The Great Escape?
A Quantitative Evaluation of the Fed’s Non-Standard Policies

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Gauti Eggertsson, Nobuhiro Kiyotaki
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ESSIM, Tarragona (Bank of Spain); May 25, 2010

Disclaimer: The views expressed are mine and do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System
The Fed’s Response to a Black Swan

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The Great Escape
Questions

- We incorporate the financial friction proposed by Kiyotaki and Moore (2008) – differences in liquidity across assets – into a DSGE model with standard real and nominal rigidities and ask:

1. Can a KM-type liquidity shock quantitatively generate the crisis?
   - Large response of both macro and financial variables.
Questions

• We incorporate the financial friction proposed by Kiyotaki and Moore (2008) – differences in liquidity across assets – into a DSGE model with standard real and nominal rigidities and ask:

1. Can a KM-type liquidity shock quantitatively generate the crisis?
   • Large response of both macro and financial variables.

2. What is the quantitative effect of unconventional monetary policy in such a setting?
   • In an environment where standard monetary policy no longer works (the “great escape” from the liquidity trap)
KM Model – The Actors

1. Entrepreneurs = \{ \text{Saving, Investing} \}

\begin{align*}
    k_{t+1} &= \begin{cases} 
        \lambda k_t + i_t & \text{with probability } \kappa \\
        \lambda k_t & \text{with probability } 1 - \kappa 
    \end{cases}
\end{align*}

2. Intermediate firms

3. Final good producing firms

4. Capital producing firms

5. Workers

6. Government

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The Great Escape
Entrepreneurs & Frictions

- Balance sheet:

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>real bonds</td>
<td>$l_{t+1}$</td>
</tr>
<tr>
<td>nominal bonds</td>
<td>$b_{t+1}/P_{t}$</td>
</tr>
<tr>
<td>equity of other entrepreneurs</td>
<td>$q_t n_{t+1}^O$</td>
</tr>
<tr>
<td>capital stock</td>
<td>$q_t k_{t+1}$</td>
</tr>
<tr>
<td></td>
<td>own equity issued $q_t n_{t+1}^I$</td>
</tr>
<tr>
<td></td>
<td>net worth $q_t n_{t+1}$</td>
</tr>
<tr>
<td></td>
<td>+ $l_{t+1}$ + $b_{t+1}/P_{t}$</td>
</tr>
</tbody>
</table>

where $n_t \equiv n_{t}^O + (k_t - n_{t}^I)$.

- Income: $r_t^k n_t$
### Entrepreneurs & Frictions

- **Balance sheet:**

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<td>( b_{t+1} / P_t )</td>
</tr>
<tr>
<td>equity of other entrepreneurs</td>
<td>( q_t n^O_{t+1} )</td>
</tr>
<tr>
<td>capital stock</td>
<td>( q_t k_{t+1} )</td>
</tr>
<tr>
<td>own equity issued</td>
<td>( q_t n^l_{t+1} )</td>
</tr>
<tr>
<td>net worth</td>
<td>( q_t n_{t+1} ) ( + l_{t+1} + b_{t+1} / P_t )</td>
</tr>
</tbody>
</table>

where \( n_t \equiv n^O_t + (k_t - n^l_t) \).

- **Income:** \( r_t^k n_t \)

- **Constraint:**

\[
n_{t+1} \geq (1 - \phi_t) \lambda n_t + (1 - \theta) i_t
\]
Entrepreneurs & Frictions

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</tr>
<tr>
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<td>net worth</td>
</tr>
<tr>
<td>$b_{t+1}/P_t$</td>
<td>$q_t n_{t+1}$</td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>entrepreneurs</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
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where $n_t \equiv n_{t}^O + (k_t - n_t^l)$.

- Income: $r_t^k n_t$

- Constraint:

$$n_{t+1} \geq (1 - \phi_t) \lambda n_t + (1 - \theta) i_t$$

Borrowing Constraint
Entrepreneurs & Frictions

- **Balance sheet:**

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<td></td>
</tr>
<tr>
<td>$q_t k_{t+1}$</td>
<td>$q_t n_{t+1} + l_{t+1} + b_{t+1}/P_t$</td>
</tr>
</tbody>
</table>

where $n_t \equiv n_{t}^{O} + (k_t - n_t^l)$.

