Uncertainty and Monetary Policy in the US: A Journey into Non-Linear Territory

Giovanni Pellegrino

Aarhus University

XXI Annual Inflation Targeting Conference
Banco Central do Brasil, Rio de Janeiro – May 23, 2019
Research questions

- **Q1:** Does uncertainty influence the effectiveness of monetary policy shocks? How much?
  - U.S. facts during the Great Recession: High uncertainty, drop in the policy rate, low output growth
  - theoretical explanations: real-options caution effects (Bloom et al., 2018), uncertainty-dependent price-setting (Vavra, 2014; Baley and Blanco, 2019)
  - relevant for policy makers to design policies

- **Q2:** Does the endogeneity of uncertainty matter for the monetary transmission mechanism? How?
  - endogenous uncertainty...: Bachmann and Moscarini (2012), Ludvigson et al. (2018), ...
  - ...also to m.p. shocks: Bekaert et al. (2013)

2 ⇔ 1 ⟷ Need of a general framework
Why endogenous uncertainty?

→ to not disregard two unexplored transmission channels:

1. Endogenous uncertainty mitigation, Bernanke’s channel
   - "[T]he reduction in risk associated with an easing of monetary policy and the resulting reduction in precautionary saving may amplify the short-run impact of policy […]. Likewise, reduced risk and volatility may provide an extra kick to capital expenditure in the short run […]."
     - Governor Ben S. Bernanke, Remarks at the LSE Public Lecture, Oct. 9, 2003
   - Possibly state-dependent in a nonlinear world

2. Uncertainty mean reversion channel
   - "When uncertainty is mean reverting, high current values have a lower impact on expected long-run [uncertainty] values than if uncertainty were constant."
     - Nicholas Bloom, The Impact of Uncertainty Shocks, Econometrica, 2009
   - Relevant only in a nonlinear world!
What we do

- **Q1: Propose and estimate (SE)IVAR with post-WWII U.S. data, endogenous uncertainty as conditioning indicator**
  - aim: uncertainty-dependent impulse responses to detect/quantify nonlinearities
    - recover both historical and state-dependent evidence

- **Q2: Perform counterfactual exercises comparing cases of endogenous vs. exogenous uncertainty**
  - aim: assess the role of endogenous uncertainty
    - evaluate relevance of each endogenous uncertainty channel
Main findings

- **Q1: Uncertainty reduces monetary policy effectiveness...**
  - real effects of m.p. shocks inversely correlated with level of uncertainty at the time of the shock
  - a finding robust to unconventional m.p. shocks
- **...in a quantitatively important manner**
  - real variables react at their peak around 50% more to a m.p. shock when uncertainty is very low vs. high
- **Q2: Endogenous uncertainty matters too**
  - difference between state-dependent responses gets halved when uncertainty is treated as endogenous
  - both channels are active and quantitatively important
  - mean reversion behind the difference halving
Plan of the presentation

- Literature review
- The Interacted-VAR model
- The uncertainty-dependent effects of monetary policy shocks
- The role of endogenous uncertainty
- Robustness checks
- Conclusions
Related empirical works

Monetary policy shocks effectiveness and uncertainty:

- Aastveit, Natvik and Sola (2017)
  - closest: first exploration

- Castelnuovo and Pellegrino (2018)
  - estimate a state-of-the-art NK model to unveil instabilities in parameters behind the different transmission mechanism.

- Eickmeier, Metiu and Prieto (2019)
  - calibrate a NK model to propose a credit-based view

→ none investigates the role of endogenous uncertainty
Interacted VAR
Self-Exciting Interacted VAR

\[ Y_t = \alpha + \gamma \cdot t + \sum_{j=1}^{L} A_j Y_{t-j} + \left[ \sum_{j=1}^{L} c_j R_{t-j} \times unc_{t-j} \right] + u_t \]

\[ E(u_t u'_t) = \Omega \]

- Nonlinear effects of shocks to \( R \) conditional on realizations of \( Unc \)

