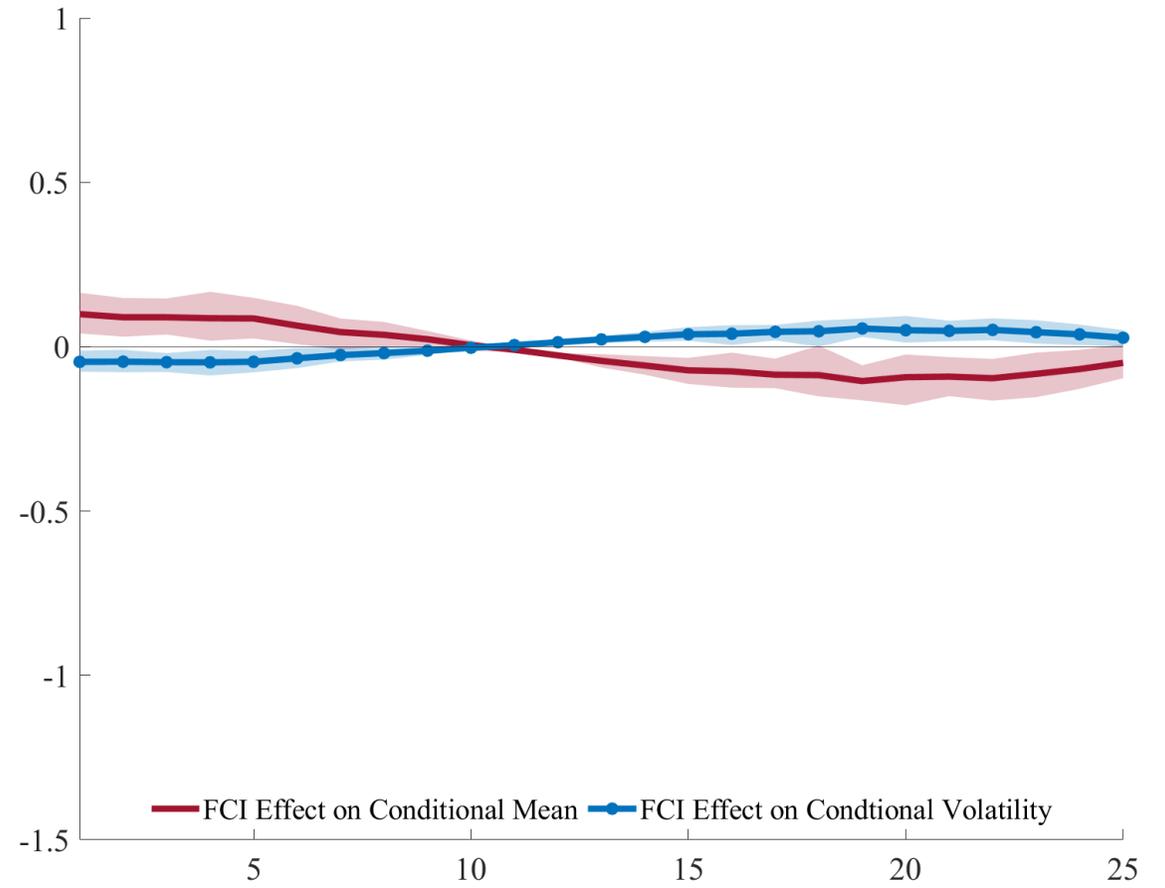
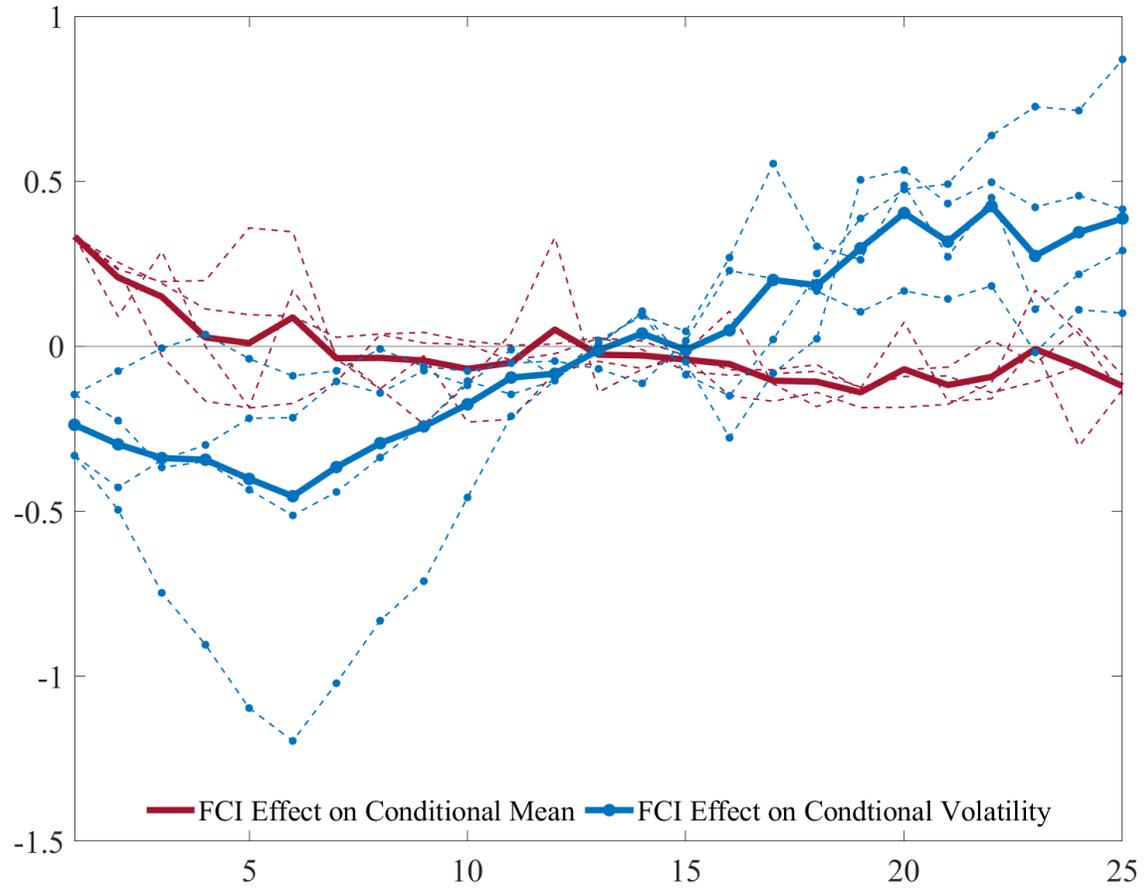


Stylized Fact III (ctd)



