‘The Empirical Implications of the Interest-Rate Lower Bound’
Gust, Lopez-Salido and Smith

Discussion
by
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FRB San Francisco March 2013
The Great Recession and the Zero Lower Bound

• Very ambitious paper that addresses important substantive questions.

• What shocks pushed the U.S. economy into the Great Recession and kept us there?

• How important, quantitatively, was the ZLB constraint on monetary policy during the Great Recession?
• Gust et. al. estimate parameters of a nonlinear New-Keynesian DSGE model.
  – Data on inflation, output and the funds rate from 1983 to 2011.
  – Bayesian methods.

• First paper to estimate fully nonlinear New-Keynesian DSGE model featuring ZLB as endogenously binding constraint.
Methodological innovation

- Solve model using projection methods.

- Use surrogate transitions in selecting time consuming particle filter evaluations of the likelihood function
  - Exploit easy-to-compute likelihood functions to pre-screen proposed parameter configurations using first-stage acceptance criterion.

- Impressive technically and a very useful methodological contribution.
Organization of discussion

- Solution algorithm is still subject to curse of dimensionality, so they have to use a very simple model.

- Should we trust their inferences about the sources of the Great Recession and the quantitative impact of the ZLB?

- The multiple equilibrium problem.

- Short-run trade-offs: what kinds of errors do we want to commit?
The Shocks

- Household discount factor

\[ \delta_t = \frac{\beta^t}{\prod_{s=0}^{t} \eta_s} \]

\[ \frac{\delta_{t+1}}{\delta_t} = \frac{\beta}{\eta_{t+1}} \]

\[ \ln(\eta_t) = \rho_\eta \ln(\eta_{t-1}) + \varepsilon_{\eta,t} \]

- Decrease in \( \eta_t \) induces a drop in aggregate demand for goods.
The Shocks

- Production function for intermediate goods producing firms:
  \[ Y_t(j) = Z_t H_t(j) \]

- Neutral Technology Shock
  \[ \ln(Z_t) = \ln(G) + \ln(Z_{t-1}) + \varepsilon_{Z,t} \]

- No factor utilization margin and no investment.
The Shocks

- Monetary Policy

\[ R_t = \max[1, R_t^*] \]

\[ R_t^* = \left( \frac{\bar{\Pi}G}{\beta} \right)^{1-\rho_R} (R_{t-1}^*) \left( \frac{\Pi_t}{\bar{\Pi}} \right)^{\gamma_{\Pi}} \left( \frac{Y_t}{G Y_{t-1}} \right)^{\gamma_y} \varepsilon_{R,t} \]

- Inertia in terms of notional interest rate rather than actual interest rate.

- \( R_t^* \) depends on the growth rate of output, not output gap.
Central Empirical Result

- Great Recession was triggered and prolonged by extremely unlikely sequence of negative discount rate, TFP shocks.

- Key force triggering the ZLB episode during 2008-2009: a sequence of discount rate shocks.

- Productivity shocks played relatively larger role in slow output growth from 2009 on.

- Large, persistent fall in discount rate was relatively more important in explaining inflation, nominal interest rates.
Problem

- Behavior of TFP in their model differs sharply from state-of-the-art (Fernald) estimates during the Great Recession itself.

- Reason: model has no way to account for sharp rise in utilization rates that began at the end of ‘official recession’.
  - There’s no utilization in the model.
  - If there was, you’d need a rise in TFP or a rise in discount rate to generate rise in utilization rate.
  - Both these shocks would lead to a rise in aggregate demand.
  - ZLB episode would have been over much sooner.

- Model is missing *some* essential feature of the Great Recession.
TFP and the Great Recession
Utilization
Model Implied Discount Rates
Ongoing importance of discount rate shocks

• Why do discount rate shocks play a key role in explaining behavior of inflation and the interest rate?

• Mean of posterior values for structural parameters implies a linearized slope coefficient for NK Phillips curve of 0.052.
  
