On the Empirical (Ir)Relevance of the Zero Lower Bound Constraint

Davide Debortoli    Jordi Galí    Luca Gambetti

NBER Macro Annual, April 12th 2019
Overview

The *ZLB Irrelevance Hypothesis*

The economy’s performance has not been affected by the ZLB constraint

- **Focus on two dimensions:**
  1. No increase in volatility of macro variables
  2. No changes in response of macro variables to shocks

- ... this is indeed what we find

- **Interpretation:** Unconventional policies effective at getting around the ZLB constraint
Related Literature

- **Papers estimating effects of forward guidance and QE**

- **Papers assessing “irrelevance hypothesis”**
  - **Model-based evidence**
    [Christiano et. al. (2015), Gust et al. (2017)]
  - **Indirect evidence**
    response of yields to news [e.g. Swanson and Williams (2014)]
    shadow rate approach [Wu and Xia (2016), Wu and Zhang (2017)]
1. Did the ZLB increase Macro Volatility? Some Evidence
Macroeconomic Volatility and the ZLB

GDP growth

Inflation
No Significant Change during ZLB (1)

Table 1
Relative Volatility: $\frac{std(x)^{ZLB}}{std(x)^{NO-ZLB}}$

<table>
<thead>
<tr>
<th></th>
<th>ZLB</th>
<th>Pre-84</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>0.92</td>
<td>0.89</td>
</tr>
<tr>
<td>Hours</td>
<td>1.32</td>
<td>0.74</td>
</tr>
<tr>
<td>GDP Deflator</td>
<td>1.02</td>
<td>0.88</td>
</tr>
<tr>
<td>Great Recession?</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

Standard deviations are computed relative to the NO-ZLB period given by 1984Q1-2008Q4 and 2016Q1-2018Q2. The ZLB period is 2009Q1-2015Q4. When the Great Recession is excluded the pre-ZLB sample period ends in 2007Q4 and the ZLB period starts in 2009Q3. The pre-84 period starts in 1960Q1 and ends in 1983Q4.
### Table 2

**Volatility Regressions:**

\[ |x_t - \bar{x}_t| = \text{CONST} + \alpha ZLB_t + \beta GR_t \]

<table>
<thead>
<tr>
<th></th>
<th>CONST</th>
<th>ZLB</th>
<th>GR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GDP</strong></td>
<td>0.41* (0.04)</td>
<td>0.01 (0.05)</td>
<td>0.37* (0.03)</td>
</tr>
<tr>
<td><strong>Hours</strong></td>
<td>0.47* (0.05)</td>
<td>0.05 (0.16)</td>
<td>0.42* (0.04)</td>
</tr>
<tr>
<td><strong>GDP Deflator</strong></td>
<td>0.70* (0.07)</td>
<td>0.03 (0.12)</td>
<td>0.69* (0.07)</td>
</tr>
</tbody>
</table>

The Table reports the estimated coefficients from an OLS regression of the absolute value of the deviation of each variable’s growth rate from its mean, on a constant and a dummy for the ZLB period (2009Q1-2015Q4), with and without a control dummy for the Great Recession period (2008Q1-2009Q2). The sample period is 1984Q1-2018Q2. Standard errors obtained using the Newey-West estimator (4 lags).
Macroeconomic Volatility and the ZLB?
Predictions from a Benchmark Model
Standard New-Keynesian Model

\[ \hat{y}_t = \mathbb{E}_t\{\hat{y}_{t+1}\} - (i_t - \mathbb{E}_t\{\pi_{t+1}\} - z_t) \]  
\[ \hat{\pi}_t = \beta\mathbb{E}_t\{\hat{\pi}_{t+1}\} + \kappa\hat{y}_t \]  
\[ i_t = \max\left[0, \phi_i i_{t-1} + (1 - \phi_i)(\rho + \pi + \phi_\pi \hat{\pi}_t + \phi_\Delta \Delta\hat{y}_t)\right] \]  
\[ i_t^L = (1 - \beta\gamma)i_t + \beta\gamma\mathbb{E}_t\{i_{t+1}^L\} \]

- **Discount rate shock:** \( z_t = \eta_t + \rho_t \)
  - “recurrent” component: \( \eta_t = \rho_\eta \eta_{t-1} + \epsilon_t^\eta \)
  - two-state component: \( \rho_t \in \{\rho > 0; \rho_L < 0\} \)

- **Calibration of shock process**
  \( \Rightarrow \) ZLB episode every 140 quarters, last 3 quarters (on average)
  \( \Rightarrow \) \(~4\%\) decline in GDP when large shock hits

- **Monte-Carlo exercise:** 1000 simulations with ZLB binding for 28 quarters
Macroeconomic Volatility and the ZLB