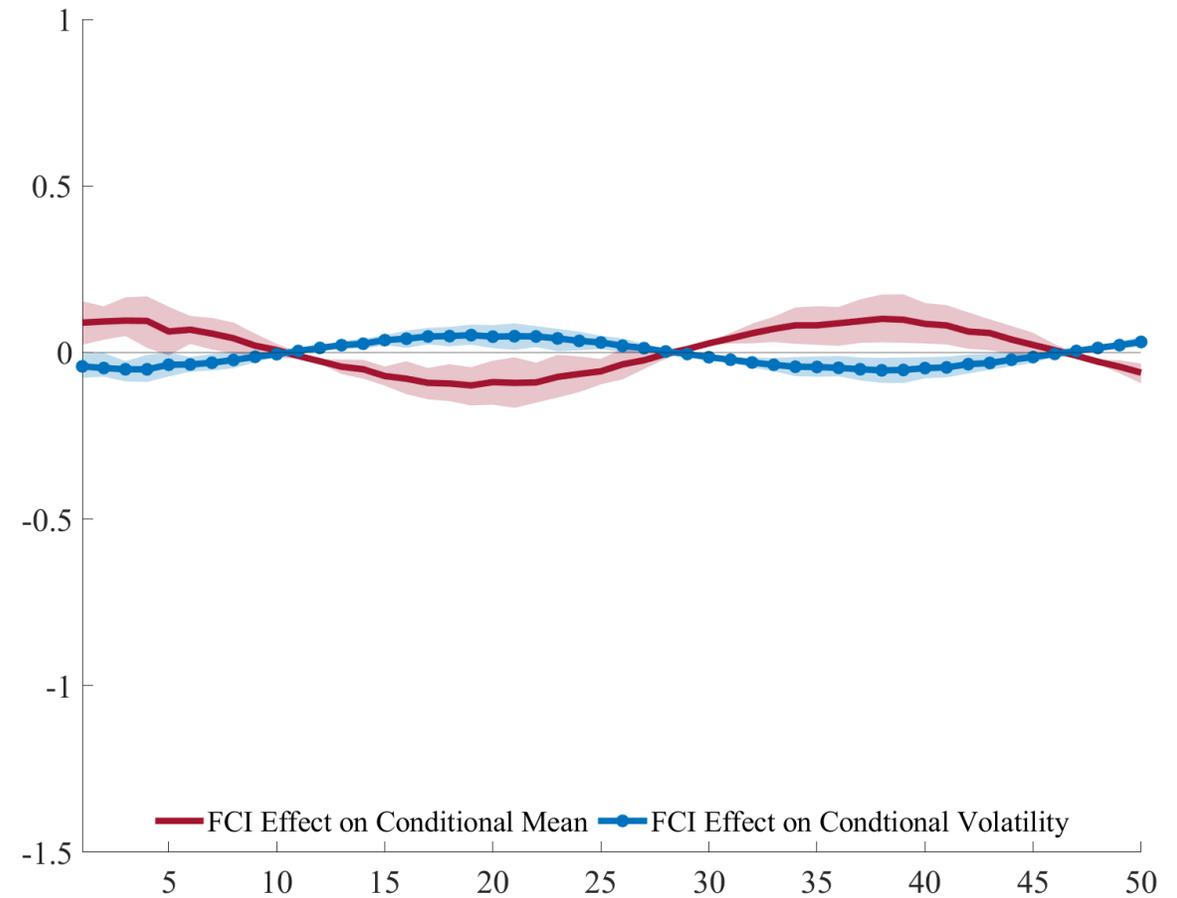
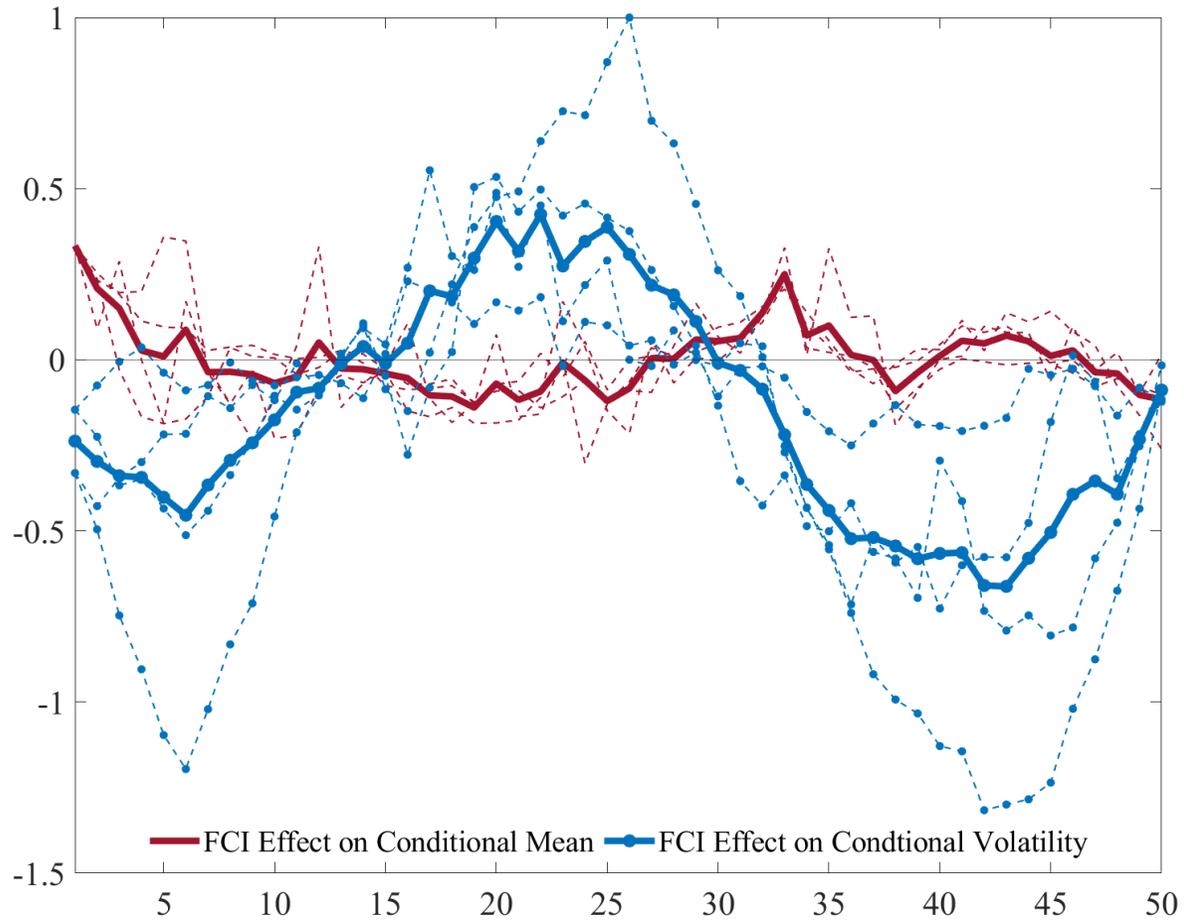


