Transmission of Quantitative Easing: The Role of Central Bank Reserves

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Term Structure Modeling and the Lower Bound Problem
Lecture III.2

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The views expressed here are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Federal Reserve Bank of San Francisco, the Board of Governors of the Federal Reserve System, or the Swiss National Bank.
Constrained by the zero lower bound (ZLB), a number of central banks have resorted to unconventional monetary policies, including quantitative easing (QE).

QE aims to lower long-term interest rates, and is implemented through large-scale asset purchases and unprecedented creation of reserves.

Details of transmission matter for how to best design, communicate, and eventually exit QE programs.

Still, the understanding of the transmission of QE to long-term rates remains at best partial, conceptually and empirically.

We focus on the role of central bank reserves for transmission.
“When the short-term interest rate gets all the way to zero, an open market purchase of a short-term Treasury security with newly created base money represents an exchange of essentially equivalent assets. Such an exchange is obviously incapable of lowering the short-term rate any further, and it is not clear how the exchange could affect any economic magnitude of interest.”

Hamilton and Wu (JMCB 2012, p. 6)
We argue that QE can affect long-term rates through reserve expansions *per se*, independently of which assets are purchased—a reserve-induced portfolio balance effect.

For evidence, we study the SNB reserve expansions in August 2011. These did not involve any long-term security purchases.

We use term structure models to decompose Swiss long-term bond yields into policy expectations and term premiums.

Results from an event study suggest that term premiums dropped significantly following SNB announcements regarding reserve expansions.

Hence, we claim to be the first to document a case of reserve expansions *without* purchases of long-term assets leading to declines in long-term yields through a portfolio balance effect.
The Existing Literature Focuses on Two Channels

1. **Signaling channel**: Announcements of QE programs provide information about current or future economic conditions or monetary policy intentions.

2. **Portfolio balance channel**: CB purchases of long-term bonds reduce their supply available for trading, and thereby increase (reduce) their price (yield)—a supply-induced portfolio balance effect.

   Underlying assumption: bonds of different maturities are imperfect substitutes for some investors (preferred habitat) and markets are segmented as per Vayanos and Vila (2009).

However, as Bernanke and Reinhart (2004) emphasize, an expansion of reserves by itself can potentially lead to portfolio balance effects. See also Tobin (1969) and Brunner and Meltzer (1973).
Example: Reserves and short bonds are near-perfect substitutes at the ZLB, but *not* perfect—only banks can hold reserves!
Initial impact of QE: Bank asset duration is shortened.

The extra reserves must stay in banks: Hot potato effect ....

... until longer-duration yields decline (prices increase) enough to make banks content to hold the extra reserves.
Reserve effects are independent of the assets purchased and may arise provided assets are purchased from non-banks. QE in long bonds can have both reserve and supply effects.
Has this channel been empirically relevant in QE programs?

Event studies of US and UK QE cannot identify them separately, but circumstances make reserve-induced effects likely.

**US:**
- Carpenter et al. (2015) provide evidence for the US that QE counterparties have tended to be non-banks.
- Ennis and Wolman (2015) provide evidence that the increase in domestic banks’ holdings of reserves was accompanied by a nearly proportional increase in deposits.

**UK:**
- Joyce et al. (2011) describe UK QE as designed for non-bank counterparties with the aim of increasing broader money.
- In effect, UK bank holdings of the purchased long-term gilts increased, non-bank private sector holdings declined, in connection with the initial QE in 2009.
For outright identification in event studies, we need a case of central bank reserve expansions in the absence of long-term bond purchases.

The Swiss reserve expansion program in August 2011 represents exactly such a case.
• Conventional operational tool for Swiss monetary policy: Target range for the three-month CHF LIBOR.

• Three-month CHF LIBOR reached its zero lower bound in early 2009, while further easing was desirable.
In the summer of 2011, the Swiss franc was rapidly approaching par with the euro—an unprecedented and unsustainable level.
Swiss policy interest rates reached ZLB in early 2009.

The Swiss franc strongly appreciated starting in late 2008, compounding the negative shocks from the global financial and European debt crises while constrained by the ZLB.