- **Income:** $r_t^k n_t$

- **Constraint:**

$$n_{t+1} \geq \left(1 - \phi_t\right) \lambda n_t + \underbrace{(1 - \theta)i_t}_{\text{Resaleability Constraint}}$$
Entrepreneur’s problem

\[ \max \{ c_s, i_s, n_{s+1}, l_{s+1} \}_{t=0}^{\infty} E_t \sum_{s=t}^{\infty} \beta^{s-t} \log(c_s) \]

subject to

\[ n_{t+1} - (1 - \phi_t) \lambda n_t \geq (1 - \theta) i_t \]

\[ c_t + p_t^i i_t + q_t (n_{t+1} - i_t) + l_{t+1} + \frac{b_{t+1}}{P_t} = (r_t^k + \lambda) n_t + r_{t-1} l_t + \frac{R_{t-1} b_t}{P_t} \]

\[ l_{t+1} \geq 0, \ b_{t+1} \geq 0 \]
Entrepreneur’s problem – Saver

\[
\text{Max}\{c_{s,i,s,n_{s+1},l_{s+1}}\} \sum_{s=t}^{\infty} E_t \beta^{s-t} \log(c_s)
\]

subject to

\[
n_{t+1} - (1 - \phi_t) \lambda n_t \geq (1 - \theta) i_t \leftarrow \text{not binding}
\]

\[
c_t + q_t n_{t+1} + l_{t+1} + \frac{b_{t+1}}{P_t} = (r_t^k + q_t \lambda) n_t + r_{t-1} l_t + \frac{R_{t-1} b_t}{P_t}
\]
Entrepreneur’s problem – Investor

\[ \max \{c_s, i_s, n_{s+1}, l_{s+1}\}_{t} \infty E_t \sum_{s=t}^{\infty} \beta^{s-t} \log(c_s) \]

subject to

\[ n_{t+1} - (1 - \phi_t) \lambda n_t \geq (1 - \theta) i_t \leftarrow \text{binding} \]

\[ \downarrow \]

\[ c_t + q_t^R n_{t+1} + l_{t+1} + \frac{b_{t+1}}{P_t} \leq [r_k + (\phi_t q_t + (1 - \phi_t) q_t^R) \lambda] n_t + r_{t-1} i_t + \frac{R_{t-1} b_t}{P_t} \]

where

\[ q_t > 1 > q_t^R = \frac{p_t^l - \theta q_t}{1 - \theta} \]
Key equilibrium conditions

\[
(1 - \kappa) E_t \left[ \frac{1}{C_{t+1}} \frac{r_{t+1}^k + q_{t+1} \lambda}{q_t} \right] + \kappa E_t \left[ \frac{1}{C_{t+1}^i} \frac{r_{t+1}^k + ((1 - \phi_{t+1}) q_{t+1}^R + \phi_{t+1} q_{t+1}) \lambda}{q_t} \right] = \\
(1 - \kappa) E_t \left[ \frac{1}{C_{t+1}} r_t \right] + \kappa E_t \left[ \frac{1}{C_{t+1}^i} r_t \right]
\]
Key equilibrium conditions

\[(1 - \kappa)E_t \left[ \frac{1}{c_{t+1}^s} \frac{r_{t+1}^k + q_{t+1}^k \lambda}{q_t} \right] + \kappa E_t \left[ \frac{1}{c_{t+1}^l} \frac{r_{t+1}^k + \left((1 - \phi_{t+1})q_{t+1}^R + \phi_{t+1}q_{t+1}\right)\lambda}{q_t} \right] \]

\[
= (1 - \kappa)E_t \left[ \frac{1}{c_{t+1}^s} r_t \right] + \kappa E_t \left[ \frac{1}{c_{t+1}^l} r_t \right]
\]

\[(p_t^l - q_t^l \theta_t)l_t = \beta \left( \kappa r_{t-1}^L L_t + (r_t^k + q_t^k \phi^k) \kappa K_t \right) - (1 - \beta)(1 - \phi_t)q_t^R \kappa K_t
\]

\[r_t^k K_t = l_t [1 + S(l_t) + \tau_t]
\]

\[+ (1 - \beta) \left\{ r_{t-1}^L L_t + [r_t^k + (1 - \kappa + \kappa \phi_t) q_t^l \lambda + \kappa (1 - \phi_t) q_t^R] K_t \right\}
\]