Stylized Fact IV: Volatility Paradox



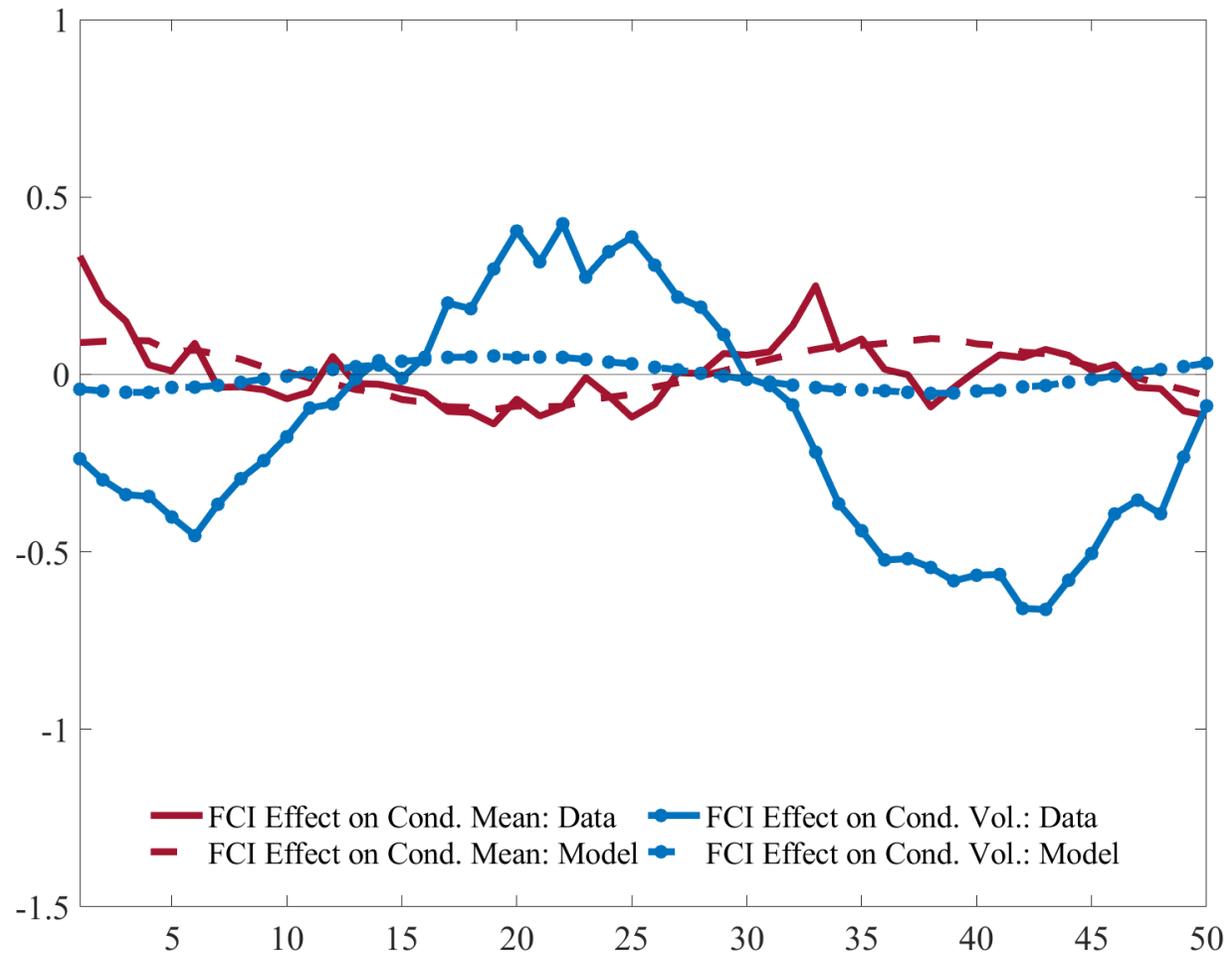


Stylized Fact IV: Volatility Paradox (ctd)



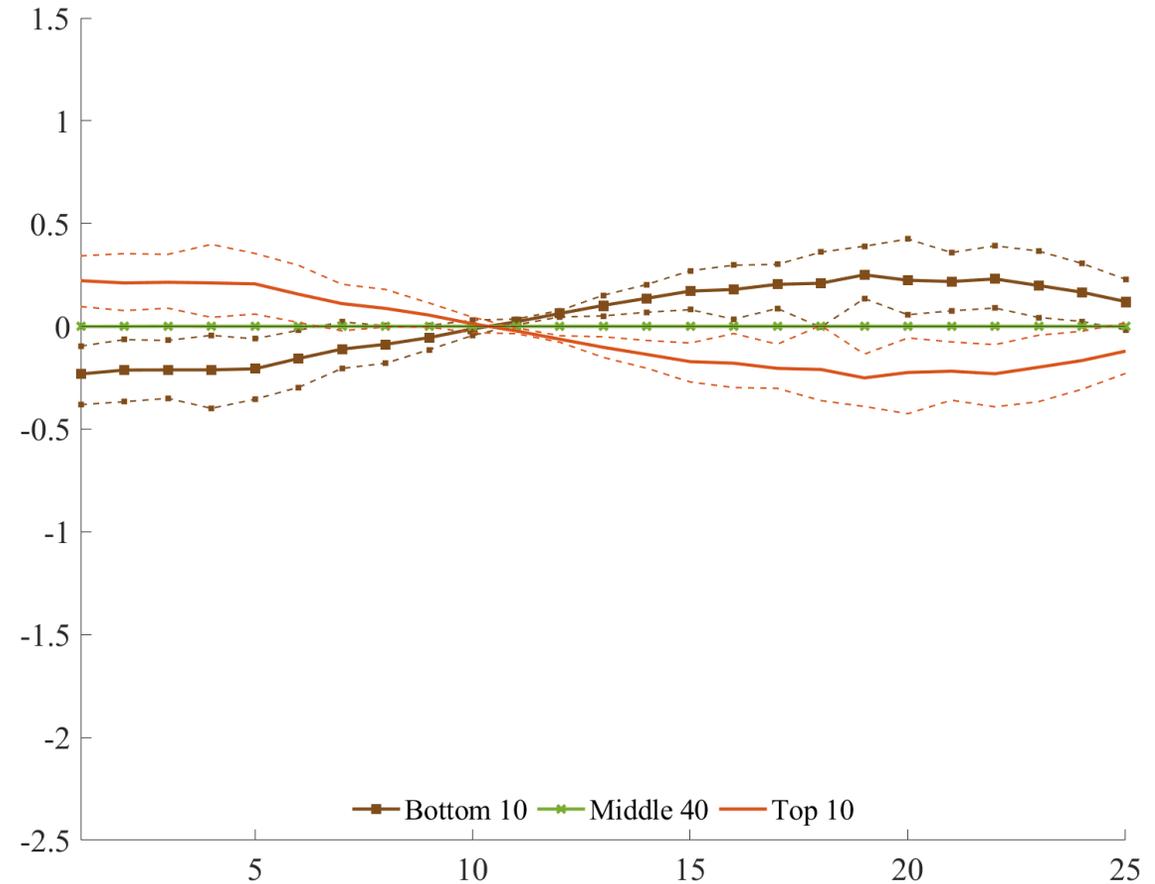
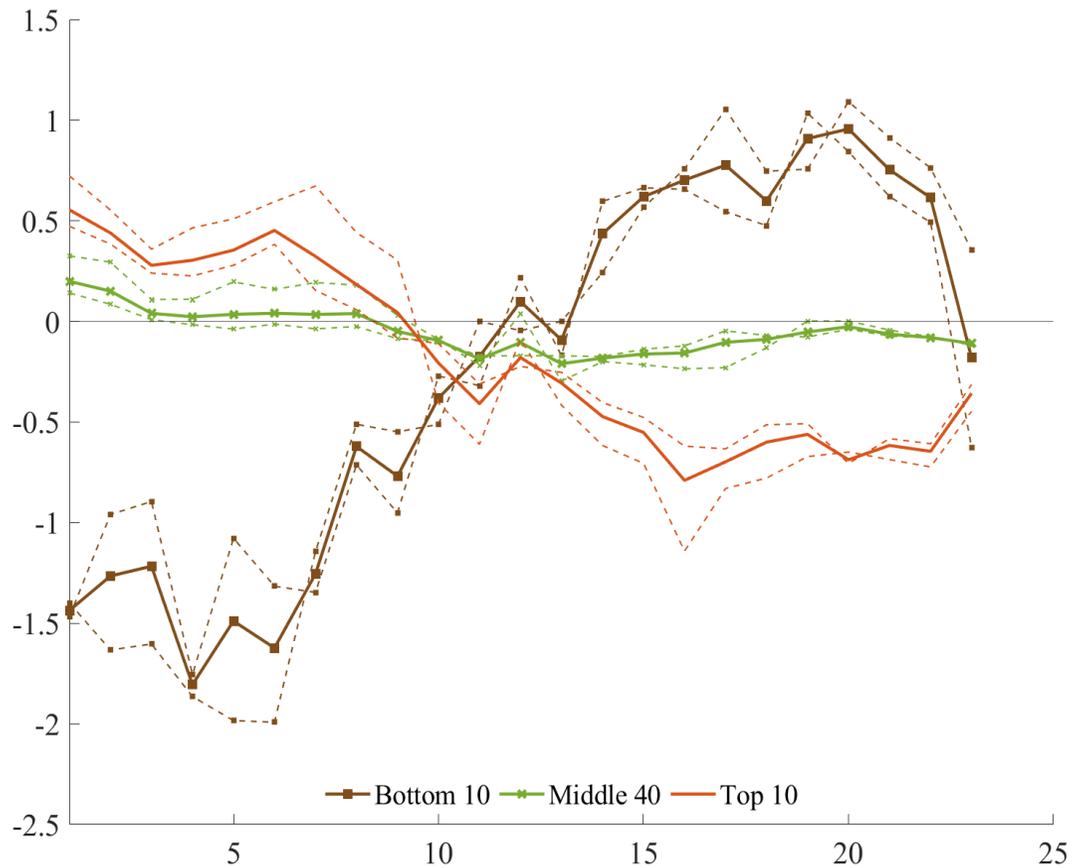


