Linking Systematic Macroeconomic Movements to Interest Rate and Credit Spread Term Structures

presented by

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based on joint work with

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New York
Overview

• Objective: How/why macroeconomic risks interact with the financial markets:
  – Bond market: term structure of interest rates (with Bill Lu)
  – Credit market: term structure of credit spreads (with Frank Zhang).
  – Stock market: stock returns (with Yi Tang).

• Questions that economists/policy makers/traders want to address:
  – Can macroeconomic movements explain/predict movements in financial security prices?
  – Can financial security prices tell us (more) about the current/future state of the economy?
  – What are the driving forces behind these co-movements?
    — Pricing kernel: Whether and how the financial market prices different types of economic risks differently?
    — Cash flows: How the state of the economy affects the cash flows to a security?
Challenges

First thing that comes to mind: *Regress returns on economic variables.*

- **Which economic variables (CPI, PPI, PCE, GDP, ...)?**
  - Many are available. Each contains information, and (a lot of) noise ...
  - It is inefficient to focus on a few while discarding others (error-in-variable).
  - It is unrealistic to incorporate all (multi-colinearity).
  - Coefficients vary with the set of economic variables you choose.

- **Which bond maturities to choose?**
  - Extrapolating regression results from one maturity to another is dangerous.

- **How to maintain the consistency across different maturities?**
  - The impacts on two nearby maturities cannot be too different.
  - Why different variables affect the term structure differently?

- **Many other specification issues...**
Our take (starting with the linkage to interest rate term structure)

• It is important to extract the systematic states of the economy from many noisy economic releases.
  – Picking one or two indicators is not enough.
  – Adding more to a regression is dangerous.

• It is also important to understand why the term structure responds to different types of economic risk differently.
  – Regression is not enough!
  – Need to link the response functions on the whole term structure to the different market pricing on different sources of economic risks.
We specify a dynamic factor structure, assuming that all macroeconomic releases ($M_t \in \mathbb{R}^N$) are (somewhat) informative about two dynamic factors (real and nominal, $X_t$), but all with noise:

$$dX_t = -\kappa X_t dt + dW_t, \quad M_t = HX_t + e_t.$$  

We extract the two dynamic factors daily from 17 \textit{real-time} macroeconomic releases, using MLE joint with Kalman filter (KF).

The dynamic factors are updated whenever there is an economic release.

- The dynamic factor structure and the Kalman filter help us to extract the dynamic systematic risks of the economy from many noisy macroeconomic indicators that are released at different times and frequencies.

- \textit{It helps us to separate the systematic signal from the noise:}
  - \textit{It solves both the error-in-variable issue and the multi-collinearity issue.}
  - \textit{The measured response function is less contaminated by noise.}
Step II

- Specify *monetary policy instrument rule* and flexible *market prices of economic risks*:

  \[ r(X_t) = a_r + b_r^\top X_t, \quad \gamma(X_t) = \gamma_0 + \gamma_1 X_t. \]

- Use *no-arbitrage* arguments to derive the zero-coupon bond prices at *all* maturities as exponential-affine functions of the dynamic factors:

  \[ P(X_t, \tau) = \exp(-a(\tau) - b(\tau)^\top X_t). \]

  - Instead of obtaining a response function on one or two interest rate series, this framework allows us to obtain the response function on the whole term structure.

  - It traces the origin of the response-function to monetary policy and the market pricing of different sources of economic risks. ⇒ *It helps us to answer the why question.*

⇒ Both steps are important to achieve our objectives.
How to choose macroeconomic variables?

- Common practices in the literature:
  - Cherry pick a few macroeconomic series to proxy for inflation and/or GDP.
  - Stack the data into monthly or quarterly series.

- Our practices:
  - We do not take a stance on which macro series best proxies inflation or GDP. We include all available/relevant releases in our estimation.
  - Our data are dated based on real release time: not ex post revised, nor monthly/quarterly stacked.

