Does a Big Bazooka Matter? Central Bank Balance-Sheet Policies and Exchange Rates

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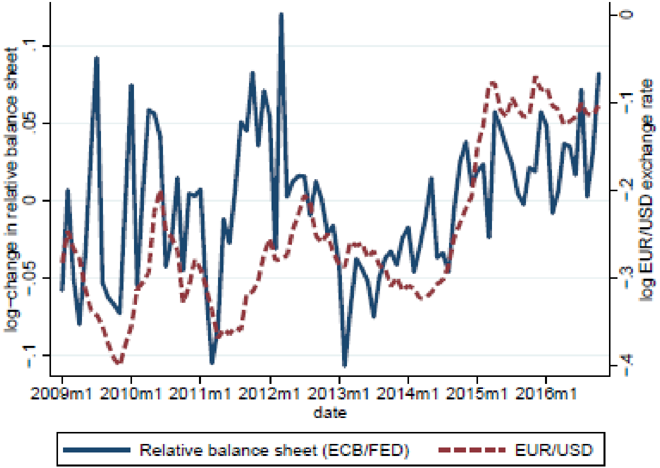
Motivation: Policy and modeling questions

- What are the effects over time of unconventional monetary policy (QE/UMP)?
  - Bulk of the evidence based on high frequency, event studies
- What are their transmission channels?
  - Many frictions have been suggested to rationalize above evidence
  - But estimated effects can also arise in frictionless asset markets, e.g., due to "signaling" — Cochrane (2012), Woodford (2012)
- Focus on dollar-euro exchange rate
  - Exchange rate depends on sum of expected future fundamentals, whose dynamics can be estimated through their impulse responses (Engel (2016))
  - Evidence of failure of basic arbitrage conditions like covered interest rate parity (CIP) by, e.g., BIS (2016)

Correlation relative ECB-Fed balance sheet and EUR/USD

Figure 2: Relative balance sheet movements and the EUR/USD exchange rate



What we do and why

- We build on literature studying news about future policies (Mertens and Ravn 2011)
- Effects of *actual* balance sheet changes occurring after QE/UMP announcements — 2SLS approach
- Estimate impulse responses of spot and forward exchange rate, interest rate differentials, CIP deviations — Local projections
- IRF of expected fundamentals conditional on UMP shocks allow to decompose exchange rate response, similarly to Engel (2016)

Findings

- UMP increasing size of ECB balance sheet relative to Fed's by 1%:
  - Depreciates euro-dollar rate by 1% over 10 months, reduces 3-month interest differential
  - Narrows 3-month CIP deviations in euro-dollar markets — different from Du et al. (2016)
  - Little effects beyond foreign exchange and money markets
- Transmission channels:
  - Large role of currency risk premia — similar to Engel (2016)
  - Limited role of signaling as exchange rate mean-reverting

Selected literature review

- Plenty of event studies on QE, including with focus on exchange rates: Altavilla et al. (2015), Fratzscher et al. (2016), Georgiadis and Graeb (2016),Glick and Leduc (2015), Neely (2015), Rogers et al. (2014), Weale and Wieladek (2016),...
- A few studies based on a VAR approach:
  Gambacorta et al. (2014), Manganelli et al. (2015), Peersman et al. (2014),...
- Contributions on CIP deviations:
  Baba and Packer (2009), Borio et al.(2016), Bottazzi et al. (2012), Du et al. (2016), Ivashina et al. (2015), Mancini Griffoli and Ranaldo (2010),...

Outline

- Exchange rate determination, including role of CIP deviations
- Empirical framework based on IV and local projections
- Results: Evidence on the effects and trasmission of QE/UMP
- A few robustness checks
- Caveats and open issues

Asset pricing formulation of exchange rate determination

Some notation

$R_t^{€}$: risk-free 1-period euro rate

$R_t^{\$}$: risk-free 1-period dollar rate

S_t : spot euro-dollar exchange rate (dollars per 1 euro)

$F_{t,t+h}$: h-period forward euro-dollar exchange rate

CIP deviations

- Given investor's discount factor $\mathcal{D}^{\$}_{t+1}$, standard optimality conditions for safe 1-period investment in cash and "synthetic" dollar:

$$1 \geq 1 - \lambda^{\$}_t = E_t\left(\mathcal{D}^{\$}_{t+1}\right) R^{\$}_t$$

$$1 \geq 1 - \lambda^{F}_t = E_t\left(\mathcal{D}^{\$}_{t+1}\right) \frac{F_{t,t+1} R^{€}_t}{S_t}$$