Stylized Fact IV: Volatility Paradox (ctd)



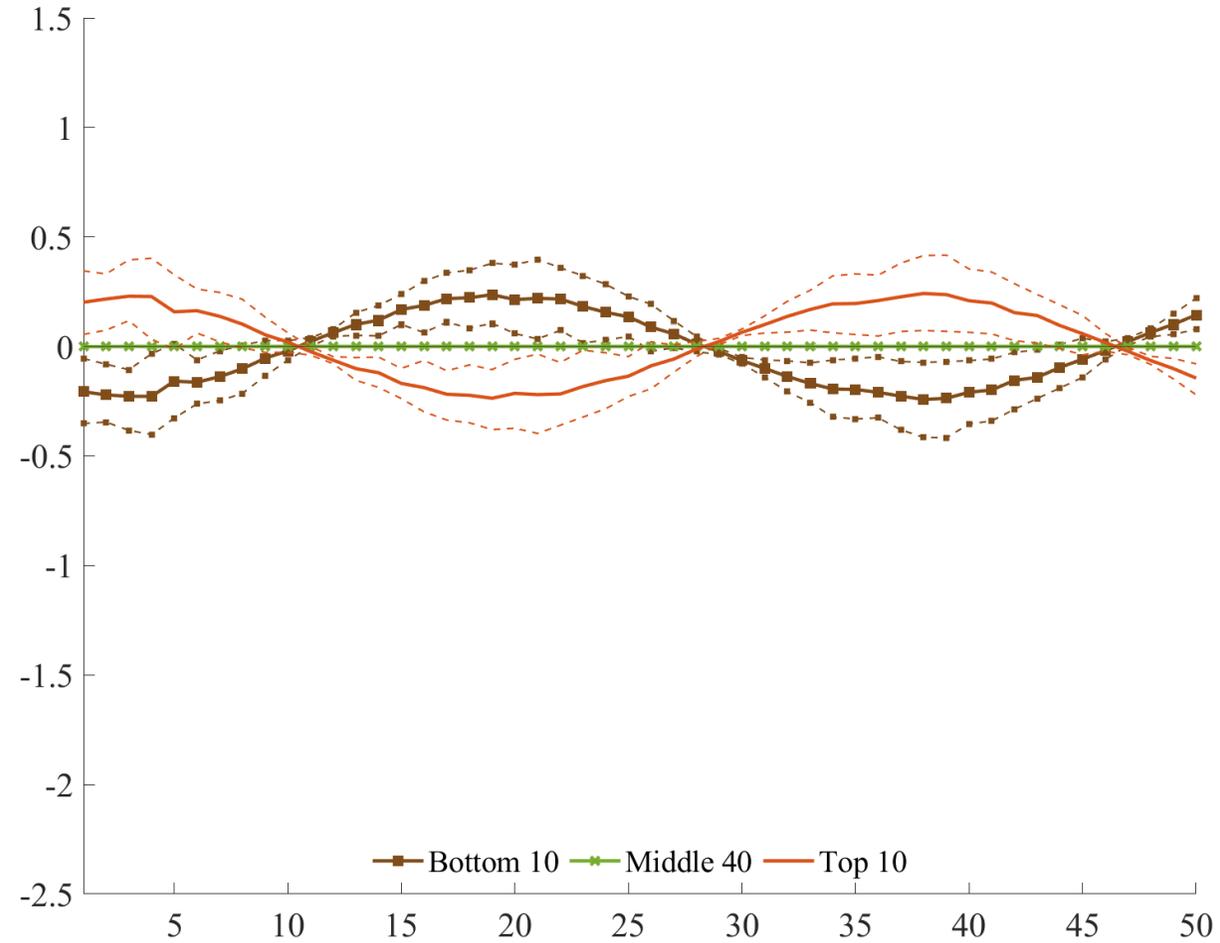
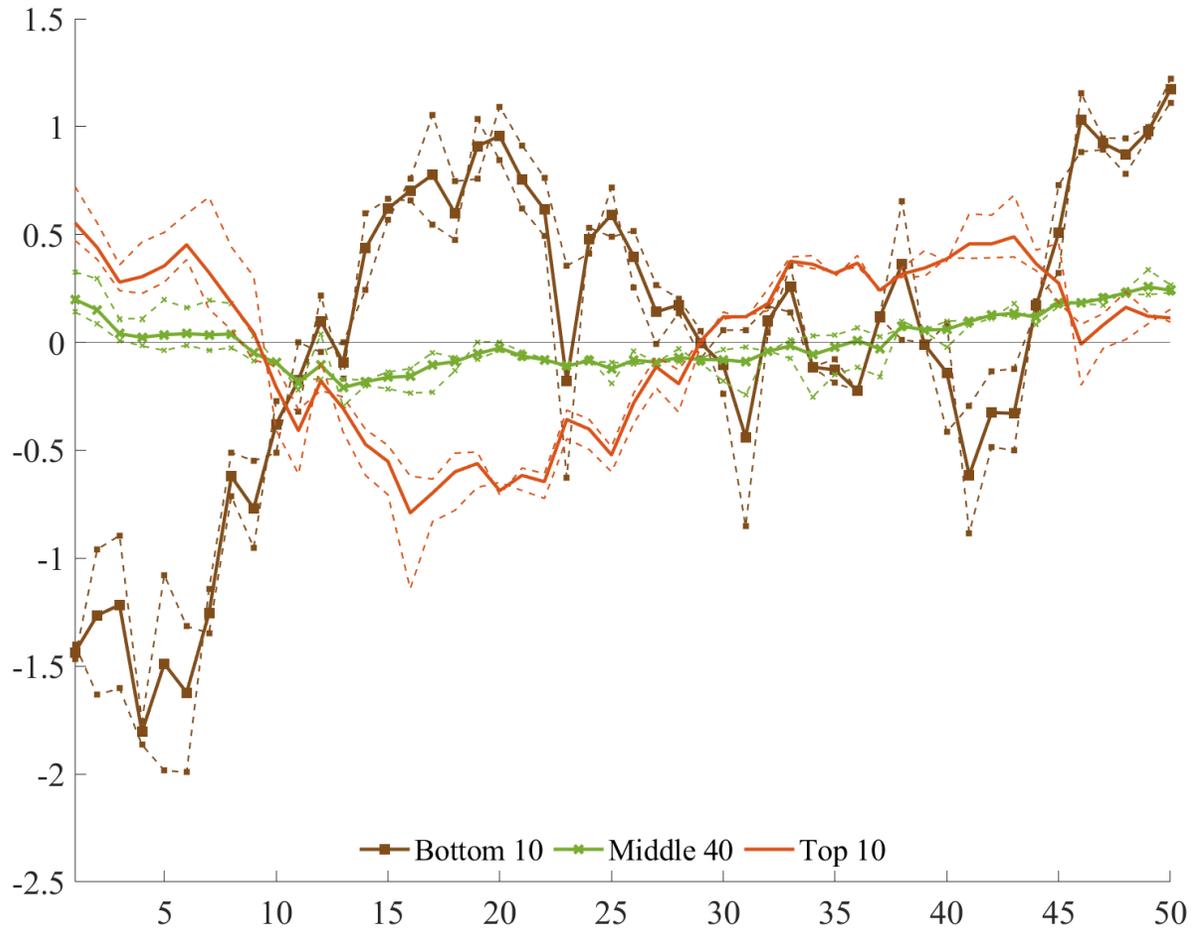