- **Novel approach in this work:**
  - Conditioning variable modeled as endogenous:
    \[ Y_t = [\ln P_t, \ln GDP_t, \ln I_t, \ln C_t, R_t, Unc_t]' \]
  - Use Generalized IRFs (according to Koop et al. (1996)):
    \[ GIRF_y(h, \delta, \omega_{t-1}) = E[Y_{t+h} \mid \delta, \omega_{t-1}] - E[Y_{t+h} \mid \omega_{t-1}] \]
    with \( \omega_{t-1} = \{Y_{t-1}, ..., Y_{t-L}\} \)
Main features of the SEIVAR

\[
Y_t = \alpha + \gamma \cdot t + \sum_{j=1}^{L} A_j Y_{t-j} + \left[ \sum_{j=1}^{L} c_j R_{t-j} \times unc_{t-j} \right] + u_t
\]

\[
E(u_t u'_t) = \Omega
\]

- **Parsimony**: nonlinearity strictly connected to the uncertainty-policy rate relationship; avoids denser parameterization (no thresholds, no transition function); no higher terms to maintain stability (Granger, 1998)

- **Full sample estimation**: efficiency, no lack of degrees of freedom issues; any regime is imposed prior to estimation

- **Flexibility of fully nonlinear models**: quarter-specific GIRFs

  ⇒ possibility to study extreme events!
Baseline Specification

- Monetary policy shock identified via a Cholesky-decom. of $\Omega$ (CEE, 1999, 2005)
  - $\mathbf{Y}_t = [\ln P_t, \ln GDP_t, \ln I_t, \ln C_t, R_t, Unc_t]'$

- OLS estimation
- Sample: 1971Q1-2015Q4
- $L = 2$ (HQC, Kilian and Ivanov, 2005)
- Linearity rejected (pval < 0.05) via LR tests
- $R_t$: FFR & Wu-Xia shadow rate (negative since 2009Q3: "binding" ZLB)
Uncertainty data

- **Micro (firm-)level: IQR of sales growth (Bloom et al., 2018)**
  - relevant for firms’ investment behaviour (Bernanke 1983, Bertola and Caballero 1994, Dixit and Pindyck 1994, ...)
  - important driver behind aggregate time-varying volatility (Carvalho and Grassi, 2015)

- **Macro-level: Stock Market Volatility (VIX), (Bloom, 2009)**

- Jurado, Ludvigson and Ng’s (2015) macro and firm level indexes.
Uncertainty data (cont’d)
The uncertainty-dependent effects of monetary policy shocks
Historical evidence; temporal GIRFs (-25 bp shock)

- GDP peak- and cumulative-reaction (3D):

  - IQR of sales growth as uncertainty proxy
  - VIX as uncertainty proxy

  - Real effects of m.p. shocks are smaller in periods of high uncertainty, also at ZLB (role initial conditions)
Avoid use of the Shadow rate, because of:
- instability documented
- sensitiveness to SR modeling assumption (Bauer and Rudebusch, 2016)

Focus on extreme events (Vavra 2014, Bloom et al. 2007):

**Uncertain times:** \( \{ \omega_{t-1}: 85^{th} \text{ perc.} \leq Unc_{t-1} \leq \text{its } 95^{th} \text{ perc.} \} \)

**Tranquil times:** \( \{ \omega_{t-1}: 5^{th} \text{ perc.} \leq Unc_{t-1} \leq \text{its } 15^{th} \text{ perc.} \} \)

\[
GIRF_{Y,t} (h, \delta_t, \Omega_{t-1}^{\text{state } i}) = E \left[ GIRF_{Y,t} (h, \delta_t, \{ \omega_{t-1} \in \Omega_{t-1}^{\text{state } i} \}) \right]
\]

Bootstrapped 68% and 90% bands
State-conditional evidence

GDP reacts roughly 50-70% more during Tranquil times than Uncertain times

Robust to wider states
State-conditional evidence (cont’d)

- IQR of sales growth as uncertainty proxy (part I):

![Graphs showing the relationship between GDP, FFR, and Uncertainty (IQRsg) in uncertain and tranquil times.](image)
State-conditional evidence (cont’d)

- IQR of sales growth as uncertainty proxy (part II):

![Graphs showing state-conditional evidence](image-url)
State-conditional evidence (cont’d)

- VIX as uncertainty proxy (part I):
State-conditional evidence (cont’d)

- VIX as uncertainty proxy (part II):

![Graphs showing investment, consumption, and prices in uncertain and tranquil times.](image-url)
State-conditional evidence, WRAP-UP:

- Effects of m.p. shocks on GDP two-thirds milder if very high uncertainty
- Investment and (durable) consumption response: consistent with the presence of real options effects (Bernanke (1983), Bertola and Caballero (1994), Dixit and Pindyck (1994), Bloom et al. (2007), Bloom (2009), Bloom et al. (2014))
- Price Response: at first glance against Vavra (2014)’s mechanism. However, cautiousness is required:
  - "price puzzle" → but robust to its fix (Castelnuovo and Surico (2010))
  - recursive assumption → not relevant (Romer and Romer (2004) and Gertler and Karadi (2015)) / robust to its fix
  - macro response of $P$ may not carry enough info (Boivin, Giannoni and Mihov (2009))

⇒ Vavra’s mechanism not so relevant at the macro level.

