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Nonlinearities, Smoothing, and Countercyclical Monetary Policy

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- The following presentation does not reflect the official opinions of the Federal Reserve Bank of St. Louis or the Federal Reserve System.
Empirical Models of Monetary Policy

- Monetary policy is a major instrument for countercyclical policy
- Much of the literature assessing the efficacy of monetary policy takes place in linear (or linearized) models
- In these models, a decrease in the fed funds rate when growth is negative has the mirror effect of an increase when growth is positive
- Responses of macro aggregates are scaled by the shock magnitudes—a 50-basis-point increase has twice the effect of a 25-basis-point increase
Nonlinear models (e.g., Markov-switching models) allow for the possibility of state-dependent dynamics [Hamilton (1989)].

This has led some to explore the effects of countercyclical policy in models with embedded cycles [e.g., Sims and Zha (2006), Ravn and Sola (2004), Owyang and Ramey (2004), Weise (1999)].

Modeling approaches include: discrete Markov-switching (MS) with exogenous states, MS with endogenous states, threshold models, and smooth-transition models [Weise (1999)].
Nonlinearities and Countercyclical Policy

- One criticism of the canonical MS model (e.g., the MS-VAR) is that the macro variables do not influence the state of the economy
  - The probability of transitioning between regimes is constant across time
- Lowering the fed funds rate when the economy is in recession has no effect over how long the economy stays in recession
- The resulting model is quasi-linear, with the same scaling and sign symmetry effects present in purely linear models
Issues to Explore

- Do the responses to monetary policy vary across business cycle phases?
- How do changes in monetary policy affect the probability of beginning or ending recessions?
- Is the response to countercyclical monetary policy dependent on the size (and sign) of the innovation?
- If so, does it make sense for the Fed to smooth interest rates?
- How does smoothing interest rates affect sentiment and expectations of future activity?
Sentiment within the Monetary Policy Framework

- Previous studies have shown that uncertainty and expectations may also influence the efficacy of countercyclical policy [e.g. Galvao and Owyang (2014)]
- Monetary models, and policy rules, also tend to be forward-looking
- Smoothing in the (empirical) Taylor rule is often justified by the Fed’s desire to manage expectations and overall confidence [e.g., Woodford (1999)]
- We construct a latent factor to summarize a small panel of variables meant to proxy overall sentiment and expectations of future economic dynamics
Our Approach

- Propose a model in which the macro variables in the VAR affect the state of the economy
  - Self-exciting time-varying transition probability VAR
- Changes in the state of the economy affect the dynamics
  - Countercyclical policy can affect the variables within state as well as affecting the latent state
- Include a factor meant to represent consumer and producer sentiment
- Compute impulse responses that take into account the possible changes in regime
What We Find

- Empirically relevant differences between the macroeconomic responses to contractionary and expansionary policy shocks, depending on the underlying state of the economy at the time of the shock
- Significant differences between gradual policy changes and one-time, large policy shocks
Empirical policy analysis is often conducted in linear models (i.e., VARs or linearized DSGE models that are approximated by VARs)

- We start with the baseline linear VAR to fix notation
- We then consider both a standard Markov-switching VAR and a time-varying probability VAR
- The time variation in the transition probabilities is driven by output growth, a variable in the VAR
- We include a latent factor in the TVTP-VAR meant to proxy sentiment
The Reduced-Form VAR(P)

The canonical VAR($P$) can be expressed in the reduced form as

$$y_t = B(L) y_{t-1} + \varepsilon_t$$

- $y_t$ represent the $N \times 1$ vector of period $-t$ variables of interest.
- $\varepsilon_t \sim N(0, \Omega)$ is the reduced-form innovation.
- $\Omega$ is left unrestricted.
- Any constant and trends are suppressed.
The Reduced-Form VAR(P) with Regime-Switching

Suppose we believe that the model dynamics change over the cycle:

\[ y_t = [1 - S_t] B_0 (L) y_{t-1} + S_t B_1 (L) y_{t-1} + \varepsilon_t, \]

- \( S_t = \{0, 1\} \) follows a irreducible first-order Markov process with time-varying transition probabilities
- \( p_{ji} = \Pr [S_t = j \mid S_{t-1} = i], \ i \in \{0, 1\} \)
- \( \varepsilon_t \sim N(0, \Omega_t) \) with regime-dependent covariance matrix
- \( \Omega_t = [1 - S_t] \Omega_0 + S_t \Omega_1 \)
Time-Varying Transition Probabilities

Suppose that the transitions depend on lags of a variable, $z_{t-d}$

$$p_{ji} = \Pr [S_t = j | S_{t-1} = i] = \frac{\exp (\gamma_{ji} + \gamma_{ji} z_{t-d})}{\sum_m \exp (\gamma_{jm} + \gamma_{jm} z_{t-d})}$$

- Defined for each of the regimes, $i \in \{0, 1\}$, with $\sum_m p_{mi} = 1$ for all $i$
- If, as we will hypothesize, $z$ is a transformation of variables in the vector $Y$, the system is deemed self-exciting [see, Potter (1995)]
- Shocks to the policy variable can affect the macro variables which, in turn, affect the state of the economy
Modeling Sentiment

- Include a factor $F_t$ to proxy overall sentiment
- Define $Y_t = [F_t, y_t']'$; the VAR can be rewritten as:

$$Y_t = [1 - S_t] B_0 (L) Y_{t-1} + S_t B_1 (L) Y_{t-1} + \varepsilon_t$$

- $F_t$ summarizes the information in a panel of $M$ series, $X_t$:

$$X_{mt} = \lambda_m F_t + \zeta_{mt}, \text{ for } m = 1, ..., M$$

- Assume that the factor provides the sole source of correlation:

$$\zeta_{mt} \text{ iid } \mathcal{N} (0, \sigma_m^2)$$
Identification of Shocks and Regimes