Stylized Fact V: GaR Term Structures

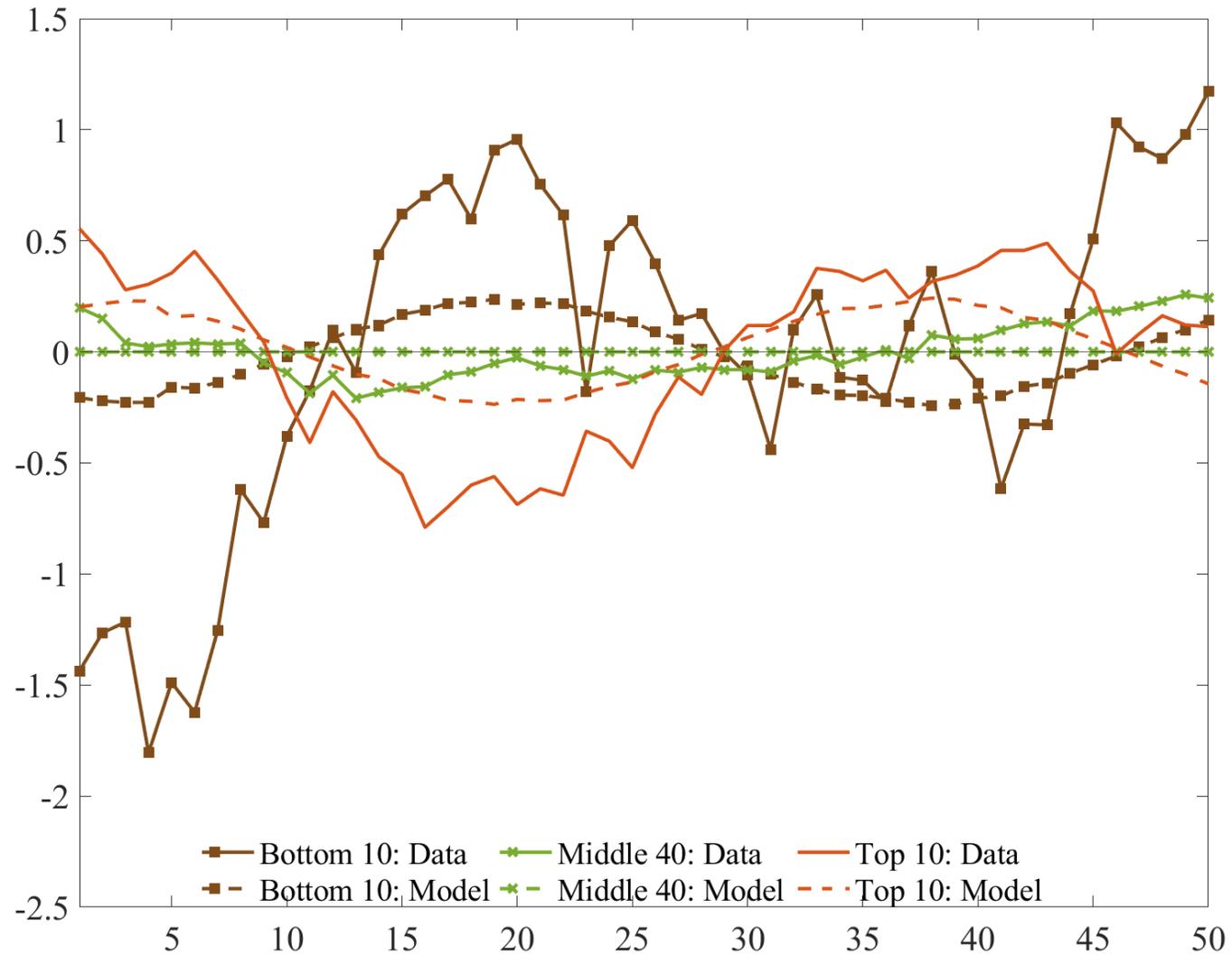




Stylized Fact V: GaR Term Structures (ctd)