Some monetary policy reactions to the appreciation and deflationary concerns:

- FX interventions in 2009-2010.
- Announcement and implementation of **three rounds of reserve expansions in August 2011**.
- Floor of 1.20 Swiss francs per euro in September 2011.
## SNB Announcements in August 2011

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Announcement description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Aug. 3, 2011</td>
<td>9:05 a.m. Target range for three-month CHF LIBOR lowered to 0 to 25 basis points. In addition, banks’ sight deposits at the SNB will be expanded from CHF 30 billion to CHF 80 billion.</td>
</tr>
<tr>
<td>II</td>
<td>Aug. 10, 2011</td>
<td>8:55 a.m. Banks’ sight deposits at the SNB will rapidly be expanded from CHF 80 billion to CHF 120 billion.</td>
</tr>
<tr>
<td>III</td>
<td>Aug. 17, 2011</td>
<td>9:05 a.m. Banks’ sight deposits at the SNB will immediately be expanded from CHF 120 billion to CHF 200 billion.</td>
</tr>
</tbody>
</table>

- Total expansion of reserves: CHF 170 billion, or 30% of GDP.
- Achieved within a month.
- Unprecedented in terms of both size and pace.
Note that the balance sheet expanded in August 2011.

On the asset side, most of the expansion came about through foreign exchange swaps.
The amount of excess reserves expanded rapidly.

Part of this expansion was achieved by buying back SNB bills.
Data and sample:
- Daily bond market data collected between 9:00 and 11:00 a.m.
- Sample contains six maturities, \{1, 2, 3, 5, 7, 10\}, from January 6, 1998, to December 30, 2011.

Two-day event window:
- SNB made announcements around 09:00 a.m., which may be before or after data collection.
- Ranaldo and Rossi (2010): Swiss bond markets can take up to 30 min. to react to SNB policy announcements.

Were the announcements unexpected?
- They were unscheduled, and the nature, size, and pace of measures were most likely unexpected.
### First Look at the Data: Swiss Confederation Yields

<table>
<thead>
<tr>
<th>Event</th>
<th>Maturity</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-year</td>
<td>2-year</td>
<td>3-year</td>
<td>5-year</td>
<td>7-year</td>
<td>10-year</td>
</tr>
<tr>
<td>Aug. 2, 2011</td>
<td>30</td>
<td>17</td>
<td>24</td>
<td>65</td>
<td>100</td>
<td>133</td>
</tr>
<tr>
<td>Aug. 4, 2011</td>
<td>26</td>
<td>12</td>
<td>20</td>
<td>61</td>
<td>98</td>
<td>131</td>
</tr>
<tr>
<td>Change</td>
<td>-4</td>
<td>-5</td>
<td>-5</td>
<td>-4</td>
<td>-3</td>
<td>-2</td>
</tr>
<tr>
<td>Aug. 9, 2011</td>
<td>26</td>
<td>13</td>
<td>14</td>
<td>47</td>
<td>83</td>
<td>119</td>
</tr>
<tr>
<td>Aug. 11, 2011</td>
<td>21</td>
<td>8</td>
<td>10</td>
<td>43</td>
<td>79</td>
<td>114</td>
</tr>
<tr>
<td>Change</td>
<td>-5</td>
<td>-5</td>
<td>-5</td>
<td>-4</td>
<td>-4</td>
<td>-6</td>
</tr>
<tr>
<td>Aug. 16, 2011</td>
<td>19</td>
<td>8</td>
<td>13</td>
<td>49</td>
<td>84</td>
<td>119</td>
</tr>
<tr>
<td>Aug. 18, 2011</td>
<td>18</td>
<td>8</td>
<td>7</td>
<td>32</td>
<td>64</td>
<td>99</td>
</tr>
<tr>
<td>Change</td>
<td>0</td>
<td>0</td>
<td>-6</td>
<td>-17</td>
<td>-21</td>
<td>-20</td>
</tr>
<tr>
<td>Total net change</td>
<td>-9</td>
<td>-10</td>
<td>-15</td>
<td>-25</td>
<td>-28</td>
<td>-28</td>
</tr>
</tbody>
</table>

- For comparison, the sample standard deviation of two-day changes is 5 bps (or 6-8 bps in the summer of 2011).
- To what extent did the yield declines reflect policy expectations (signaling) vs. portfolio balance effects?
Define the term premium:

\[ TP_t(\tau) = y_t(\tau) - \frac{1}{\tau} \int_t^{t+\tau} E_t^P[r_s] ds. \]

We follow the literature and make the following simplifying assumptions:

- Changes in policy expectations are associated with signaling effects;
- Changes in term premiums are associated with portfolio balance effects.

To operationalize in daily data, we estimate arbitrage-free Nelson-Siegel (AFNS) models, see Christensen, Diebold, and Rudebusch (2011). These are Gaussian models.
Through 2011 Swiss Confederation bond yields respected the zero lower bound.

However, since the spring of 2012 this has not been the case.