- Caveat: Judicious choice of macro series and transformation is still important:
  7 inflation measures; 2 output measures; 1 employment; and some variables on the demand side of the economy...
<table>
<thead>
<tr>
<th>List of Chosen Macro Series</th>
<th>Frequency</th>
<th>Example Release Date</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer Price Index</td>
<td>monthly</td>
<td>April 14, 2004</td>
<td>2.85</td>
<td>1.09</td>
</tr>
<tr>
<td>Core Consumer Price Index</td>
<td>monthly</td>
<td>April 14, 2004</td>
<td>2.93</td>
<td>0.98</td>
</tr>
<tr>
<td>Producer Price Index</td>
<td>monthly</td>
<td>April 22, 2004</td>
<td>1.71</td>
<td>1.94</td>
</tr>
<tr>
<td>Core Producer Price Index</td>
<td>monthly</td>
<td>April 22, 2004</td>
<td>1.36</td>
<td>1.00</td>
</tr>
<tr>
<td>PCE Deflator</td>
<td>monthly</td>
<td>April 30, 2004</td>
<td>2.30</td>
<td>0.96</td>
</tr>
<tr>
<td>Core PCE Deflator</td>
<td>monthly</td>
<td>April 30, 2004</td>
<td>2.26</td>
<td>0.96</td>
</tr>
<tr>
<td>GDP Deflator</td>
<td>quarterly</td>
<td>April 29, 2004</td>
<td>2.08</td>
<td>1.09</td>
</tr>
<tr>
<td>Real GDP</td>
<td>quarterly</td>
<td>April 29, 2004</td>
<td>2.81</td>
<td>1.57</td>
</tr>
<tr>
<td>Industrial Production</td>
<td>monthly</td>
<td>April 16, 2004</td>
<td>1.90</td>
<td>3.00</td>
</tr>
<tr>
<td>Non-farm Payrolls</td>
<td>monthly</td>
<td>April 02, 2004</td>
<td>1.21</td>
<td>1.43</td>
</tr>
<tr>
<td>Durable Goods Order</td>
<td>monthly</td>
<td>April 23, 2004</td>
<td>4.12</td>
<td>5.96</td>
</tr>
<tr>
<td>Durable Goods Order less Trans</td>
<td>monthly</td>
<td>April 23, 2004</td>
<td>3.05</td>
<td>6.20</td>
</tr>
<tr>
<td>Retail Sales</td>
<td>monthly</td>
<td>April 13, 2004</td>
<td>3.44</td>
<td>1.84</td>
</tr>
<tr>
<td>Capacity Utilization Rate</td>
<td>monthly</td>
<td>April 16, 2004</td>
<td>0.81</td>
<td>0.03</td>
</tr>
<tr>
<td>Business Inventories</td>
<td>monthly</td>
<td>April 13, 2004</td>
<td>2.63</td>
<td>2.58</td>
</tr>
<tr>
<td>Consumer Spending</td>
<td>monthly</td>
<td>April 30, 2004</td>
<td>4.92</td>
<td>1.14</td>
</tr>
<tr>
<td>Personal Income</td>
<td>monthly</td>
<td>April 30, 2004</td>
<td>5.13</td>
<td>1.28</td>
</tr>
</tbody>
</table>
Extracting systematic macroeconomic movements

- State propagation and measurement equations:
  
  State: \( X_t = \Phi X_{t-1} + \sqrt{Q} \varepsilon_t \),
  
  Measurement: \( M_t = HX_t + e_t \)

- Ex ante predictions:
  \( \bar{X}_t = \Phi \hat{X}_{t-1} \); \( \bar{V}_t = \Phi \hat{V}_{t-1} \Phi^\top + Q \);
  \( \bar{M}_t = H\bar{X}_t \); \( \bar{A}_t = H\bar{V}_t H^\top + \mathcal{R}^M \).

- Ex post updates (on observed series):
  \( \hat{X}_{t+1} = \bar{X}_{t+1} + K_{t+1}(M_{t+1} - \bar{M}_{t+1}) \);
  \( \hat{V}_{t+1} = \bar{V}_{t+1} - K_{t+1}\bar{A}_{t+1}K_{t+1}^\top, \quad K_{t+1} = \bar{V}_{t+1} H^\top (\bar{A}_{t+1})^{-1} \).

- No updates in a day with no macroeconomic releases: \( \hat{X}_{t+1} = \bar{X}_{t+1}, \hat{V}_{t+1} = \bar{V}_{t+1} \).

