Nonlinearities, Smoothing, and Countercyclical Monetary Policy

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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 of Monetary Policy

- 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

Model Overview

- 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
- $\varepsilon_t \sim N(\mathbf{0}, \Omega)$ is the reduced-form innovation
- Ω 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
- $p_{ji} = \Pr[S_t = j | S_{t-1} = i], i \in \{0, 1\}$
- $\varepsilon_t \sim N(0, \Omega_t)$ 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}

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

- 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, $\mathbf{X}_t$:

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

- Assume that the factor provides the sole source of correlation:
 $\varsigma_{mt} \stackrel{iid}{\sim} N(0, \sigma_m^2)$

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 γ_{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

Expectations Factor: MS-VAR vs. Linear VAR

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

Generalized Impulse Responses

- As an alternative to regime-dependent responses, Krolzig (2006) argued that one should take into account the probability of changing regime
- Koop, Pesaran, and Potter (1998) developed the idea of generalized impulse responses
- Impulse responses can be thought of as the difference between two counterfactual expected paths

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

- 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

Generalized Impulse Responses: Output Growth in Recession

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

The Effect of Interest Rate Smoothing

- 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:
 $\{u_{t+p-1} = -25\}_{p=1}^4$

$$Y_{t+h} | \mathbf{Y}_{t-1}, \Theta, S_t = 1, \{u_{t+p-1} = -25\}_{p=1}^4, \{u_{t+l}\}_{l=1}^h$$

- Compare this to the path following a single shock: $u_t = -100$

$$Y_{t+h} | \mathbf{Y}_{t-1}, \Theta, S_t = 1, u_t = -100, \{u_{t+l}\}_{l=1}^h$$

- The difference between these paths shows the effect of smoothing countercyclical policy during the recession

Responses to Compound Shocks vs. Single Large Shock

Final Thoughts

- 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.)

The Structural-Form VAR

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
- $AA' = \Omega$
- Σ is diagonal and collects the variances of the structural shocks