Thus, the Gaussian AFNS modeling approach appears warranted in the Swiss context—unlike what is the case for US data.
Proposition: If the risk-free rate is defined by

\[ r_t = L_t + S_t \]

and the \( Q \)-dynamics of \( X_t = (L_t, S_t, C_t) \) are given by

\[
\begin{pmatrix}
    dL_t \\
    dS_t \\
    dC_t
\end{pmatrix} =
\begin{pmatrix}
    0 & 0 & 0 \\
    0 & \lambda & -\lambda \\
    0 & 0 & \lambda
\end{pmatrix}
\begin{pmatrix}
    \theta_1^Q \\
    \theta_2^Q \\
    \theta_3^Q
\end{pmatrix} -
\begin{pmatrix}
    L_t \\
    S_t \\
    C_t
\end{pmatrix}
\]

\[ dt + \Sigma dW_t^Q, \]

where \( \Sigma \) is a constant matrix, then zero-coupon yields have the Nelson-Siegel factor structure:

\[
y_t(\tau) = L_t + \left( \frac{1 - e^{-\lambda \tau}}{\lambda \tau} \right) S_t + \left( \frac{1 - e^{-\lambda \tau}}{\lambda \tau} - e^{-\lambda \tau} \right) C_t - \frac{A(\tau)}{\tau}.
\]

- This defines the AFNS model class.
- The constant yield-adjustment term, \( A(\tau)/\tau \), ensures absence of arbitrage.
- This is the measurement equation in the Kalman filter.
Using the essentially affine risk premiums introduced in Duffee (2002), the state variables have $P$-dynamics characterized by:

$$
\begin{pmatrix}
    dL_t \\
    dS_t \\
    dC_t
\end{pmatrix}
= 
\begin{pmatrix}
    \kappa_{11}^P & \kappa_{12}^P & \kappa_{13}^P \\
    \kappa_{21}^P & \kappa_{22}^P & \kappa_{23}^P \\
    \kappa_{31}^P & \kappa_{32}^P & \kappa_{33}^P
\end{pmatrix}
\begin{pmatrix}
    \theta_1^P \\
    \theta_2^P \\
    \theta_3^P
\end{pmatrix}
- 
\begin{pmatrix}
    L_t \\
    S_t \\
    C_t
\end{pmatrix}
\, dt
+ 
\begin{pmatrix}
    \sigma_{11} & 0 & 0 \\
    \sigma_{21} & \sigma_{22} & 0 \\
    \sigma_{31} & \sigma_{32} & \sigma_{33}
\end{pmatrix}
\begin{pmatrix}
    dW_{t}^{L,P} \\
    dW_{t}^{S,P} \\
    dW_{t}^{C,P}
\end{pmatrix}.
$$

This is the transition equation in the Kalman filter estimation.

To reduce the number of parameters:

- We restrict the $\Sigma$ matrix to be diagonal (following CDR).
- We employ a general-to-specific approach to obtain an appropriate specification of $K^P$ (AIC/BIC).
- We use the 1998-2007 period for model selection to stay clear of the noise from the financial and sovereign debt crises.
The Preferred AFNS Model

Our preferred specification of the AFNS model for the Swiss Confederation yields $P$-dynamics given by

$$
\begin{pmatrix}
    dL_t \\
    dS_t \\
    dC_t
\end{pmatrix}
= 
\begin{pmatrix}
    \kappa_{11}^P & 0 & 0 \\
    0 & \kappa_{22}^P & 0 \\
    \kappa_{31}^P & 0 & \kappa_{33}^P
\end{pmatrix}
\begin{pmatrix}
    \theta_1^P \\
    \theta_2^P \\
    \theta_3^P
\end{pmatrix}
- 
\begin{pmatrix}
    L_t \\
    S_t \\
    C_t
\end{pmatrix}
$$

$$
= + \begin{pmatrix}
    \sigma_{11} & 0 & 0 \\
    0 & \sigma_{22} & 0 \\
    0 & 0 & \sigma_{33}
\end{pmatrix}
\begin{pmatrix}
    dW_t^{L,P} \\
    dW_t^{S,P} \\
    dW_t^{C,P}
\end{pmatrix}
$$

Two things are worth noting regarding this specification:

1. The Nelson-Siegel level and slope factors are independent processes under the objective real-world probability measures.

2. The five parameter restrictions on the mean-reversion matrix are statistically insignificant.
In AFNS models, we test the significance of parameter restrictions with standard likelihood ratio tests.