  Expressions hold with equality if the investor does not face a binding borrowing constraint ($\lambda^{i}_t = 0$) — e.g., long in both assets

- Violations obviously arise if either $R^{\$}_t$ or $R^{€}_t$ risky also when $\lambda^{\$}_t = \lambda^{F}_t = 0$:

$$E_t\left(\mathcal{D}^{\$}_{t+1} R^{\$}_t\right) = E_t\left(\mathcal{D}^{\$}_{t+1} R^{€}_t\right) \frac{F_{t,t+1}}{S_t}$$

Interpreting the sign of CIP deviations

- Write generalized CIP relation

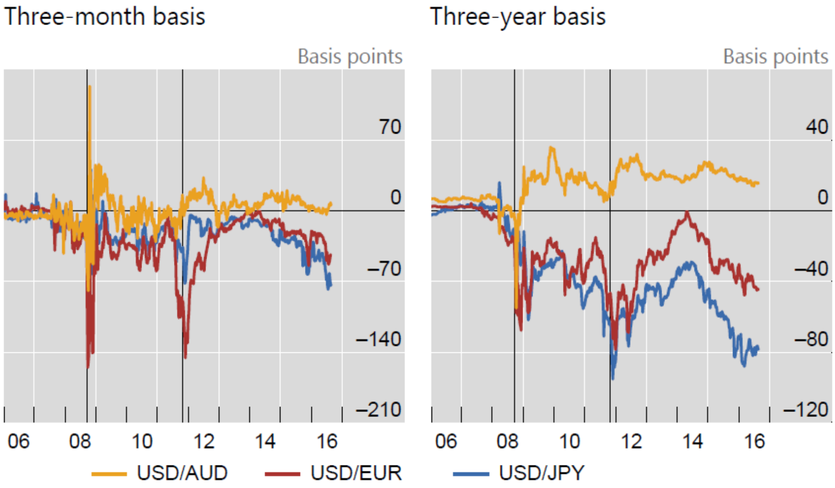
$$R_t^{\$} = \left(\frac{1-\lambda_t^{\$}}{1-\lambda_t^{F}}\right) \cdot \frac{F_{t,t+1} R_t^{€}}{S_t} \equiv (1-\lambda_t) \cdot \frac{F_{t,t+1} R_t^{€}}{S_t}$$

- $\lambda_t > 0 <=> \lambda_t^{\$} > \lambda_t^{F} \geq 0$:
  - Borrowing more expensive at synthetic dollar rate $\frac{F_{t,t+1} R_t^{€}}{S_t}$ than at the cash dollar rate $R_t^{\$}$ (or at the cash euro rate $R_t^{€}$ than at the synthetic euro rate $\frac{S_t R_t^{\$}}{F_{t,t+1}}$)
  - Cash dollar (synthetic euro) borrowing constraints are tighter, two markets are segmented (e.g., Gabaix-Maggiori 2015)

- Market convention is to denote CIP deviations as $\ln R_t^{\$} - \ln \frac{F_{t,t+1} R_t^{€}}{S_t} \simeq -\lambda_t < 0$

CIP deviations (basis) against USD

[1]



[1] Source BIS Quarterly Review, September 2016

Exchange rate determination in asset markets

- Arbitrage equalizes risk-adjusted return of foreign currency investment in dollar-euro forward and spot market:

$$1 - \lambda_t^F = \frac{E_t\left(\mathcal{D}_{t+1}^{\$}\right) F_{t,t+1} R_t^{€}}{S_t} = \frac{E_t\left(\mathcal{D}_{t+1}^{\$} S_{t+1}\right) R_t^{€}}{S_t}$$

- Replace $F_{t,t+1}$ with the CIP, take logs and under log-normality obtain generalized version of UIP:

$$s_t = E_t\left(s_{t+1}\right) + \left(r_t^{€} - r_t^{\$}\right) - \lambda_t + \underbrace{Cov_t\left(d_{t+1}^{\$}, s_{t+1}\right) + 1/2 Var_t\left(s_{t+1}\right)}_{risk\ \ premium \equiv \pi_{t,t+1}}$$