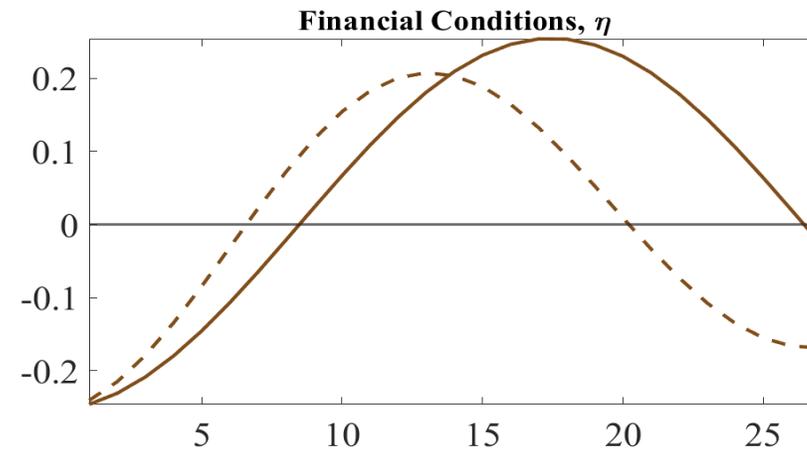
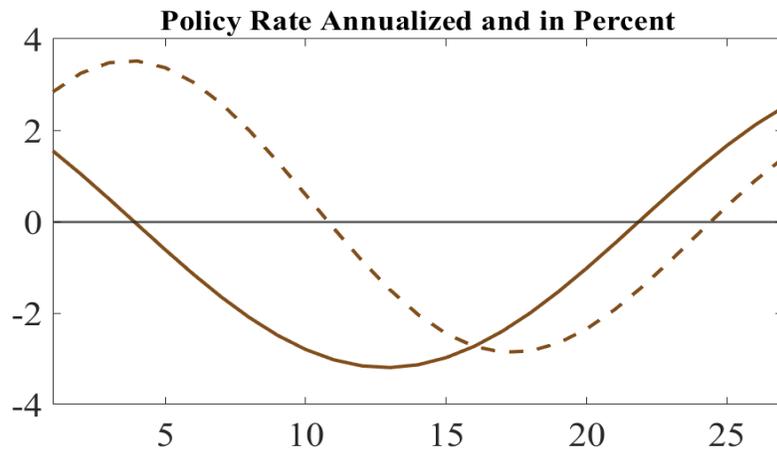
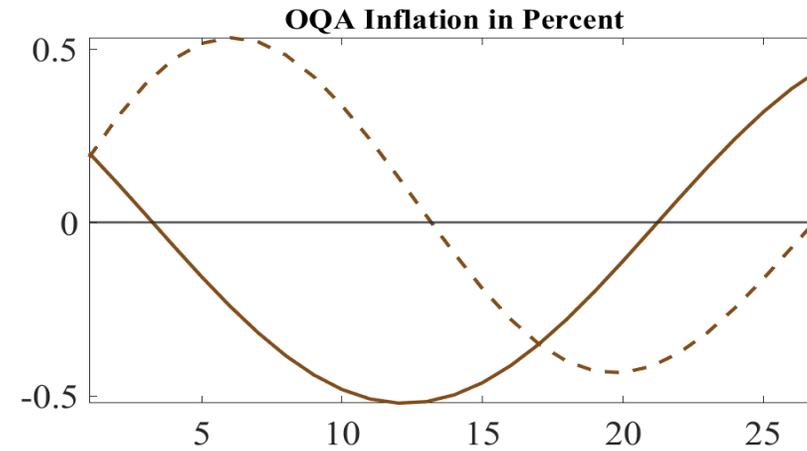
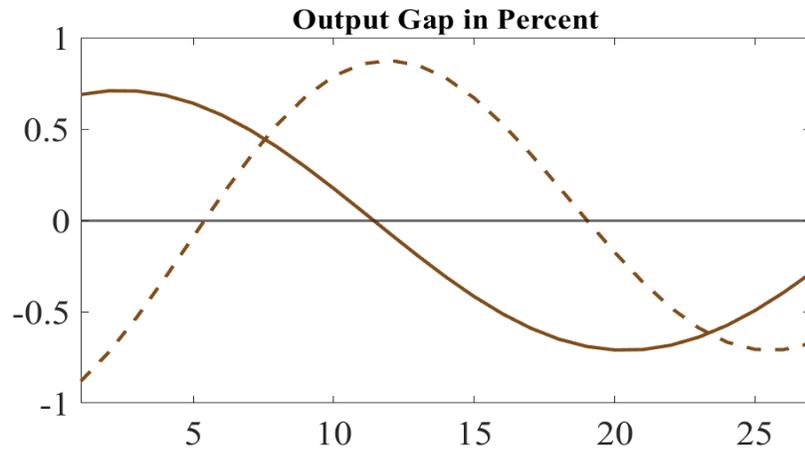
Stylized Fact V: GaR Term Structures (ctd)



Presentation Outline

- Stylized facts
- Towards an NKV model
- Matching the facts
- **Policy Implications**
- Conclusions

Policy experiments

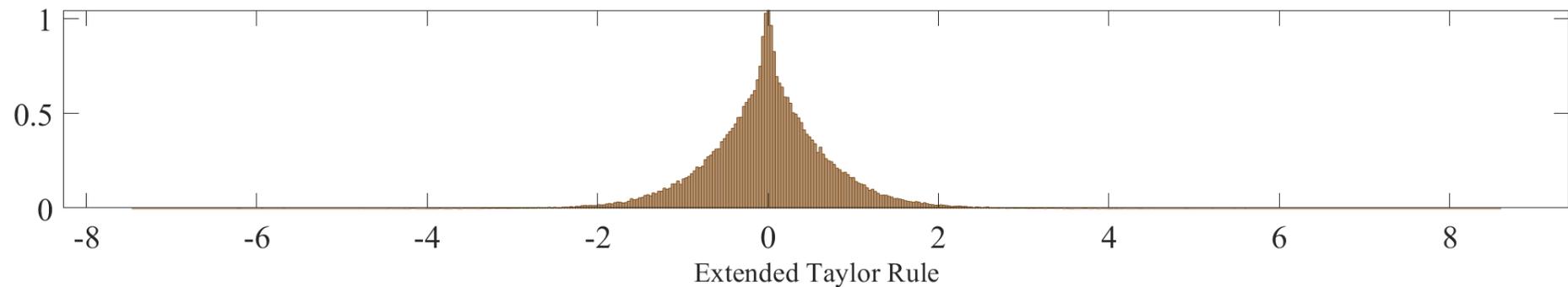
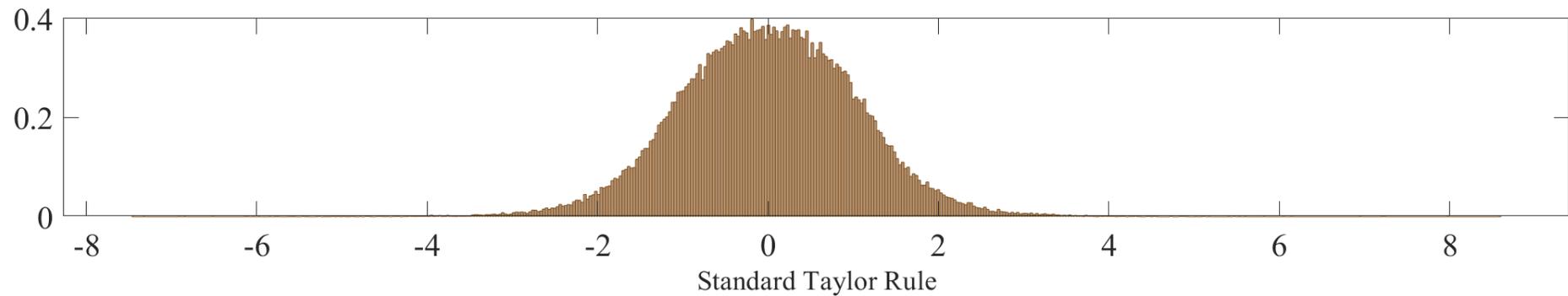
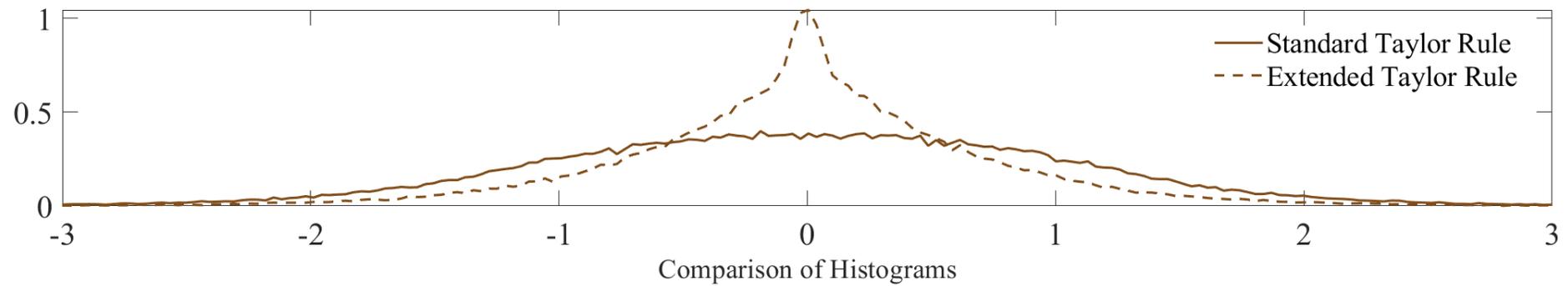