- Log likelihood on observed macro series:
  \( l_{t+1}(\Theta) = -\frac{1}{2} \log |\bar{A}_{t+1}| - \frac{1}{2} \left( (M_{t+1} - \bar{M}_{t+1})^\top (\bar{A}_{t+1})^{-1} (M_{t+1} - \bar{M}_{t+1}) \right). \)
<table>
<thead>
<tr>
<th>Factor Loading</th>
<th>$H_1$</th>
<th>$H_2$</th>
<th>FV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>0.579 (8.233)</td>
<td>-0.117 (1.572)</td>
<td>0.739</td>
</tr>
<tr>
<td>Core CPI</td>
<td>0.544 (11.668)</td>
<td>-0.210 (2.868)</td>
<td>0.895</td>
</tr>
<tr>
<td>PPI</td>
<td>0.341 (6.822)</td>
<td>-0.027 (0.508)</td>
<td>0.182</td>
</tr>
<tr>
<td>Core PPI</td>
<td>0.458 (7.337)</td>
<td>-0.173 (2.738)</td>
<td>0.618</td>
</tr>
<tr>
<td>PCE Deflator</td>
<td>0.520 (10.864)</td>
<td>-0.195 (2.820)</td>
<td>0.833</td>
</tr>
<tr>
<td>Core PCE Deflator</td>
<td>0.482 (9.325)</td>
<td>-0.235 (3.450)</td>
<td>0.911</td>
</tr>
<tr>
<td>GDP Deflator</td>
<td>0.485 (9.996)</td>
<td>-0.237 (3.572)</td>
<td>0.898</td>
</tr>
<tr>
<td>Real GDP</td>
<td>0.059 (0.718)</td>
<td>0.387 (3.082)</td>
<td>0.752</td>
</tr>
<tr>
<td>Industrial Production</td>
<td>0.236 (3.015)</td>
<td>0.390 (7.332)</td>
<td>0.660</td>
</tr>
<tr>
<td>Non-farm Payrolls</td>
<td>0.414 (4.737)</td>
<td>0.449 (6.706)</td>
<td>0.968</td>
</tr>
<tr>
<td>Durable Goods Order</td>
<td>0.053 (0.717)</td>
<td>0.220 (5.482)</td>
<td>0.203</td>
</tr>
<tr>
<td>Durable Less Trans</td>
<td>0.117 (1.432)</td>
<td>0.254 (5.289)</td>
<td>0.259</td>
</tr>
<tr>
<td>Retail Sales</td>
<td>-0.062 (0.830)</td>
<td>0.284 (6.467)</td>
<td>0.449</td>
</tr>
<tr>
<td>Capacity Utilization</td>
<td>0.631 (8.618)</td>
<td>0.327 (4.189)</td>
<td>0.829</td>
</tr>
<tr>
<td>Business Inventories</td>
<td>0.387 (5.368)</td>
<td>0.323 (5.473)</td>
<td>0.577</td>
</tr>
<tr>
<td>Consumer Spending</td>
<td>0.484 (6.486)</td>
<td>0.111 (1.681)</td>
<td>0.356</td>
</tr>
<tr>
<td>Personal Income</td>
<td>0.601 (7.717)</td>
<td>0.333 (3.917)</td>
<td>0.809</td>
</tr>
</tbody>
</table>
Inflation has been coming down. The sample spans two recessions...
Dynamic term structure model

- A dynamic term structure model links three key components into one framework:
  1. Factor dynamics ($X_t$): $dX_t = -\kappa X_t dt + dW_t$.
  2. Market price of risk: $\gamma(X_t) = \gamma_0 + \gamma_1 X_t$ (time varying risk premium).
  3. Monetary policy instrument rule: $r_t = a_r + b_r^\top X_t$.

- and uses no arbitrage arguments to derive the whole term structure as a function of the dynamic factors:

  $$y(X_t, \tau) = \left[\frac{a(\tau)}{\tau}\right] + \left[\frac{b(\tau)}{\tau}\right]^\top X_t.$$  

  - Think of $b(\tau)/\tau$ as the instantaneous impulse-response function: Given a unit shock on the systematic state of the economy $X_t$, how will the yield curve respond?