- Solving forward for s_t over T periods:

$$s_t = E_t\left(s_{t+T}\right) + \sum_{j=0}^{T-1} E_t\left(r_{t+j}^{€} - r_{t+j}^{\$}\right) - \sum_{j=0}^{T-1} E_t \lambda_{t+j} + \sum_{j=0}^{T-1} E_t \pi_{t+j,t+j+1}$$

$E_t \lambda_{t+j} > 0$ results in *more appreciated* spot dollar-euro

How shocks affect the exchange rate

- Write the change in the exchange rate as follows:

$$s_t - s_{t-1} = -\left(r^{€}_{t-1} - r^{\$}_{t-1}\right) + \lambda_{t-1} + \pi_{t-1,t} + \Gamma_0' \varepsilon_t .$$

- The coefficients Γ_0' capture the effects of innovations ε_t, $E_{t-1}\left(\varepsilon_t\right) = 0$:

$$\Gamma_0' \varepsilon_t \equiv \sum_{j=0}^{T-1} \left[E_t \left(r^{€}_{t+j} - r^{\$}_{t+j} \right) - E_{t-1} \left(r^{€}_{t+j} - r^{\$}_{t+j} \right) \right] +$$
$$- \sum_{j=0}^{T-1} \left[E_t \lambda_{t+j} - E_{t-1} \lambda_{t+j} \right] + \sum_{j=0}^{T-1} \left[E_t \pi_{t+j,t+j+1} - E_{t-1} \pi_{t+j,t+j+1} \right]$$
$$+ E_t \left(s_{t+T} \right) - E_{t-1} \left(s_{t+T} \right)$$

- In general we can write the following IRF that can be estimated by local projections:

$$E_t s_{t+h} - s_{t-1} = \Omega_{h,t-1} + \Gamma_h' \varepsilon_t ,$$

Implications for QE/UMP shocks

- Two groups of shocks, with ε_t^{QE} the UMP shock to the relative balance sheet:

$$\varepsilon_t = \left[\varepsilon_t^{QE}, \varepsilon_{2t}\right]$$

- ε_{2t} include all other shocks (including shocks to the policy interest rates of the ECB and the Fed, and "money demand" shocks to the relative balance sheet).
- The impulse response to ε_t^{QE} is thus given by the coefficients $\gamma_j^{QE}, j = 0, .., h$
- We can also estimate the impulse responses of fundamentals, including CIP deviations
  E.g., $E_t\left(s_{t+T}\right) - E_{t-1}\left(s_{t+T}\right)$ "signaling" beyond $t + T$

Empirical framework

Anticipated QE shocks

- Allow ε_t^{QE} to include both a component affecting contemporaneously the relative balance sheet ($\eta_{t|t}^{QE}$) *and* one known today but that will affect the balance sheet as of $t+1$ ($\eta_{t+1|t}^{QE}$):

$$\varepsilon_t^{QE} = \eta_{t|t}^{QE} + \phi \eta_{t+1|t}^{QE}$$

- Forward looking exchange rate will react to anticipated ("news") shock $\eta_{t+1|t}^{QE}$:

$$\begin{aligned} s_t - s_{t-1} &= -\left(r_{t-1}^{€} - r_{t-1}^{\$}\right) + \lambda_{t-1} + \pi_{t-1,t} + \\ &\quad \Gamma_{0,2}' \varepsilon_{2t} + \gamma_0^{QE}\left(\eta_{t|t}^{QE} + \phi \eta_{t+1|t}^{QE}\right) \end{aligned}$$

Empirical strategy

- Since $\eta^{QE}_{t+1|t}$ unobserved, posit the following equation for relative balance sheet:

$$\Delta BS_{t+1} = \delta_0 + \eta^{QE}_{t+1|t} + \eta^{QE}_{t+1|t+1} + \delta' \varepsilon_{2t+1} + \rho' X_t$$

$$=> \eta^{QE}_{t+1|t} = \Delta BS_{t+1} - \left[\delta_0 + \delta' \varepsilon_{2t+1} + \eta^{QE}_{t+1|t+1} + \rho' X_t \right]$$