consumption
Key equilibrium conditions

\[
(1 - \kappa) E_t \left[ \frac{1}{c_{t+1}^s} \left( \frac{r_{t+1}^k}{q_t} + q_{t+1}\lambda \right) \right] + \kappa E_t \left[ \frac{1}{c_{t+1}^l} \left( \frac{r_{t+1}^k}{q_t} + \left( 1 - \phi_{t+1} \right) q_{t+1}^R + \phi_{t+1} q_{t+1} \right) \lambda \right] + q_{t+1} \lambda (K_t - N_t^g) \]

\[
= (1 - \kappa) E_t \left[ \frac{1}{c_{t+1}^s} r_t \right] + \kappa E_t \left[ \frac{1}{c_{t+1}^l} r_t \right]
\]

\[
(p_t^l - q_t \theta_t) l_t = \beta (\kappa r_{t-1} L_t + (r_t^k + q_t \phi_t \lambda) \kappa (K_t - N_t^g) - (1 - \beta)(1 - \phi_t) q_t^R \lambda \kappa (K_t - N_t^g))
\]

\[
r_t^k K_t = l_t [1 + S(\frac{K_t}{l_t^*})] + \tau_t + (1 - \beta) \left\{ r_{t-1} L_t + [r_t^k + (1 - \kappa + \kappa \phi_t) q_t \lambda + \kappa (1 - \phi_t) q_t^R \lambda] (K_t - N_t^g) \right\}
\]

consumption
Government

- Taylor rule:
  \[ R_t = R_\pi \left( \frac{\pi_t}{\pi_*} \right)^\psi_1 \]

- The government budget constraint is:
  \[ L_{t+1} - r_{t-1}L_t + \frac{B_{t+1} - R_{t-1}B_t}{P_t} = \tau_t, \]

- In absence of intervention: \( L_{t+1} = L_*, \ B_{t+1} = 0. \)
Unconventional monetary policy

- **Intervention rules:**

\[
\tilde{N}_t^g = K_* \xi(\frac{\phi_t}{\phi_*} - 1).
\]

\[
q_t (\tilde{N}_t^g - N_t^g) = \tilde{L}_t - L_t.
\]

- The government budget constraint:

\[
\tau_t = \left( r_t + q_t \lambda \right) \tilde{N}_t^g - r_{t-1} \tilde{L}_t + r_t^k \tilde{N}_t^g - q_t N_{t+1}^g + L_{t+1},
\]
Liquidity Share: \( \frac{L}{L + qK} \)
Steady State as a Function of $\phi_*$

(for $L_*/Y_* = .40$)
Calibration

• Impose $\theta = \phi = 15\%$ to obtain:
  1. steady state liquidity share of 14%
  2. real return on liquid assets of 2% (1952Q1:2008Q4)

• Probability of receiving investment opportunity: $\kappa = 6\%$
  Doms and Dunne (1998) and Cooper, Haltiwanger and Power (1999)

• Standard stuff:
  • Discount factor: $\beta = 0.991$
  • Depreciation rate: $\lambda = 0.975$ (Annual depreciation = 10%)
  • Capital share: $\gamma = 0.33$
  • Taylor rule response to inflation: $\psi_1 = 1.5$
  • Inverse Frisch elasticity: $\nu = 1$
  • Nominal rigidities: $\zeta_p = \zeta_w = 0.66$
  • Investment adjustment costs: $S''(1) = 3$
Calibration of the $\phi_t$ Shock and the Fed’s Response

- Expected duration of the liquidity shock (Markov process):
  - 8 quarters (Baseline), 8 years (Extreme) (Japan, Great Depression)
Paths for the Nominal Interest Rate

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Nominal Interest Rate

Quarters

Annualized % points

IRF
Contingency
Response of Macro Variables to a liquidity shock (with intervention)

- Output
- Inflation
- Nominal Interest Rate
- GDP
- CPI
- FFR

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Response of Financial Variables to a liquidity shock (with intervention)

- Spread Illiquid–Liquid Assets
- Tobin Q
- Empirical Spreads (1st P.C.)
- Wilshire 5000

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The Effect of Policy Intervention

**Output**

- % Δ from steady state
- Quarters: 0, 5, 10, 15, 20
- Policy Response: No Intervention

**Inflation**

- Annualized % points
- Quarters: 0, 5, 10, 15, 20
- Policy Response: No Intervention

**Spread Illiquid–Liquid Assets**

- Annualized bps.
- Quarters: 0, 5, 10, 15, 20
- Policy Response: No Intervention