  - Impulse-response function: $b(\tau) = \left(I - e^{-(\kappa + \gamma_1)\tau}\right) (\kappa^\top + \gamma_1^\top)^{-1} b_r$

  ⇔ Economic risk dynamics + Market prices of economic risks + Policy rule
Estimating market price and policy rule
from the yield curve response

- State propagation: \( X_t = \Phi X_{t-1} + \sqrt{Q} \epsilon_t \)

- Measurement equations:
  \[ y_t = \begin{bmatrix} \text{LIBOR}(X_t, i) \\ \text{SWAP}(X_t, j) \end{bmatrix} + e_t, \quad \text{cov}(e_t) = R^r, \quad i = 1, 2, 3, 6, 12 \text{ months} \]
  \[ j = 2, 3, 5, 7, 10 \text{ years}. \]

- Extended KF (to deal with slight non-linearity in the measurement equations):
  \[ \overline{X}_t = \Phi \hat{X}_{t-1}; \quad \overline{V}_t = \Phi \hat{V}_{t-1} \Phi^\top + Q; \]
  \[ \overline{y}_t = g(\overline{X}_t; \Theta), \quad \overline{A}_t = G(\overline{X}_t; \Theta) \overline{V}_t G(\overline{X}_t; \Theta)^\top + R^r. \]

- Ex post updates:
  \[ \hat{X}_{t+1} = \hat{X}_{t+1}^m; \quad \hat{V}_{t+1} = \hat{V}_{t+1}^m. \]

- MLE to estimate the instrument rule (monetary policy) and market prices of economic risks.
**Performance**

FV (Daily Forecasted variance) = 1 - Var(forecasting error)/Var(interest rates)

<table>
<thead>
<tr>
<th>LIBOR with maturities in months:</th>
<th>Swap rates with maturities in years:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>1</td>
</tr>
<tr>
<td>FV</td>
<td>0.783</td>
</tr>
</tbody>
</table>

*Pure macroeconomic risks explain 70-80% of the daily variation on the term structure, without artificial boosting from circular references:*

- Add short rate as an additional factor ...
- Add additional latent variables ...
Factor dynamics and market price of economic risks

$\kappa$

$\kappa^Q$

$\kappa^Q\theta^Q$

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.252</td>
<td>0</td>
<td>0.0003</td>
</tr>
<tr>
<td>(0.98)</td>
<td>(20.0)</td>
<td>(20.0)</td>
</tr>
<tr>
<td>0.866</td>
<td>0.252</td>
<td>0.836</td>
</tr>
<tr>
<td>(3.05)</td>
<td>(1.52)</td>
<td>(20.0)</td>
</tr>
</tbody>
</table>

- Inflation predicts negatively on real output growth (the off-diagonal term of $\kappa$).

- Time-varying market prices of economic risks: $\gamma(X_t) = \gamma_0 + \gamma_1 X_t$
  - $\gamma_0 = \kappa \theta - \kappa^Q \theta^Q = [-0.308, -1.336]^\top$ is negative for both factors.
  - $\gamma_1 = \kappa^Q - \kappa = \begin{bmatrix} -0.252 & 0 \\ -0.030 & 0.412 \end{bmatrix}$: negative for inflation, positive for real growth.

$\Rightarrow$ The risk premium becomes more negative under adverse economic environments ([1] high inflation and [2] low real growth).
• Economists directly estimate the relation between the short rate and the (expected) inflation and output gap. The Taylor rule is one example.

• We identify the instrument rule based on the response of the whole yield curve:

\[ r_t = a_r + b_r^\top X_t = 0.045 + \begin{bmatrix} 0.015 \\ 0.005 \end{bmatrix}^\top X_t \]

• Converting \( X \) to inflation and real growth, we have a Taylor-rule analog:

\[ r_t = 4.5\% + 2.19(\pi_t - \bar{\pi}) + 1.22(g_t - \bar{g}) \]

• But importantly, the short rate responds to all economic indicators that have more or less information about the systematic state of the economy, not just to CPI or GDP:

\[ r_t = a_r + b_r^\top (H^\top H)^{-1} H^\top M_t. \]
The term structure response to macroeconomic releases