- Uncertainty decreases due to the shock → role to assess!
State-conditional evidence (cont’d)

- Test for the difference of responses between states:

  - Responses are statistically different between regimes.
The role of endogenous uncertainty
Assessing the role of endogenous uncertainty

Does endogenous uncertainty play a role in the mechanism?
→ Two exercises:

1. Estimate an I-VAR model where uncertainty is exogenous (Aastveit, Natvik and Sola (2017)):

\[ \tilde{Y}_t = \alpha + \gamma \cdot t + \sum_{j=1}^{L} A_j \tilde{Y}_{t-j} + \sum_{j=1}^{L} B_j unc_{t-j}^{ex} + \left[ \sum_{j=1}^{L} c_j R_{t-j} \cdot unc_{t-j}^{ex} \right] + u_t \]

and after estimation impose: \( unc^{ex} \) = 1st(9th) decile value.

2. Perform a counterfactual on estimated SEIVAR where uncertainty remains fixed to its pre-shock value (Sims and Zha (2006))
Modeling endogenous uncertainty matters

- Uncertainty not modelled endogenously:

  → State-cond. responses get more distant when treating uncertainty as exogenous
Modeling endogenous uncertainty matters (cont’d)

- Counterfactual with fixed uncertainty:

State-cond. responses get more distant when treating uncertainty as exogenous
Modeling endogenous uncertainty matters (cont’d)

<table>
<thead>
<tr>
<th>IQR of sales growth</th>
<th>Difference between state-conditional:</th>
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<tr>
<td></td>
<td>peak effects</td>
<td>cumulative effects</td>
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<tr>
<td></td>
<td>GDP</td>
<td>Inv.</td>
</tr>
<tr>
<td>endogenous uncertainty</td>
<td>-0.10</td>
<td>-0.38</td>
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<tr>
<td>exogenous uncertainty</td>
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<td>-0.69</td>
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<tr>
<td>endog. unc./exog. unc.</td>
<td>0.53</td>
<td>0.55</td>
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<tr>
<th>VIX</th>
<th>Difference between state-conditional:</th>
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<tr>
<td></td>
<td>GDP</td>
<td>Inv.</td>
</tr>
<tr>
<td>endogenous uncertainty</td>
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<td>-0.43</td>
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<tr>
<td>exogenous uncertainty</td>
<td>-0.22</td>
<td>-0.84</td>
</tr>
<tr>
<td>endog. unc./exog. unc.</td>
<td>0.49</td>
<td>0.52</td>
</tr>
</tbody>
</table>

→difference between state-dependent responses gets halved when uncertainty is endogenous.
WHY?: What is driving this result?

- The interaction between two endogenous uncertainty channels neglected by conditionally-linear IRFs:
  - Unc. mitigation as a consequence of the shock (Bernanke’s)
  - Unc. mean reversion after the shock

⇒ Let’s disentangle the effect of each of them!
WHY?: What is driving this result? (cont’d)

→ both channels act as expected & are quantitatively relevant; mean reversion is behind halving of difference (VIX case)
Robustness checks
Robustness checks

- Jurado et al. (JLN, 2015) macro and firm-level uncertainty measures
  - common factor of the time-varying volatility of the estimated h-steps ahead forecast errors of a large number of economic time-series
- Sharpen identification m.p. shocks
  - Control for Inflation expectation: Sims (1992), Castelnuovo and Surico (2010)
  - Uncertainty ordered first
- Control for the NBER recession dummy indicator
Robustness checks (cont’d)

- Accounting for the Great Moderation:
    - \( E(\mathbf{u}_t \mathbf{u}_t') = \Omega_r \) with \( r = 1 \) if \( t < 1984Q1 \) and \( r = 2 \) if \( t \geq 1984Q1 \).