Benchmark model, sample simulation

**Output Growth**

**Inflation**
Large Increase in Volatility in Benchmark Model (1)

Table 3
Relative Volatility: Simulations
Baseline Interest Rate Rule

<table>
<thead>
<tr>
<th></th>
<th>Output</th>
<th>Inflation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.49</td>
<td>1.94</td>
</tr>
<tr>
<td></td>
<td>[0.86,2.37]</td>
<td>[0.91,3.38]</td>
</tr>
<tr>
<td></td>
<td>2.29</td>
<td>2.39</td>
</tr>
<tr>
<td></td>
<td>[1.69,2.95]</td>
<td>[1.02,3.86]</td>
</tr>
</tbody>
</table>

Markov transitions?  yes  no

For each variable the Table reports the mean of the standard deviation in the ZLB period relative to the no-ZLB period over 1000 model simulations under the baseline interest rate rule. The no-ZLB period is given by the first 100 observations and the last 8 observations in the simulation. The ZLB period corresponds to the intermediate 28 observations. 95% confidence intervals reported in brackets.
Table 4

Volatility Regressions: Simulations

Baseline Interest Rate Rule

<table>
<thead>
<tr>
<th></th>
<th>CONST</th>
<th>ZLB</th>
<th>MT</th>
<th>%REJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>0.32*</td>
<td>0.35*</td>
<td></td>
<td>86%</td>
</tr>
<tr>
<td></td>
<td>[0.27,0.36]</td>
<td>(0.16,0.56)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.26*</td>
<td>0.34*</td>
<td>4.15*</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>[0.23,0.3]</td>
<td>[0.19,0.50]</td>
<td>[3.34,4.92]</td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>0.27*</td>
<td>0.47*</td>
<td></td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>[0.23,0.32]</td>
<td>[0.21,0.79]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.26*</td>
<td>0.47*</td>
<td>0.61*</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td>[0.22,0.30]</td>
<td>[0.22,0.79]</td>
<td>[0.02,1.31]</td>
<td></td>
</tr>
</tbody>
</table>

For each variable the Table reports the mean, over 1000 model simulations under the baseline interest rate rule, of the estimated coefficients from an OLS regression of the absolute value of the demeaned growth rate of each variable on a constant, a dummy indicating the ZLB period and, when it applies, a dummy for the two periods when a Markov transition occurs ($MT$). 95% confidence bands reported in brackets. $%REJ$ is the fraction of simulations for which the estimated coefficient on the ZLB dummy is positive and statistically significant using the Newey-West estimate of the standard error (4 lags).
Dynamic Responses to a Demand Shock
Baseline Taylor Rule

Output

Inflation

Short-Term Rate

Long-Term Rate

Non-Binding ZLB

Binding ZLB
2. Did the ZLB Affect the Response to Shocks? A Time-Varying VAR Approach
Empirical Framework
Based on Primiceri (2005)

Vector autoregression with **time-varying coefficients** and **stochastic volatility**

\[ x_t = A_{0,t} + A_{1,t}x_{t-1} + A_{2,t}x_{t-2} + \ldots + A_{p,t}x_{t-p} + u_t \]

where

- \( x_t \equiv [\Delta \text{productivity}_t, \text{hours}_t, \text{inflation}_t, 10\text{yr} – \text{yield}_t] \)
- \( A_{j,t} \): matrices of time-varying coefficients (random walk)
- \( u_t \sim N(0, \Sigma_t) \): linear combination of “structural” shocks

**Sample**: 1953:Q1 to 2015:Q4, quarterly frequency
**Identification**

Mix of long run and sign restrictions

- **Long Run Restriction**
  \[ \Rightarrow \text{"Technology	op"}: \text{only source of unit root in labor productivity} \]

- **Sign Restrictions** (sign of comovements at one-year horizon)

<table>
<thead>
<tr>
<th></th>
<th>output, inflation</th>
<th>output, 10yr – yield</th>
<th>inflation, 10yr – yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Demand”</td>
<td>positive</td>
<td>positive</td>
<td>positive</td>
</tr>
<tr>
<td>“Monetary”</td>
<td>positive</td>
<td>negative</td>
<td>negative</td>
</tr>
<tr>
<td>“Transitory Supply”</td>
<td>negative</td>
<td>any</td>
<td>any</td>
</tr>
</tbody>
</table>
Dynamic Responses: The Impact of the Binding ZLB

Average impulse responses (with 68% and 95% confidence bands)

Dynamic Responses Differentials
Average differences (with 68% and 95% confidence bands)
Did the ZLB affect the Response of Long-Term Rates?

