Transmission of Quantitative Easing: The Role of Central Bank Reserves

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Motivation and Contribution

- The understanding of the transmission of QE to long rates remains at best partial, conceptually and empirically.
- Details of transmission matter for how to best design, communicate, and eventually exit QE programs.
- We posit that QE can affect long 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, but nevertheless resulted in reduced term premiums, suggestive of portfolio balance effects.

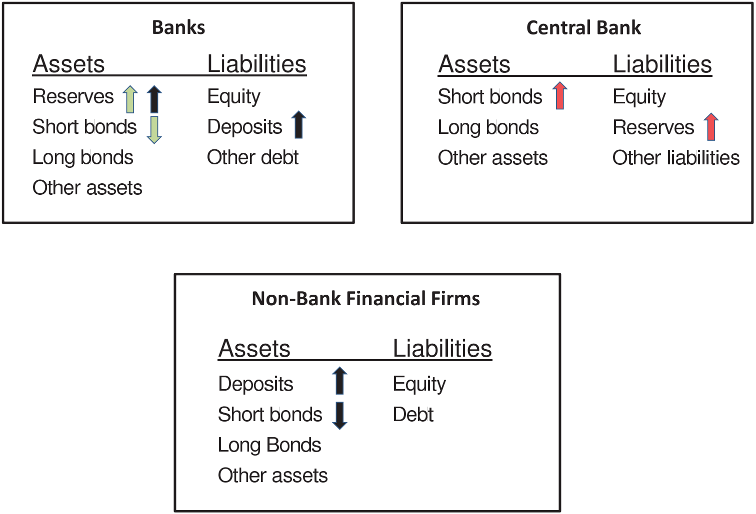
The Existing Literature Focuses on Two Channels

1. Signaling channel: QE announcements 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 (Vayanos and Vila (2009)).

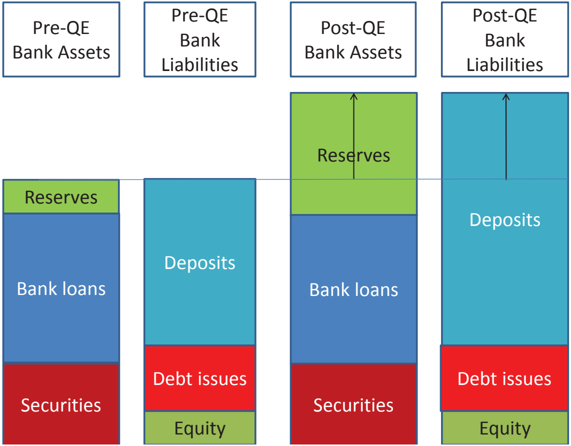
3. However, as Bernanke and Reinhart (2004) emphasize, an expansion of reserves by itself can potentially lead to portfolio balance effects.

Additional Transmission Channel: Reserve Effects (1)



Example: Reserves and short bonds are near-perfect substitutes at the ZLB, but *not* perfect: Only banks can hold reserves.

Additional Transmission Channel: Reserve Effects (2)



- 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.

Additional Transmission Channel: Reserve Effects (3)

Banks

Assets	Liabilities
Reserves ↑ ↑	Equity
Short bonds	Deposits ↑
Long bonds ↓	Other debt
Other assets	

Central Bank

Assets	Liabilities
Short bonds	Equity
Long bonds ↑	Reserves ↑
Other assets	Other liabilities

Non-Bank Financial Firms

Assets	Liabilities
Deposits ↑	Equity
Short bonds	Debt
Long Bonds ↓	
Other assets	

- Reserve effects are independent of the assets purchased. Can arise if assets are purchased from non-banks.
- QE in long bonds can have both reserve and supply effects.

Additional Transmission Channel: Reserve Effects (4)

- For outright identification in event studies, we need a case of QE-style central bank reserve expansions, but in the absence of long-term bond purchases.

- The Swiss reserve expansion program of August 2011 represents exactly such a case.