- No time trend / trending variables in first difference

- Smaller scale VAR:
  - \( \mathbf{Y}_t = [\ln P_t, \ln GDP_t, R_t, Unc_t]' \)

- Higher-order interaction terms:
  - \( \mathbf{Y}_t = \alpha + \gamma \cdot t + \sum_{j=1}^{L} A_j \mathbf{Y}_{t-j} + \\
    \left[ \sum_{j=1}^{L} (c_{junc_{t-j}} \cdot R_{t-j} + d_{junc_{t-j}} \cdot R_{t-j}^2 + e_{junc_{t-j}} \cdot R_{t-j}^2) \right] + \\
    \mathbf{u}_t \)
  - ...
Robustness checks (cont’d)

Deeper look

GDP

Investment

Consumption

Checks: first part

Checks: second part

Checks: third part
Conclusions

- I find that:
  - Uncertainty plays an important role into the m.p. transmission mechanism:
    - it reduces significantly the real effects of m.p. shocks
    - in a nonlinear world, it affects the monetary policy transmission through two novel channels
- Policy implications:
  - Fed should be aware of the degree of uncertainty when designing policies: need more aggressiveness in periods of high uncertainty
- Suggestions for microfounded model interested in policy assessment under uncertainty:
  - i) modeling the endogenous reaction of uncertainty to policies and ii) modeling empirically-grounded mean-reverting uncertainty processes
- Open question for the transmission mechanism of m.p. shocks:
  - why does uncertainty decrease after a monetary stimulus?
Extra stuff
Historical evidence

- Quarter-specific GIRFs (−25 bp $R_t$ shock), full 3D evidence
Exogenous uncertainty case

IQR of sales growth as uncertainty proxy

VIX as uncertainty proxy

GDP peak resp., conventional m.p. shocks
GDP peak resp., unconventional m.p. shocks
Alternative shadow rates

VIX as uncertainty proxy

Baseline: Wu and Xia’s shadow rate
GDP peak resp., conventional m.p. shocks
GDP peak resp., unconventional m.p. shocks

Bauer and Rudebusch’s shadow rate YZ(3)

Krippner’s shadow rate

uncertainty
gdp
Wider tolerance band for states definition

IQR of sales growth as uncertainty proxy

VIX as uncertainty proxy
Alternative test for statistical difference

- Cumulative effects of monetary policy shocks:

![Graphs showing cumulative effects of monetary policy shocks with IQR sales growth and VIX as uncertainty proxies.](image-url)
In loosen terms:

\[
\left. \frac{\partial GDP(h)}{\partial R(0)} \right|_{\omega_{t-1}}^{\text{end. unc.}} = \left. \frac{\partial GDP(h)}{\partial R(0)} \right|_{\omega_{t-1}}^{\text{ex. unc.}} + \left. \frac{\partial GDP(h)}{\partial \text{unc}} \right|_{\omega_{t-1}} \left( \frac{\partial \text{unc}}{\partial R(0)} + \frac{\partial \text{unc}}{\partial \text{time}} \cdot \left[ \frac{\partial (R \cdot \text{unc})}{\partial (R(0) \& \text{time})} - \frac{\partial (R \cdot \text{unc})}{\partial \text{time}} \right] \right)
\]

, for \( h = 0, 1, \ldots, H \).

- \( \frac{\partial \text{unc}}{\partial R(0)} \neq 0 \): Bernanke’s channel
- \( \frac{\partial \text{unc}}{\partial \text{time}} \neq 0 \): Mean reversion channel
Counterfactuals for the VIX case

- Exogenous uncertainty (both channels are shut down)
- GDP (response)
- Uncertainty (response)
- Uncertainty (level in non-shocked path)

- Only 'Bernanke' channel is shut down
- Tranquil times: Basel, end. unc.
- Uncertain times: Basel, end. unc.
- Only 'Mean Reversion' channel is shut down
- Tranquil times: Counterf. channel, no Bernanke
- Uncertain times: Counterf. channel, no Bernanke
- Tranquil times: Counterf. channel, no Mean rev.
- Uncertain times: Counterf. channel, no Mean rev.
A deeper look to the checks

![Graphs showing the relationship between different economic indicators and variables over time.](image-url)

- Prices
- GDP
- Investment
- Consumption

Legend:
- Baseline bands: Tranquil times
- Baseline bands: Uncertain times
- GIRFs alt. spec: Tranquil times
- GIRFs alt. spec: Uncertain times
A deeper look to the checks (cont’d)
A deeper look to the checks (cont’d)

High.­ord. terms

Alt. ordering

P last (& in f. exp.)

CPI

PPI