The restrictions in the preferred AFNS model are well supported during our period of analysis.
## Model Forecast Performance

<table>
<thead>
<tr>
<th>Forecasting method</th>
<th>One-year forecast</th>
<th>Two-year forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>RMSE</td>
</tr>
<tr>
<td>Random walk</td>
<td>62.37</td>
<td>113.65</td>
</tr>
<tr>
<td>Unconstrained AFNS model</td>
<td>44.62</td>
<td>73.67</td>
</tr>
<tr>
<td>Unrestricted $K^P$ AFNS model</td>
<td>72.80</td>
<td>85.43</td>
</tr>
<tr>
<td>Indep.-factor AFNS model</td>
<td>51.96</td>
<td>72.89</td>
</tr>
<tr>
<td>CR (2012) AFNS model</td>
<td>80.94</td>
<td>93.03</td>
</tr>
<tr>
<td>Preferred AIC AFNS model</td>
<td>71.48</td>
<td>83.23</td>
</tr>
<tr>
<td>Preferred BIC AFNS model</td>
<td>54.31</td>
<td>73.97</td>
</tr>
</tbody>
</table>

- In the paper, we compare the three-month CHF LIBOR forecast performance of various AFNS models to that of the random walk over the period from January 4, 2008 to December 30, 2011 (209 weekly forecasts).

- The preferred AFNS model performs well in this exercise, in particular it is better than the random walk as measured by RMSEs.
Here, I compare the one-year forecast performance of the various AFNS models estimated with daily data to:

- The random walk;
- The Consensus Forecasts survey.

The frequency is monthly covering the period from January 2006 to June 2014 (102 forecasts).

Again, the preferred AFNS model performs well.
The chart shows monthly (approx.) one-year ahead forecasts of the three-month CHF LIBOR from the Consensus Forecasts survey and various AFNS models.

Also shown are subsequent realizations of the three-month CHF LIBOR.
### Summary of Model Performance Evaluation

<table>
<thead>
<tr>
<th>Maturity in months</th>
<th>Preferred AFNS model</th>
<th>Mean</th>
<th>RMSE</th>
<th>$\hat{\sigma}_\varepsilon(t_i)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>-4.78</td>
<td>13.51</td>
<td>13.64</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>-0.12</td>
<td>1.20</td>
<td>1.96</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>0.55</td>
<td>2.04</td>
<td>2.29</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0.06</td>
<td>0.60</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>-0.39</td>
<td>1.14</td>
<td>1.44</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>0.00</td>
<td>0.00</td>
<td>2.24</td>
<td></td>
</tr>
</tbody>
</table>

- In general, the AFNS models provide a very close fit to the cross section of yields.
- Their empirical tractability is robust and well documented.
- Our preferred AFNS model is competitive at forecasting the three-month CHF LIBOR up to two years ahead.

Next, we use the AFNS models to decompose, in real time, the yield response to the SNB announcements.
## Decomposition of Swiss Ten-Year Yield Response

<table>
<thead>
<tr>
<th>Event</th>
<th>Model</th>
<th>Avg. target rate next 10 years</th>
<th>10-year term premium</th>
<th>Res.</th>
<th>10-year yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 8/3/11</td>
<td>Unconstr.</td>
<td>-5</td>
<td>2</td>
<td>1</td>
<td>-2</td>
</tr>
<tr>
<td></td>
<td>Unrestrict. $K^P$</td>
<td>-2</td>
<td>-1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indep.-factor</td>
<td>-3</td>
<td>-1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>-2</td>
<td>-1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>II 8/10/11</td>
<td>Unconstr.</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>-6</td>
</tr>
<tr>
<td></td>
<td>Unrestrict. $K^P$</td>
<td>0</td>
<td>-4</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indep.-factor</td>
<td>1</td>
<td>-5</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>1</td>
<td>-5</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>III 8/17/11</td>
<td>Unconstr.</td>
<td>0</td>
<td>-20</td>
<td>0</td>
<td>-20</td>
</tr>
<tr>
<td></td>
<td>Unrestrict. $K^P$</td>
<td>4</td>
<td>-23</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indep.-factor</td>
<td>-1</td>
<td>-17</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>0</td>
<td>-19</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Unconstr.</td>
<td>-8</td>
<td>-19</td>
<td>0</td>
<td>-28</td>
</tr>
<tr>
<td></td>
<td>Unrestrict. $K^P$</td>
<td>2</td>
<td>-28</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indep.-factor</td>
<td>-3</td>
<td>-23</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>-1</td>
<td>-25</td>
<td>-2</td>
<td></td>
</tr>
</tbody>
</table>

- Yield declines reflect declines in term premiums.
- Very similar decompositions across model specifications.
Summary of Results

- We find 25 bps accumulated drop in the term premium of the Swiss ten-year yield.