— Standard Taylor Rule - - Extended Taylor Rule

$$i_t = \phi^\pi \pi_t + \phi^y y_t^{gap} - \phi^\eta E_t \eta_{t+1}$$

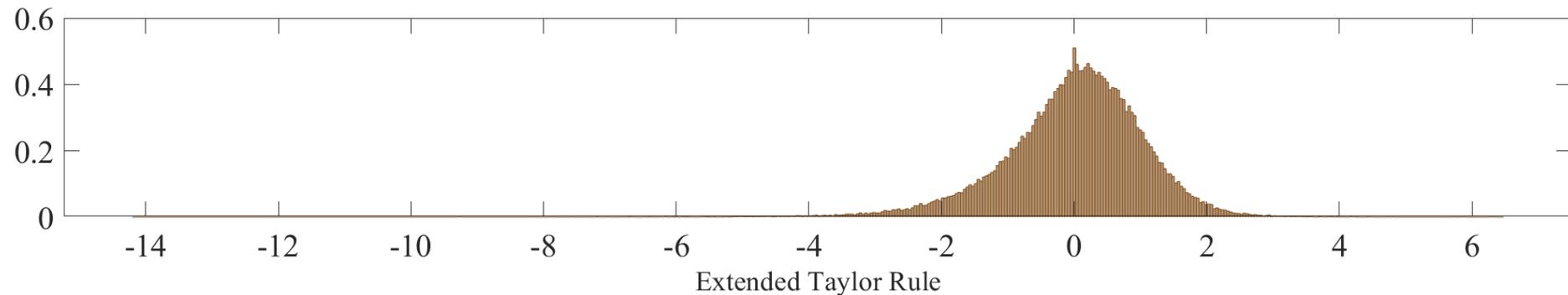
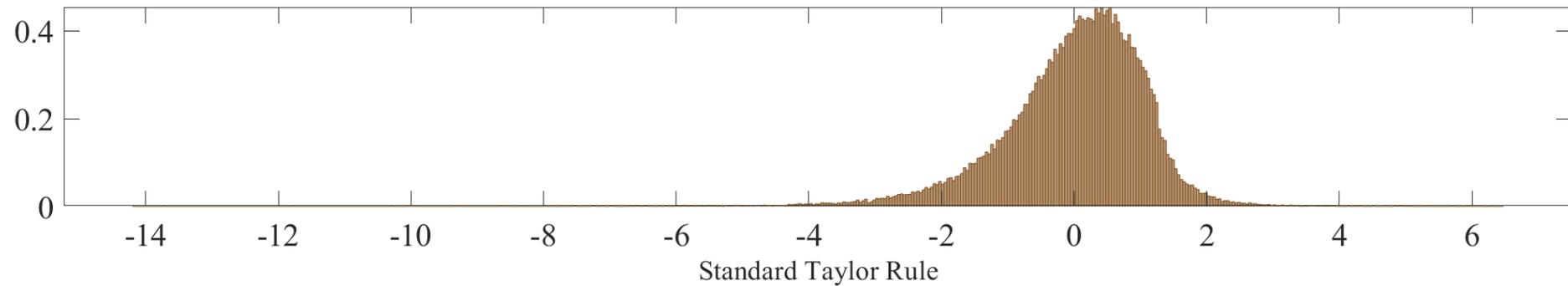
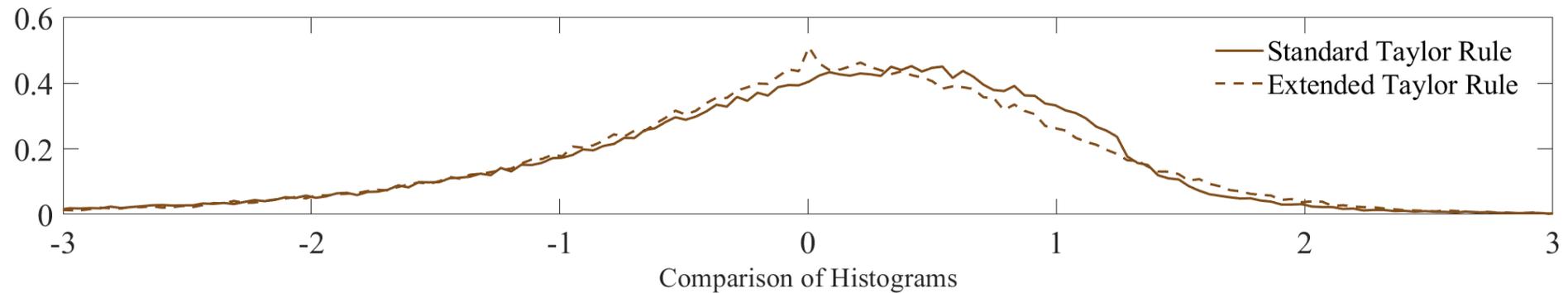