SNB QE-Type Announcements in August 2011

No.	Date	Announcement description
I	Aug. 3, 2011 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.
II	Aug. 10, 2011 8:55 a.m.	Banks' sight deposits at the SNB will rapidly be expanded from CHF 80 billion to CHF 120 billion.
III	Aug. 17, 2011 9:05 a.m.	Banks' sight deposits at the SNB will immediately be expanded from CHF 120 billion to CHF 200 billion.

- Total expansion of reserves: CHF 170 billion, or 30% of GDP.
- Was achieved within a month.
- Achieved mainly through repurchases of short-term CB bills (liabilities) and FX swaps (assets).

Effect on Yields: Term Structure Decomposition

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).

Data and Event Study Details

Data and sample:

- Daily bond market data collected between 9:00 and 11:00 a.m.
- Zero-coupon yields generated by SNB staff using a Svensson (1995) discount function.
- Out 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.

Decomposition of Swiss Ten-Year Yield Response

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

- Term premiums declined in response to announcements.
- 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.

Conclusion

- 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.
- The transmission channel of QE to long-term interest rates may hence partly derive from the reserve expansions *per se*—**a reserve-induced portfolio balance effect**.
- The broader point is that transmission of QE is more complex than usually portrayed, and likely to depend on the mix of financial intermediaries, domestic financial market structure, and bank regulation. Need for more research to better understand these factors.

Some Tentative Policy Implications

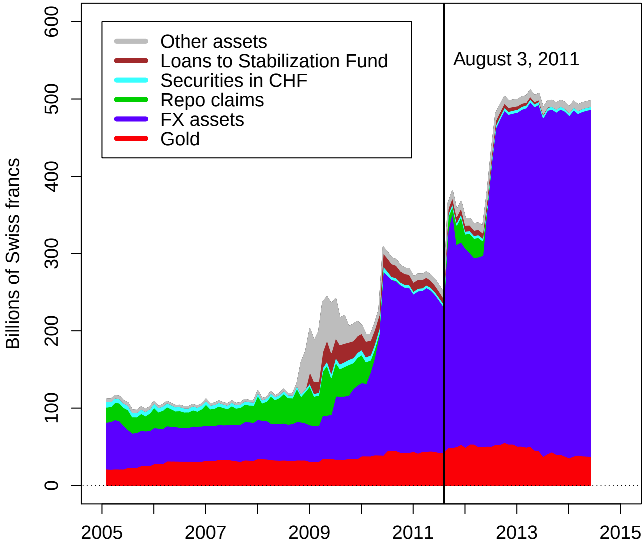
- Implications for the design of QE programs: At the ZLB, long-lived asset purchases are not necessary for QE to affect long-term yields.

- 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).

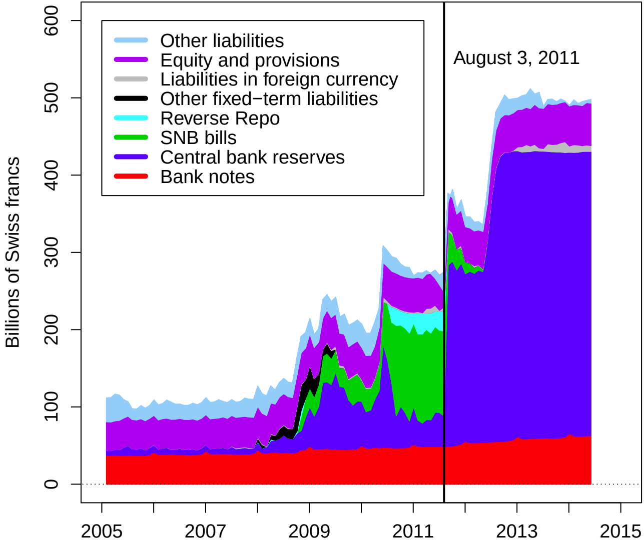
Appendix

SNB Assets



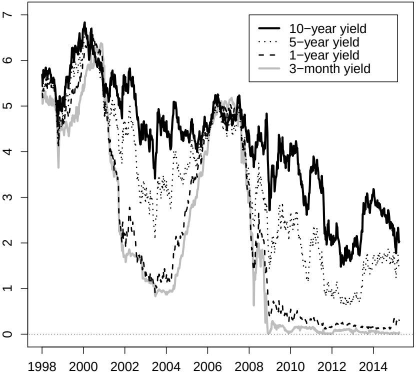
- On the asset side, most of the expansion came about through foreign exchange swaps.