An Estimated Long-Term Interest Rate Rule

\[ i_t^L = \phi_0 + \phi_i i_{t-1}^L + (1 - \phi_i) [\phi_\pi \pi_t + \phi_y \Delta y_t] + \varepsilon^m_t \]

Multiplicative dummies for binding ZLB period

**Instruments:** estimated non-monetary components from TVC-SVAR

<table>
<thead>
<tr>
<th>Table 5: Estimated Long-Term Interest Rate Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \pi_t )</td>
</tr>
<tr>
<td>( \pi_t * ZLB_t )</td>
</tr>
<tr>
<td>( \Delta y_t )</td>
</tr>
<tr>
<td>( \Delta y_t * ZLB_t )</td>
</tr>
<tr>
<td>( \phi_0 ) and ( \phi_i ) dummies?</td>
</tr>
</tbody>
</table>
4. Reconciling Theory with Evidence?
An Attempt
**New-Keynesian Model with Shadow Rate Taylor Rule**

- **A shadow rate rule**

  \[ i_t = \max[0, i_t^s] \]
  \[ i_t^s = \phi_i i_{t-1}^s + (1 - \phi_i) \left( \rho + \pi + \phi_\pi \hat{\pi}_t + \phi_y \Delta \hat{y}_t \right) \]

- **Simulations:**
  - relative standard deviations
  - volatility regressions
Macro Volatility with Shadow Rate Rule

Output Growth

Inflation

Debertoli, Gali, Gambetti

Empirical (Ir)Relevance of ZLB Constraint

NBER Macro Annual, April 12th 2019
Dynamic Responses to a Demand Shock

Shadow Rate Rule

Debortoli, Galí, Gambetti

Empirical (Ir)Relevance of ZLB Constraint

NBER Macro Annual, April 12th 2019 23 / 26
Table 6  
Relative Volatility: Simulations  
Shadow Rate Rule

<table>
<thead>
<tr>
<th></th>
<th>Output</th>
<th>Inflation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.01</td>
<td>1.50*</td>
</tr>
<tr>
<td></td>
<td>[0.65, 1.9]</td>
<td>[1.03, 1.94]</td>
</tr>
<tr>
<td></td>
<td>0.82</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>[0.50, 1.38]</td>
<td>[0.59, 1.41]</td>
</tr>
<tr>
<td>Markov transitions?</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

For each variable the Table reports the mean of the standard deviation in the ZLB period relative to the no-ZLB period over 1000 model simulations under the shadow rate interest rate rule. The no-ZLB period is given by the first 100 observations and the last 8 observations in the simulation. The ZLB period corresponds to the intermediate 28 observations. 95% confidence intervals reported in brackets.
Table 7
Volatility Regressions: Simulations

*Shadow Rate Rule*

<table>
<thead>
<tr>
<th></th>
<th>CONST</th>
<th>ZLB</th>
<th>MT</th>
<th>%REJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>0.31*</td>
<td>0.1</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.28,0.35]</td>
<td>(−0.03,0.27)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>0.26*</td>
<td>0.14*</td>
<td>49%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.23,0.3]</td>
<td>[0.02,0.26]</td>
<td>[2.66,3.6]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.28*</td>
<td>0.03</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.24,0.32]</td>
<td>[−0.06,0.14]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.26*</td>
<td>0.05</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.22,0.29]</td>
<td>[−0.04,0.14]</td>
<td>[1.07,1.69]</td>
<td></td>
</tr>
</tbody>
</table>

For each variable the Table reports the mean, over 1000 model simulations under the shadow rate interest rate rule, of the estimated coefficients from an OLS regression of the absolute value of the demeaned growth rate of each variable on a constant, a dummy indicating the ZLB period and, when it applies, a dummy for the two periods when a Markov transition occurs ($MT$). 95% confidence bands reported in brackets. %$REJ$ is the fraction of simulations for which the estimated coefficient on the ZLB dummy is positive and statistically significant using the Newey-West estimate of the standard error (4 lags).
Concluding Comments

- Little evidence against the “ZLB irrelevance hypothesis”
  - increase in volatility
  - change in response of macro variables to shocks
  - change in response of long rate to macro developments

- Possible Interpretation
  - Unconventional policies effective at getting around the ZLB
Appendix
Dynamic Responses: The Impact of the Binding ZLB Excluding the Great Recession

Debortoli, Gali, Gambetti

Empirical (Ir)Relevance of ZLB Constraint

NBER Macro Annual, April 12th 2019
Dynamic Responses: The Impact of the Binding ZLB

Extended pre-ZLB sample

Dynamic Responses: Pre-Volcker vs. Pre-ZLB


Debortoli, Galí, Gambetti
Dynamic Responses: Pre-Volcker vs. Post-Volcker

Dynamic Responses (with 2008:Q4)