- The drop was particularly large after the third "strongest" announcement.

- Only the first announcement is associated with signaling effects, as it affected expected future policy rates. This is consistent with the message.
Robustness Checks

- We use regression analysis to control for foreign developments, Swiss bond market liquidity, and broader financial market uncertainty.

- We look at intraday interest rate swap data to confirm findings.

- We look for other events to account for the results.

- We repeat the exercise using shadow-rate models.

- Finally, we note that all results hold up at the five-year maturity.
Control for Other Factors

To account for changes in foreign term premiums, we include real-time estimated term premiums for the US and the euro area:

1. US term premiums are from the shadow-rate AFNS model analyzed in Christensen and Rudebusch (2015b).
2. Euro-area term premiums are from our own analysis of German bund yield curves from the Bundesbank website.

To account for variation in the liquidity of Swiss Confederation bonds, we use the weighted average of bid-ask spreads in the secondary market.

To account for general market uncertainty, we use the VIX.
Regression Analysis

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>First differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td>DUM 3 Aug 2011</td>
<td>−0.78**</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
</tr>
<tr>
<td>DUM 10 Aug 2011</td>
<td>−8.35**</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
</tr>
<tr>
<td>DUM 17 Aug 2011</td>
<td>−17.58**</td>
</tr>
<tr>
<td></td>
<td>(0.17)</td>
</tr>
<tr>
<td>Euro-area term premium</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
</tr>
<tr>
<td>US term premium</td>
<td>0.20**</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
</tr>
<tr>
<td>Bid-ask spread</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>VIX</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.07</td>
</tr>
</tbody>
</table>

- We regress the ten-year Swiss term premium on the foreign term premiums, the bid-ask spread, and the VIX (daily, 1/4/10-12/12/11), all in first differences.
- The last two event dummies are highly statistically significant!
To provide intraday evidence, we turn to the Swiss interest rate swap market.

On August 3, 2011, the ten-year swap rate dropped immediately after the SNB announcement.

This suggests a signaling effect of about 5 basis points consistent with our model decompositions.
Note that the August 9, 2011, FOMC statement with explicit forward guidance provided for the first time had little effect on Swiss fixed-income markets.

More importantly, the portfolio balance effects from the SNB announcement take quite some time to materialize.
The portfolio balance effects from the largest and strongest SNB announcement materialized a little faster, but still in a very gradual process.
We already saw that the August 2011 FOMC statement does not seem to affect our results.

On August 18, 2011, there is a major European event related to the banking sector, but it occurs outside our event window.

Beyond those two no other major events take place during our event windows. Thus, there does not seem to be any other alternative explanations that can account for our results.
<table>
<thead>
<tr>
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<th>10-year term premium</th>
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</tr>
</thead>
<tbody>
<tr>
<td>I 8/3/11</td>
<td>Unconstr.</td>
<td>-10</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Unrestrict.</td>
<td>-4</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indep.-factor</td>
<td>-3</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preferred</td>
<td>-4</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II 8/10/11</td>
<td>Unconstr.</td>
<td>-6</td>
<td>1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
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- Shadow-rate AFNS models give more weight to signaling effects, but term premium effects remain significant for the third announcement.
Summary of Robustness Checks

- Results robust to controlling for market uncertainty (VIX); illiquidity (bid-ask spreads), and foreign term premium estimates (euro-area & US).

- Intraday evidence is consistent with model-based results.

- No other events likely to explain the yield declines.

- Results are robust to the maturity considered, not unique to any particular model specification, and do not go away if shadow-rate models are used instead.
Real-time estimation of dynamic term structure models combined with an event study suggests that SNB announcements regarding reserve expansions were associated with declines in term premiums of long-term bonds.

Since the SNB did not acquire any long-term bonds, we interpret this as evidence of portfolio balance effects of reserve expansions on long-term yields.

We conclude that reserve expansions are indeed capable of affecting long rates—an economic magnitude of interest!

They operate through a transmission channel we refer to as reserve-induced portfolio balance effects.

Are these findings relevant outside Switzerland? At a minimum, our results call for more research to better understand the bank and financial market impact of changes in central bank reserves.
Some Tentative Policy Implications

- **Implications for the design of QE programs:** At the ZLB, long-lived asset purchases are not necessary for QE to affect long-term yields.

- **Implications for the exit:** Exit from QE through absorption of reserves without asset sales could nevertheless affect long-term bond markets.

- **Implications for communication:** Signaling channel appears to be absent when QE is *not* combined with forward guidance, see also Christensen and Rudebusch (2012).