- Substitute out $\eta^{QE}_{t+1|t}$ in the equation for the exchange rate:

$$s_t - s_{t-1} = -\left(r^{€}_{t-1} - r^{\$}_{t-1} \right) + \lambda_{t-1} + \gamma_0^{QE} \left(\Delta BS_{t+1} / \phi \right) - \gamma_0^{QE} \rho' X_t$$
$$+ \gamma_0^{QE} \eta^{QE}_{t|t} - \gamma_0^{QE} \left(\delta_0 + \delta' \varepsilon_{2t+1} + \eta^{QE}_{t+1|t+1} + \right) + \pi_{t-1,t} + \Gamma'_{0,2} \varepsilon_{2t}$$

- Endogeneity bias as ΔBS_{t+1} correlated with other shocks $\eta^{QE}_{t+1|t+1}, \varepsilon_{2t+1}$

A 2SLS approach

- Assume that QE announcements as of time t (a_t^{ECB},a_t^{FED}) can forecast $\eta_{t+1|t}^{QE}$:

$$\eta_{t+1|t}^{QE} = \mu_0 + \mu_1 a_t^{ECB} + \mu_2 a_t^{FED} + u_t$$

- 2SLS estimation of γ_0^{QE} (after some normalizing assumption on ϕ)
  1st stage:

$$\Delta BS_{t+1} = \widetilde{\delta}_0 + \mu_1 a_t^{ECB} + \mu_2 a_t^{FED} + \rho' X_t + \eta_{t+1|t+1}^{QE} + \delta' \varepsilon_{2t+1}$$

  2nd stage:

$$s_t - s_{t-1} = -\left(r_{t-1}^{€} - r_{t-1}^{\$}\right) + \lambda_{t-1} + \gamma_0^{QE}\left(\Delta BS_{t+1}/\phi\right) - \gamma_0^{QE}\rho' X_t +$$
$$\gamma_0^{QE}\eta_{t|t}^{QE} - \gamma_0^{QE}\left(\delta_0 + \delta'\varepsilon_{2t+1} + \eta_{t+1|t+1}^{QE} +\right) + \pi_{t-1,t} + \Gamma_{0,2}'\varepsilon_{2t}$$

- a_t^{ECB},a_t^{FED} uncorrelated with other shocks $\eta_{t+1|t+1}^{QE}, \eta_{t|t}^{QE}, \varepsilon_{2t+1}, \varepsilon_{2t}$ (and unobservable lagged variables)

What if announcements also about contemporaneous QE?

- Announcements in t may also contain information about both current QE shocks $\eta^{QE}_{t|t}$
  - Unfortunately a feature of our monthly dataset as many ECB announcements took place at the beginning of the month, so this cannot be ruled out — but we also use weekly data below
  - In this case, including $\eta^{QE}_{t|t}$ in the error term may yield inconsistent estimates
- As an alternative, use both ΔBS_t and ΔBS_{t+1} to solve for $\eta^{QE}_{t|t}$ and $\eta^{QE}_{t+1|t}$:

$$s_t - s_{t-1} = -\left(r^E_{t-1} - r^\$_{t-1}\right) + \lambda_{t-1} + \gamma^{QE}_0 \left(\Delta BS_{t+1}/\phi + \Delta BS_t\right) + \Omega_{0,t}$$

$$\Gamma'_{0,2}\varepsilon_{2t} - \gamma^{QE}_0 \left[2\delta_0 + \delta'\varepsilon_{2t} + \eta^{QE}_{t|t-1} + \rho' X_{t-1} + \delta'\varepsilon_{2t+1} + \eta^{QE}_{t+1|t+1} + \rho' X\right.$$

  First stage with $(\Delta BS_{t+1} + \Delta BS_t)$ under the further identifying assumption that $\phi = 1$
- Overidentification test given that we have a^{ECB}_t and a^{FED}_t

What else can go wrong?

- Announced QE not really "news"
  - Then exchange rate, asset prices should not react
  - But we also assume all announcements are the same
- Announced QE correlated with interest rate policy
  - While Fed at ZLB, ECB policy rates changed quite a bit, control for this
- Announced QE response to contemporaneous shocks
  - Control for macro news for US and euro area, VIX,...
- Announcements reveal Fed, ECB information about future state of the economy
  - Difficult to control for Fed, ECB forecasts, complication in interpreting "signaling" effects

Empirical specification

- Sample period: January 2009 to December 2016
- Relative balance sheet BS_t is log of ratio of ECB nominal balance sheet to Federal Reserve's balance sheet in their respective currencies
- Estimate response of US and euro area exchange rate, interest rates, CIP deviations, currency risk premia
  - Interest rates: three-month money market rates, two and ten-year bond yields for Germany and US
  - CIP deviations λ_t: three-month and two year basis
  - Cumulated risk premia: Residual from forward solution of exchange rate