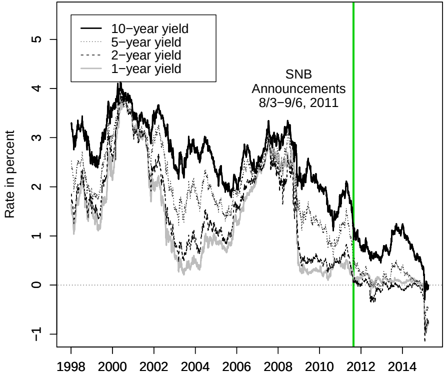
SNB Liabilities



- The amount of excess reserves expanded rapidly.
- Part of this expansion was achieved by buying back SNB bills.

US Treasury and Swiss Confederation Bond Yields





- 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.

The AFNS Class of Models (1)

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

$$\begin{pmatrix} dL_t \\ dS_t \\ dC_t \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & \lambda & -\lambda \\ 0 & 0 & \lambda \end{pmatrix} \left[\begin{pmatrix} \theta_1^Q \\ \theta_2^Q \\ \theta_3^Q \end{pmatrix} - \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} \right] dt + \Sigma dW_t^Q,$$

where Σ 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.

The AFNS Class of Models (2)

Using the essentially affine risk premiums introduced in Duffee (2002), the state variables have P-dynamics characterized by:

$$\begin{pmatrix} dL_t \\ dS_t \\ dC_t \end{pmatrix} = \begin{pmatrix} \kappa_{11}^P & \kappa_{12}^P & \kappa_{13}^P \\ \kappa_{21}^P & \kappa_{22}^P & \kappa_{23}^P \\ \kappa_{31}^P & \kappa_{32}^P & \kappa_{33}^P \end{pmatrix} \left[\begin{pmatrix} \theta_1^P \\ \theta_2^P \\ \theta_3^P \end{pmatrix} - \begin{pmatrix} L_t \\ S_t \\ C_t \end{pmatrix} \right] dt$$

$$+ \begin{pmatrix} \sigma_{11} & 0 & 0 \\ \sigma_{21} & \sigma_{22} & 0 \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{pmatrix} \begin{pmatrix} dW_t^{L,P} \\ dW_t^{S,P} \\ dW_t^{C,P} \end{pmatrix}.$$

This is the transition equation in the Kalman filter estimation.

To reduce the number of parameters:

- We restrict the Σ matrix to be diagonal (following CDR, 2011).
- 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 has P-dynamics given by

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

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

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.

Model Forecast Performance

Forecasting method	One-year forecast		Two-year forecast	
	Mean	RMSE	Mean	RMSE
Random walk	62.37	113.65	71.26	123.57
Unconstrained AFNS model	44.62	73.67	80.63	93.56
Unrestricted K^P AFNS model	72.80	85.43	110.27	116.27
Indep.-factor AFNS model	51.96	72.89	78.46	90.14
CR (2012) AFNS model	80.94	93.03	118.82	124.77
Preferred AIC AFNS model	71.48	83.23	107.97	113.27
Preferred BIC AFNS model	**54.31**	**73.97**	**80.22**	**91.15**

- 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.

Summary of Model Performance Evaluation

Maturity in months	Preferred AFNS model		
	Mean	RMSE	$\widehat{\sigma}_{\varepsilon}(\tau_i)$
12	-4.78	13.51	13.64
24	-0.12	1.20	1.96
36	0.55	2.04	2.29
60	0.06	0.60	0.92
84	-0.39	1.14	1.44
120	0.00	0.00	2.24

- 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.