  – Inflation is much more responsive to marginal costs / output gap than ‘standard’ estimates.

• So they’re not explaining surprisingly high (non-negative) inflation rates in ZLB episode with very ‘flat’ Phillips curve.
Suppose we abstract from habit formation and consider periods where $R_t = 1$

$$\frac{Y_{t+1}}{Y_t} = \frac{\beta}{G\eta_t} \frac{1}{\Pi_{t+1}}$$

Output growth has been very small (sometimes negative) relative to inflation.

Need sequence of negative $\eta_t$ shocks to reconcile the model with the data.

Euler equation fiasco once again.
Duration of the ZLB

• Model *must* interpret duration of ZLB episode as reflecting extremely unusual sequence of negative discount rate, TFP shocks.

• Authors argue that private expectations have been consistent with a short *expected* duration of ZLB.
  – They make this argument using a proxy for market expectations as of 2009:1 and 2010:2.

• Consider mean forecasts of the 3-month T-bill rate from the survey of professional forecasters.
Forecasts

Expected 3-Month Treasury Rate
Survey of Professional Forecasters

Percent

Quarters Ahead

Q+0  Q+1  Q+2  Q+3  Q+4
Explaining duration of the ZLB

- Suppose we also take into account other prolonged ZLB spells (Japan, Great Depression, ...).

- Seems clear (to me) that we need a model that doesn’t explain long ZLB spells by highly unlikely sequence of extreme shocks.
Multiple Equilibria

- Authors briefly discuss possibility of multiple equilibria in their setting.
- They focus on existence of two steady states.
  - High and low (negative) inflation steady state (Benhabib, Schmitt-Grohe and Uribe (2001)).
- Gust et. al. assume that once you exit ZLB, you switch to high inflation steady state (Eggertson and Woodford).
- Standard assumption in linearized analyses of ZLB.
A possible rationale

- Monetary policy rule: actually composed of the Taylor rule with escape clause
  - If inflation is not proceeding at its target rate, money growth rate is adjusted (Christiano and Rostagni, 2001).

- Let’s maintain assumption that when ZLB episode is over, economy jumps to high inflation steady state.
Problem is much worse than 2 steady states

- If you don’t linearize equilibrium conditions, there’s multiple fundamental equilibria, sunspot equilibria even if you focus on high inflation steady state.

- Not clear how to assess policy interventions in this type of world.

- Conditional on staying in one ‘set’ of equilibria, policies have very different implications
  - Government spending multiplier can be small in one set, large in another.
Multiple Equilibria

• What are the time series implications of such a model?

• How should a Bayesian or a classical statistician proceed?

• Did authors encounter multiple equilibria when they solved their model?
Refinements and multiplicity

- CE (2012) study properties of nonlinear ZLB equilibria in EW model.

- Suppose we impose the requirement that equilibria be E-learnable.

- Then the model has a unique equilibrium.

- Properties of this nonlinear equilibrium are similar to linearized equilibrium.
The Model

- Household preferences

\[ E_0 \sum_{t=0}^{\infty} d_t \left[ \log(C_t) - \frac{\chi}{2} h_t^2 \right] \]

- Household budget constraint, final good and intermediate firm problems same as in Gust et. al., but no technology shocks.

- Monetary policy rule is simpler

\[ R_t = \max \left\{ 1, \frac{1}{\beta} + \alpha (\pi_t - 1) \right\} . \]
The Model

- Discount rate shock

\[
\begin{align*}
    d_t &= \left\{ \begin{array}{ll}
        \frac{1}{1+r_1} \frac{1}{1+r_2} \cdots \frac{1}{1+r_t}, & t \geq 1 \\
        1, & t = 0 
    \end{array} \right. \\
    r_t &\in \left\{ r^l, r^h \right\}, r^l < 0, r^h > 0. 
\end{align*}
\]

- Economy starts with \( r_t = r^l < 0 \) in initial period, with probability \( p \), it stays there.