Controls

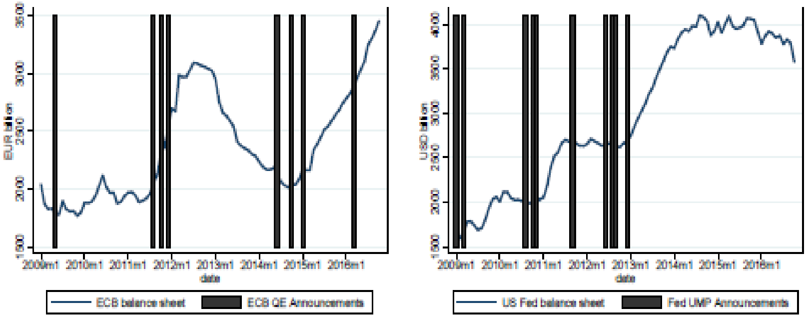
- In the vector of controls X_t, X_{t-1} we include:
  - Lagged announcements and lags of the three-month and two-year interest rate differential, the US dollar-euro exchange rate, the relative balance sheet and CIP deviations
  - Lags and contemporaneous values of the Citigroup Economic Surprise Indices for the US and the euro area, the VIX, and especially of the differential between the main ECB policy rate, the MRO, and the Federal Reserve Federal Fund target
- Change in the balance sheet assumed orthogonal to any change in policy rates, thus controlling for any contemporaneous monetary policy shock to the interest rate

Announcements

- Two sets of dummy variables d_t for announcements a_t^{ECB},a_t^{FED}, unity if the Federal Reserve or the ECB announce a QE measure in period t.
- We consider monetary policy announcements that can be assumed to have a tangible impact on the size of central bank balance sheets (7+7 events)
  - Exclude July 2012 “Whatever it takes" and Outright Monetary Transactions program in Sept. 2012, since they have not resulted in asset purchases so far
  - Also exclude Securities Market Program in 2010, since the associated asset purchases were sterilised and did not increase the ECB's balance sheet
  - Follow Rogers et al. (2014) for Fed (11 events)
- Volatility of changes in yields on the announcement days always exceeds two standard deviations of volatility in sample, consistent with announcements as surprise monetary policy actions

Announcements

Figure 1: Absolute balance sheet movements and QE announcements



Results

Are QE dummies good instruments?

- Benchmark is $BS_{t+1} - BS_{t-1}$ (contemporaneous and future effects of QE announcements)
- QE dummies predict changes in central bank balance sheets
  - Following an ECB announcement, the relative balance sheet expands by almost 4% in the current and next month ($\simeq$ 80 billion euro)
  - A bit surprisingly, Fed dummies have wrong but insignificant sign
- Model passes both the over-identification (Hansen J-test) test and the no-identification (Kleibergen-Paap) test
  - Rely on asymptotic inference but some evidence instruments are weak

Table 3: Regression results - First stage—Baseline ($BS_{t+1} - BS_{t-1}$)

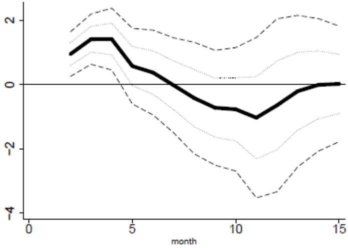
	(1) First stage
L.ECB QE announcement	0.040**
	(2.24)
L.Fed QE announcement	0.009
	(0.53)
ECB QE announcement	0.038***
	(2.65)
Fed QE announcement	0.021
	(1.35)
Observations	95
Hansen-J (p-value)	0.42
Kleibergen-Paap-Test (p-value)	0.01
R-squared	0.49

t statistics in parentheses
Robust standard errors
$^{+}$ $p < 0.15$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

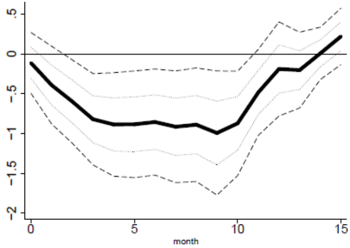
Result 1

- QE shock leads to persistent but temporary expansion in relative balance sheet and euro nominal and real depreciation
- Persistent decline in 3-month interest rate differential, but no strong associated with increase in future policy rates over horizon of exchange rate response
- Temporary response of exchange rate inconsistent with "signaling" over longer horizons