Policy experiments: ergodic output gap distribution



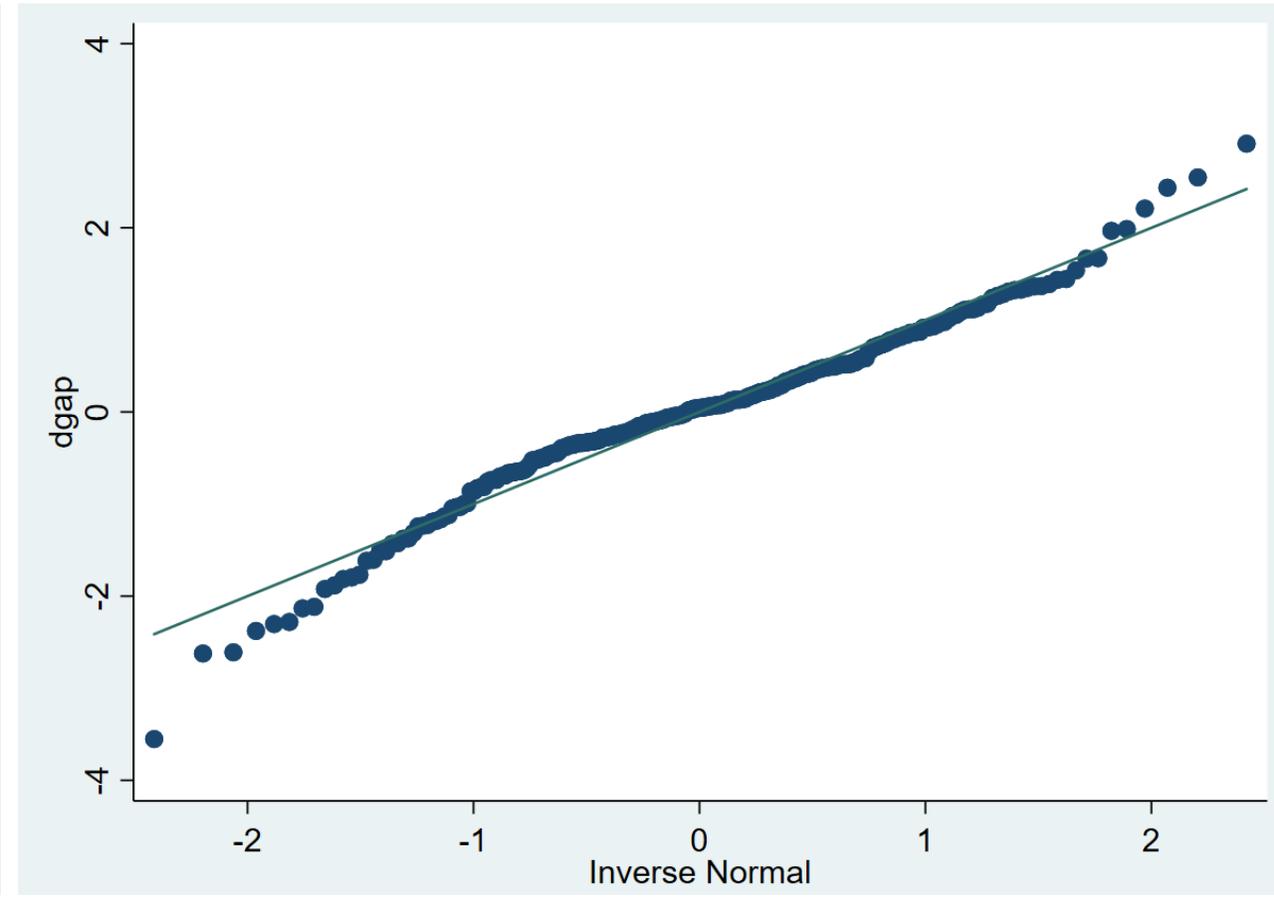
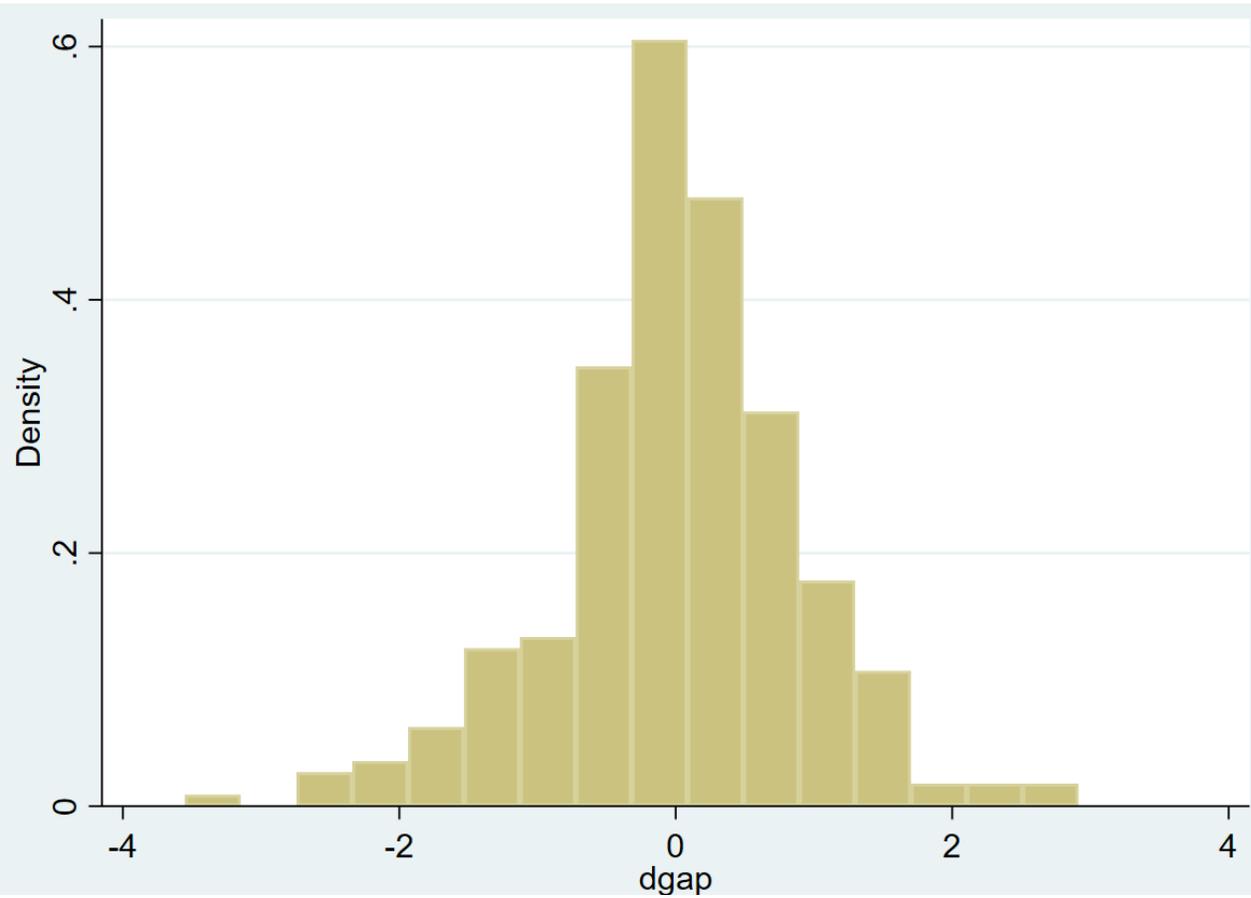


Policy experiments: ergodic Δ output gap distribution





Unconditional US Δ output gap distribution





Adding macroprudential instruments (in progress)

- Can policy eliminate inefficient fluctuations in financial conditions?
- Focus on lags in macroprudential policy implementation
 - Contemporaneously effective

$$\eta_t = \mu_t + (\lambda_\eta)\eta_{t-1} + (\lambda_{\eta\eta})\eta_{t-2} - (\theta_y)y_t^{gap} - (\theta_\eta)E_t y_{t+1}^{gap}$$

- Vs effective with a lag

$$\eta_t = \mu_{t-1} + (\lambda_\eta)\eta_{t-1} + (\lambda_{\eta\eta})\eta_{t-2} - (\theta_y)y_t^{gap} - (\theta_\eta)E_t y_{t+1}^{gap}$$

- Idea: macroprudential policy may be able to stabilize financial conditions either exactly or on average (conditions on monetary policy)



Adding macroprudential instruments (in progress)

- In reality we do not observe constant or random walk prices of risk
- This may be due to additional constraints on effectiveness:
 - Tools do not address all sources of risk
 - Implementations lags
 - Governance may have shortcomings
- In such conditions, narrow mandate for monetary policy may not be optimal

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Summary

- We adapt the New Keynesian model to include “financial vulnerability”
- Tight financial conditions amplify the impact of exogenous shocks adding an extra, inter-temporal dimension to the policy-maker’s problem
- The setup delivers a tight link between endogenous and forward-looking financial conditions and the conditional volatility of the SDF
- The NKV model does a good job of accounting for conditional density dynamics
- In our model “leaning against the wind” can efficiently mitigate future tail-risks to growth, but the benefits may be limited if macroprudential policy is efficient and can be implemented in a timely fashion