No-arbitrage arguments combine (1) economic risk dynamics, (2) market prices of the economic risks, and (3) the instrument rule to generate the response of the whole term structure to all 17 macro variables:

\[ y(M_t, \tau) = \left[ \frac{a(\tau)}{\tau} \right] + \left[ \frac{b(\tau)}{\tau} \right]^\top (H^\top H)^{-1} H^\top M_t, \]

Inflation variables (parallel shift)  
Output variables (slope effect)
Linking the term structure to the *current* state of the economy

- A steep term structure is often observed under “bad” economic conditions when the real growth is low but inflation is high.
- High real growth and low inflation risk can lead to downward sloping yield curves.
- Why so? — It is related to how different sources of economic risks are priced.
  - Upward sloping mean yield curve $\iff$ negative market price on interest rate risk.
  - Here we decompose the interest rate risk into nominal and real economic risks and show that they are priced differently ($\gamma_1$). — The market price becomes more negative when inflation is high, but less negative when real growth is high.
  - Rising inflation raises not only the short rate, but also long rates by making the risk premium more negative. (parallel shift)
  - Rising real growth raises the short rate, but can actually lower the long rate by making the risk premium less negative. (slope effect)
The Greenspan conundrum: Since 2004, long-term rates have remained low despite Fed raising short rates. ⇒ The inflation risk is low despite high real growth.
• It is important to understand what is driving the short rate movements before we explain how they influence the term structure.

• Real and nominal shocks can have similar impacts on the short rate, but different impacts on the term structure.

• Observed lead-lag effects can also be traced to the interaction between factor dynamics and market pricing.
From Interest Rates to Credit Spreads

• Cash flow effects: The probability of corporate default and the loss from such events depend crucially on the state of the macroeconomy and the financial market.
  – We need to control cash flow effects across different bonds when we analyze the pricing effect.
  – We use the credit rating as a cash flow control, and aggregate credit spreads within each rating class.

• Given the optionality effect (Merton (74)), second moments may matter more on credit spreads than on interest rates.
  – In addition to inflation and real growth, we extract an additional financial market volatility factor from stock index option prices/implied volatilities.

• Identification twists:
  – To enhance interpretation, we put more constraints on the loading coefficients so that each factor has a clearer economic interpretation.
<table>
<thead>
<tr>
<th>Series</th>
<th>$H_1$</th>
<th>$H_2$</th>
<th>$H_3$</th>
<th>PV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inflation</td>
<td>Real Growth</td>
<td>Volatility</td>
<td></td>
</tr>
<tr>
<td>CPI</td>
<td>0.439 (6.45)</td>
<td>—</td>
<td>—</td>
<td>0.891</td>
</tr>
<tr>
<td>Core CPI</td>
<td>0.415 (4.06)</td>
<td>—</td>
<td>—</td>
<td>0.841</td>
</tr>
<tr>
<td>PPI</td>
<td>0.316 (2.92)</td>
<td>—</td>
<td>—</td>
<td>0.424</td>
</tr>
<tr>
<td>Core PPI</td>
<td>0.403 (7.45)</td>
<td>—</td>
<td>—</td>
<td>0.767</td>
</tr>
<tr>
<td>PCE Deflator</td>
<td>0.454 (8.47)</td>
<td>—</td>
<td>—</td>
<td>0.949</td>
</tr>
<tr>
<td>Core PCE Deflator</td>
<td>0.424 (4.44)</td>
<td>—</td>
<td>—</td>
<td>0.857</td>
</tr>
<tr>
<td>GDP deflator</td>
<td>0.437 (7.81)</td>
<td>—</td>
<td>—</td>
<td>0.929</td>
</tr>
<tr>
<td>Real GDP</td>
<td>—</td>
<td>—</td>
<td>0.277 (5.67)</td>
<td>0.571</td>
</tr>
<tr>
<td>Industrial Production</td>
<td>—</td>
<td>—</td>
<td>0.299 (8.43)</td>
<td>0.641</td>
</tr>
<tr>
<td>Non-farm Payrolls</td>
<td>0.169 (4.50)</td>
<td>0.379 (10.7)</td>
<td>—</td>
<td>0.988</td>
</tr>
<tr>
<td>Real PCE</td>
<td>—</td>
<td>—</td>
<td>0.228 (6.89)</td>
<td>0.449</td>
</tr>
<tr>
<td>VXO</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.391 (14.0)</td>
</tr>
<tr>
<td>VIX</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.379 (13.6)</td>
</tr>
</tbody>
</table>
No-Arbitrage Dynamic Term Structure Model