**Tobin Q**

- % Δ from steady state
- Quarters: 0, 5, 10, 15, 20
- Policy Response: No Intervention

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The Great Escape
Multipliers

\[ E_0 \sum_{t=0}^{\infty} (\hat{Y}^I_t - \hat{Y}^N_t) \]
\[ \frac{E_0 \sum_{t=0}^{\infty} \hat{N}^g_{t+1}}{E_0 \sum_{t=0}^{\infty} \hat{N}^g_{t+1}} \]

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Great Escape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full model</td>
<td>0.643</td>
<td>2.240</td>
</tr>
<tr>
<td>No zero bound constraint</td>
<td>0.247</td>
<td>0.309</td>
</tr>
<tr>
<td>No nominal rigidities</td>
<td>0.064</td>
<td>0.052</td>
</tr>
</tbody>
</table>

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The Role of the Nominal Rigidities

![Graphs showing the impact of various interventions on Output, Real Interest Rate, Investment, and Consumption.]

- Output
  - Baseline & Intervention
  - Baseline & No Intervention
  - Flex Price & Intervention
  - Flex Price & No Intervention

- Real Interest Rate

- Investment

- Consumption

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The Role of the Zero Bound

The diagrams show the impact of different monetary policy interventions on output, inflation, and nominal interest rates. The Y-axis represents the percentage deviation from the steady state, while the X-axis represents the number of quarters. The graphs compare scenarios with and without zero bound constraints (ZB) and interventions.

- **Output**: Shows the percentage deviation from steady state over time for different policy interventions.
- **Inflation**: Similar to output, but focusing on inflation rates.
- **Nominal Interest Rate**: Displays the annualized percentage points change in nominal interest rates over time for different scenarios.

Legend:
- Blue solid line: ZB & Intervention
- Blue dashed line: ZB & No Intervention
- Red solid line: NO ZB & Intervention
- Red dashed line: NO ZB & No Intervention
Conclusions

1. Liquidity shocks as in Kiyotaki-Moore model can generate quantitatively large movements in real and financial variables → can explain some features of the crisis

2. Swap of liquid for illiquid assets (unconventional policy) is effective in reducing impact on spreads and real variables

- Caveat: This is not a model for normative analysis!!!
Investment Adjustment Costs

- **Capital producers:**

\[
\max_{l_t} C(l_t) = p_t l_t - l_t [1 + S(\frac{l_t}{l_\ast})]
\]

with \( S(1) = S'(1) = 0, S''(1) > 0 \)

\[\Rightarrow p_t = 1 + S(\frac{l_t}{l_\ast}) + S'(\frac{l_t}{l_\ast}) \frac{l_t}{l_\ast}\]
Sticky Prices

- Monopolistic competitors produce intermediate goods with technology:
  \[ y_t(i) = A_t k_t(i)^\gamma l_t(i)^{1-\gamma}, \]
  subject to Calvo price rigidity (\( \zeta_p \)).
- Final goods producers aggregate:
  \[ y_t = \left[ \int_0^1 y_t(i)^{\frac{1}{1+\lambda_{f,t}}} di \right]^{1+\lambda_{f,t}} \]
- Inflation determined by New-Keynesian Phillips curve
Workers

\[
\text{Max}_{\{c'_s, h'_s, n'_{s+1}, b'_{s+1}, l'_{s+1}\}} \sum_{s=t}^{\infty} \beta^{s-t} U[c'_s - \int \frac{\omega_0}{1 + \nu} h_s(\omega)'^1+\nu d\omega]
\]

subject to

\[
c'_t + q_t (n'_{t+1} - \lambda n'_t) + l'_{t+1} - r_{t-1} l''_t + \frac{b'_{t+1} - R_{t-1} b'_t}{P_t} \leq 0; \]

\[
r_t^n n'_t + \int \frac{W_t(\omega)}{P_t} h'_t(\omega) d\omega + C(l_t) + \int P(i) di + \tau_t \geq 0;
\]

\[
l'_{t+1} \geq 0, \quad b'_{t+1} \geq 0, \quad n'_{t+1} \geq 0
\]

and to Calvo nominal rigidities \((\zeta_w)\). Differentiated labor \(h'_t(\omega)\), packed into a composite:

\[
h'_t = \left[ \int_0^1 h'_t(\omega) \frac{1}{1+\lambda_w} d\omega \right]^{1+\lambda_w}.
\]