- Impose a within-regime causal ordering and use Cholesky-Decomposition
  - Sentiment factor ordered first and Fed funds rate ordered after output and inflation in the VAR
  - Allows the macro variables and the policy rate to respond contemporaneously to shocks to overall sentiment and consumer/producer confidence

- Need additional assumptions to identify (interpret) the regimes
  - Restrict $\gamma_{10}$ coefficient of the TVTP: An increase in output growth lowers the probability of switching from expansion into recession
Data

- Monthly VAR(12) with the factor, the Coincident Economic Index, PCE inflation, and the Fed Funds rate.
- Sample period spans 1960:1 to 2008:12, truncated to avoid issues with the ZLB.
- Augment the model with the factor summarizing an unbalanced panel of sentiment data:
  - Conference Board Consumer Confidence Index, the University of Michigan Consumer Sentiment Index, the OECD Consumer Confidence Index, and the Institute for Supply Management Purchasing Managers Index.
Estimation

- Model parameters are estimated with the Gibbs sampler
- Sampler simulates draws from the full joint distribution by drawing from each parameter block’s conditional distribution
- Employ five blocks
  - VAR parameters (Normal – Inverse Wishart)
  - Factor loadings and variances (Normal – Inverse Gamma)
  - Transition probability parameters (Normal)
  - Regimes (Hamilton Filter)
  - Factors (Kalman Filter)
Posterior Regime Process
Expectations Factor

Posterior Mean of Sentiment Factor

Year

Sentiment Factor

Expectations Factor: MS-VAR vs. Linear VAR

Posterior Mean of Sentiment Factor

MS-TVTP-FAVAR
Linear-FAVAR
Regime-Dependent Impulse Responses

- In the standard linear model, the response to a shock is invariant to the history of the shock and the future shocks.
- In MS-VARs with constant transition probabilities, the model is conditionally linear based on the regime.
- Ehrmann, Ellison, and Valla (2003) established the notion of a regime-dependent response:
  - Responses for each regime are computed assuming that the regime does not change after the incidence of the shock.
Regime-Dependent Impulse Responses

Regime-Dependent IRFs of 4-Variable FAVAR(12): 25 bp Shock to FFR

- Sent Factor
- ZCOPIN Growth
- PCE Inf
- FFR

Months

0 4 8 12 16 20 24
Generalized Impulse Responses

- As an alternative to regime-dependent responses, Krolzig (2006) argued that one should take into account the probability of changing regime.
- Impulse responses can be thought of as the difference between two counterfactual expected paths.

\[
IR_i(h) = E_t \left[ Y_{t+h} | S_t = i, u_t = \delta, \{u_{t+l}\}_{l=1}^{h} \right] - E_t \left[ Y_{t+h} | S_t = i, u_t = 0, \{u_{t+l}\}_{l=1}^{h} \right]
\]

- Compute separate responses for each path beginning regime \(i\).
- To obtain these expectations, integrate over the history of periods with realization \(S_t = i\).
- Integrate over 100 monte carlo simulated future paths from period \(t\).
Generalized Impulse Responses

Sentiment

Contractionary Shock to FFR in Expansion

Expansionary Shock to FFR in Recession
Generalized Impulse Responses

ZCOIN Growth

Contractionary Shock to FFR in Expansion

Expansionary Shock to FFR in Recession
Generalized Impulse Responses: Output Growth in Recession
Generalized Impulse Responses: Inflation in Recession

Generalized IRFs of 4-Variable FAVAR(12) : -100 bp and -25 bp Shock to FFR in Recession

- Sent Factor
- ZCOIN Growth
- PCE Inf
- FFR

Inflation > 3%
Inflation < 3%
Empirical evidence on Taylor rules and reaction functions suggests that the Fed smooths interest rates.

Final experiment: consider the effect of interest rate smoothing in monetary policy.

For example, the Fed may anticipate that it will reduce the funds rate, say, 100 basis points in the face of a recession.

The Fed can drop the funds rate 100 basis points in one move or make a series of smaller moves.

In most cases, the Fed has opted for a smooth approach to interest rate changes.

As shown earlier, these two policies are not equivalent in a nonlinear model.
The Experiment

- Can compute the effect of compound (smoothed) policy in the GIRF framework
- Compute the path following the compound shock:
  \[ \{ u_{t+p-1} = -25 \}_{p=1}^4 \]
  \[ Y_{t+h} \mid Y_{t-1}, \Theta, S_t = 1, \{ u_{t+p-1} = -25 \}_{p=1}^4, \{ u_{t+l} \}_{l=1}^h \]
- Compare this to the path following a single shock: \( u_t = -100 \)
  \[ Y_{t+h} \mid Y_{t-1}, \Theta, S_t = 1, u_t = -100, \{ u_{t+l} \}_{l=1}^h \]
- The difference between these paths shows the effect of smoothing countercyclical policy during the recession
Responses to Compound Shocks vs. Single Large Shock
Empirically relevant differences between the macroeconomic responses to contractionary and expansionary policy shocks, depending on the underlying state of the economy.

Framework opens up the possibility for many policy experiments:
- Interest-rate smoothing
- Managing sentiment and expectations with policy
- Effects of policy in specific economic climates (inflation $> 3\%$ and output growth low, consistent periods of negative output growth, etc.)
Inference on the effect of shocks is derived from the structural form of the VAR:

$$A^{-1} y_t = A^{-1} B(L) y_{t-1} + u_t,$$

- $u_t \sim N(0, \Sigma)$ are the structural shocks
- $A^{-1}$ which represents the contemporaneous effects of the structural shocks
- $AA' = \Omega$
- $\Sigma$ is diagonal and collects the variances of the structural shocks