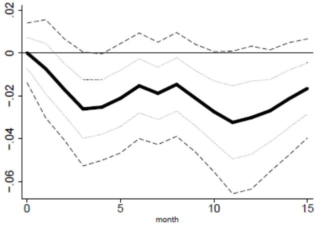
Relative balance sheet
(deviation from baseline in %)



US dollar-euro FX
(US dollar per euro, deviation from baseline in %)

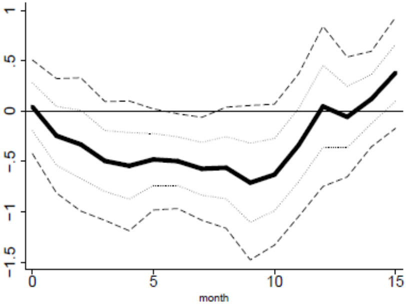


Three-month MM-rate differential (EA-US)
(deviation from baseline in %-age points)

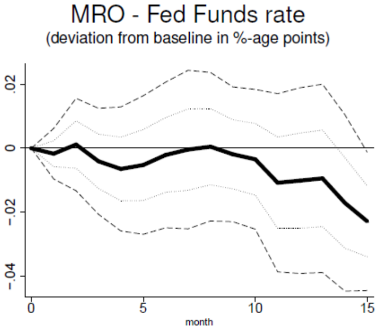


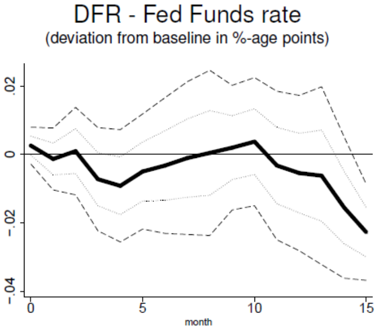
Real exchange rate depreciates

Figure 9: US dollar-euro real exchange rate in levels r_t (US dollar per euro deflated with CPI, %-deviations from baseline)



Counfounding effects from policy rates unlikely





Result 2

- Persistent decline in CIP deviations contributes to dampening euro depreciation:

$$r^{€}_{t,t+3} - \left[r^{\$}_{t,t+3} - \left(f_{t,t+3} - s_t \right) \right] = \lambda_{t,t+3} \downarrow$$

- Narrower spread between money market euro rate and synthetic euro rate, since forward rate discount does not offset fall in interest rate differential
  - Lower deviation implies a relative loosening of borrowing constraints in synthetic euro $\left(\lambda_t \downarrow = 1 - \left(\frac{1-\lambda^{\$}_t}{1-\lambda^{F}_t} \right) \uparrow \right)$
- But bulk of depreciation accounted for by currency risk premia

Figure 6: Three-month CIP deviation and forward-spot rate differential

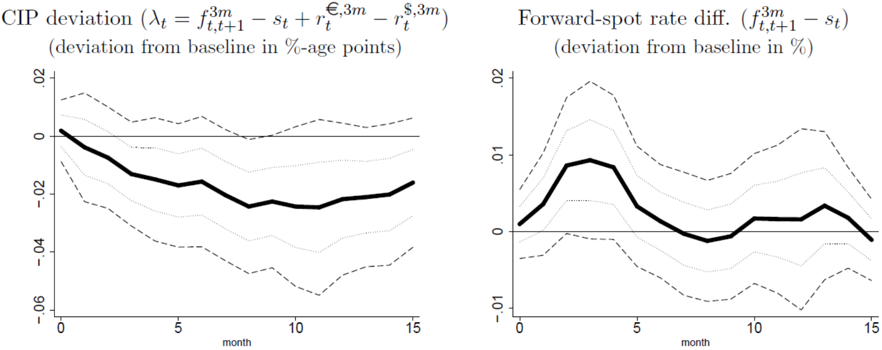
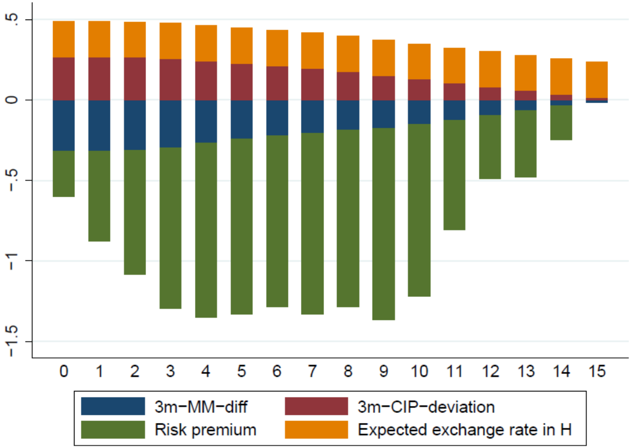