- Jump to \( r^h (\equiv 1/\beta - 1) \) with constant probability \( 1 - p \).

- \( r^h \) is an absorbing state and economy reverts to high inflation steady state.
Baseline parameters

\[
\frac{G}{G + C} = 0.20, \beta = .99, \phi = 100, \chi = 1.25
\]
\[
\alpha = 1.5, p = .775,
\]
\[
r_l = -.02/4.
\]

- Implied slope on marginal cost in log linearized Phillips curve, 0.03.

- ‘High’ inflation steady state

\[
\pi = 1, C = 0.80, h = 1.001
\]
Multiple Equilibria

- We can reduce computation of $r = r^l$ equilibrium to one non-linear equation in $\pi^l$.

- Exists exactly two solutions for $\pi^l$. 
Multiple Fundamental Equilibria

Figure 2: EW Equilibria

Interval of candidate EW equilibrium inflation rates: [0.78, 2.27]. There are no other zeros.

Rise in G makes inflation rise in lower equilibrium and fall in higher equilibrium.

Zero bound ceases to bind at $\pi^l = 0.9933$
Properties

Table 1: Properties of EW Equilibrium for Three Parameterizations

<table>
<thead>
<tr>
<th></th>
<th>Panel A: Baseline parameterization</th>
<th>equilibrium #1</th>
<th>equilibrium #2</th>
<th>log-linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{d\text{GDP}}{dG}$</td>
<td>0.16</td>
<td>2.18</td>
<td>2.77</td>
<td></td>
</tr>
<tr>
<td>% drop in GDP</td>
<td>37.55</td>
<td>5.38</td>
<td>5.99</td>
<td></td>
</tr>
<tr>
<td>change in inflation rate</td>
<td>-11.77</td>
<td>-1.64</td>
<td>-1.90</td>
<td></td>
</tr>
</tbody>
</table>

Equilibrium #2 has properties that resemble the ones implied by the log-linear approximation.

But, equilibrium #1 is completely different!
Sunspot equilibria

- Assume \( r^l = r^h \) so that one equilibrium is normal ‘high-inflation’ equilibrium.

- Second equilibrium: economy starts out in ‘low’ state, escapes with constant probability, \( 1 - p \).

- Shock driving economy into ZLB is loss in confidence.
  - Agents anticipate deflation, creating perception that real interest rate is high.
  - Households lower expenditures, drive the economy into a recession.
  - Marginal costs (wages) falls, creates downward pressure on price level.
  - Price-setting frictions generate sustained fall in price level.
  - So initial fear of deflation is self-fulfilling.
E-Learnability

- If economy converges to equilibrium under a model with learning after a deviation from rational expectation beliefs, equilibrium is ‘E-Learnable’.

- Suppose agents know values of variables outside ZLB, value of government consumption in all periods and states.

- Agents use ‘no change’ assumption to forecast inflation, aggregate quantities and their own choices in the future scenario where ZLB binds.
  - These assumptions are correct in the rational expectations equilibrium.
• Only equilibrium 2 is stable.
  – That equilibrium looks like unique ‘linear’ equilibrium in ZLB analyses.

• Very low inflation, low fiscal multiplier fundamental equilibrium isn’t E-learnable.

• Sunspot equilibria aren’t E-learnable.

• Do these conclusions hold in Gust et. al. environment?
Approximations?

- According to CE, evidence that quality of linear approximations is poor rests on examples where output deviates by more than 20 percent from its steady state.

- For perturbations of reasonable size, conclusions arrived at in ZLB analysis using linear approximations appear to be robust.

- But those approximations may not be good enough for estimation exercises.
Conclusion and conundrums

• This paper is extremely ambitious and makes a very nice methodological contribution.

• But given the trade-offs required for estimation, we should be skeptical about substantive inferences authors make about the Great Recession.

• In the short run, we face difficult trade-offs between our desire to:
  – Estimate models with ‘full information methods’,
  – Work with complex, empirically plausible models,
  – Desire to work with explicit non-linear solutions.