- Factor dynamics: $dX = -\kappa X_t + dW$.
- Market price of factor risks: $\gamma(X_t) = \gamma_0 + \gamma_1 X_t$.
- Instantaneous short rate function (instrument rule): $r_t = r(X_t) + \varepsilon_t^r$, $r(X_t) = a_r + b_r^\top X_t$.
- Instantaneous credit spread function at a fixed industry/credit rating class $i$ $s^i_t = s^i(X_t) + \varepsilon_t^i$, $s^i(X_t) = a_i + b_i^\top X_t$.
- Term structure of defautable zero-coupon bonds:

$$D^i(t, \tau) = \mathbb{E}^Q \left[ \exp \left( - \int_t^{t+\tau} \left( r_u + s^i_u \right) du \right) \mid \mathcal{F}_t \right].$$

- Default free if $s = 0$.
  - Co-movements between interest rates and credit spreads are induced by their loading on the economic factors.
No-Arbitrage Links

Economic Factors and Interest Rates and Credit Spreads Term Structure

- Continuously compounded spot rates on default-free zero-coupon bonds:
  \[ R(t, \tau) = \left[ \frac{a(\tau)}{\tau} \right] + \left[ \frac{b(\tau)}{\tau} \right]^\top X_t + e(t, \tau). \]

- Continuously compounded spot rates on defaultable zero-coupon bonds:
  \[ R_i(t, \tau) = \left[ \frac{a_i(\tau)}{\tau} \right] + \left[ \frac{b_i(\tau)}{\tau} \right]^\top X_t + e_{ir}(t, \tau). \]

- Term structure of credit spreads:
  \[ S_i(t, \tau) \equiv R_i(t, \tau) - R(t, \tau) = \left[ \frac{a_i(\tau) - a(\tau)}{\tau} \right] + \left[ \frac{b_i(\tau) - b(\tau)}{\tau} \right]^\top X_t + e_i(t, \tau), \]

---

\[ [a(\tau), b(\tau), a_i(\tau), b_i(\tau)] \] are functions of the model parameters that control factor dynamics, market prices, and short rate and credit spread functions.
Time series of economic factors, interest rates, credit spreads
Same as before. Small positive effects from volatility.
Inflation: positive... Output: negative, especially at lower ratings ... Volatility: Positive.
Summary findings

- Inflation increases both the interest rate level and the credit spreads, at both short and long maturities.
- Real output growth increases the Treasury yield, but narrows the credit spread, especially at short maturities.
- Volatility has small effects on Treasury yields, but large, positive, and persistent impacts on credit spreads.
- The relation between short rate and the Treasury term structure depends on the underlying economic driving forces.
- The relation between interest rates and credit spreads also depends on the underlying economic driving forces.
  - The negative correlation documented by Duffee (98) between short rate and credit spreads is driven by the opposite effects from real output growth.
  - The correlation can be positive if the variations are driven by inflation/volatility.
Concluding remarks

• It is important to understand how different economic forces impact differently the term structure of interest rates and credit spreads.

• It is also important to gauge the current state of the economy exploiting information from the Treasury and corporate bond markets.

• Neither is easy to do because of issues on
  – Variable selection.
  – Noise reduction.
  – Internal consistency.

• We propose a dynamic factor approach that can
  – Extract information/suppress noise from a wide array of economic variables.
  – Achieve international consistency via no-arbitrage arguments.
  – Link the term structure impacts to the underlying factor dynamics and market prices.
Future/ongoing works

- Twists on economic risk dynamics:
  - Add random-walk type stochastic trend to inflation and output.
  - More general (two-way) interactions between inflation and output.
  - Account for potential serial dependence on the measurement errors.

- Twists on monetary policy rule:
  - Add lagged short rates, latent variables?

- The relation between economic risks and returns on other financial securities (stocks, currencies).

- More fundamental questions:
  - Given supply and demand curves, how to optimize the policy rule?
  - How does the policy rule affect the nominal and real economic risk dynamics?
  - Why inflation risk and real growth risk are priced? Why are they priced differently?