Figure 7: Decomposition of exchange rate response to UMP shocks



$$s_t = E_t\left(s_{t+T}\right) + \sum_{j=0}^{T-1} E_t\left(r^{€}_{t+j} - r^{\$}_{t+j}\right) - \sum_{j=0}^{T-1} E_t \lambda_{t+j} + \sum_{j=0}^{T-1} E_t \pi_{t+j,t+j+1}$$

Result 3

- Little response in longer-term interest rates, but stock prices increase
- Little effect on inflation, industrial production
- Consistent with dominant role in estimation of QE measures prior APP

Robustness exercises

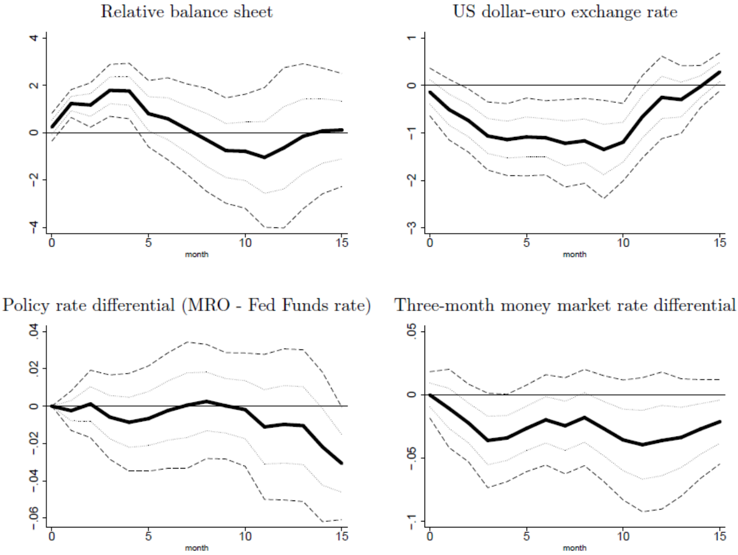
- Use only future balance sheet change ΔBS_{t+1} to check anticipation, normalization
- Document severity of endogeneity bias with OLS estimation
- Drop APP-related annuncements to assess heterogeneity in UMP measures
- Estimation with weekly frequency to control better for timing

Table 4: Regression results - First stage—Robustness 2 ($BS_{t+1} - BS_t$)

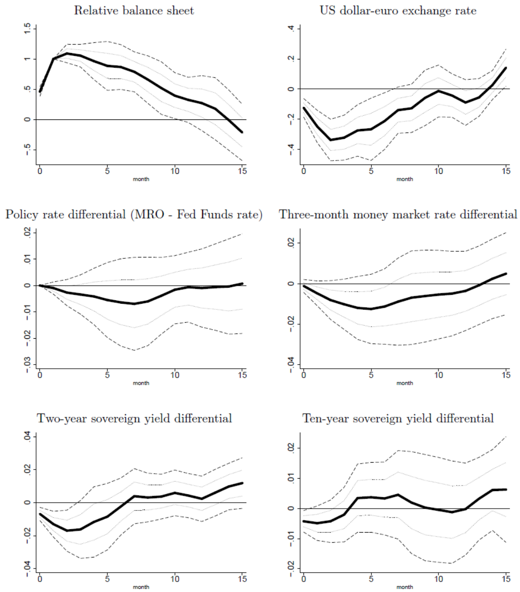
	(1) First stage
ECB QE announcement	0.029***
	(3.17)
Fed QE announcement	0.018*
	(1.74)
Observations	95
Hansen-J (p-value)	0.40
Kleibergen-Paap-Test (p-value)	0.01
R-squared	0.35

t statistics in parentheses
Robust standard errors
$^{+}$ $p < 0.15$, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

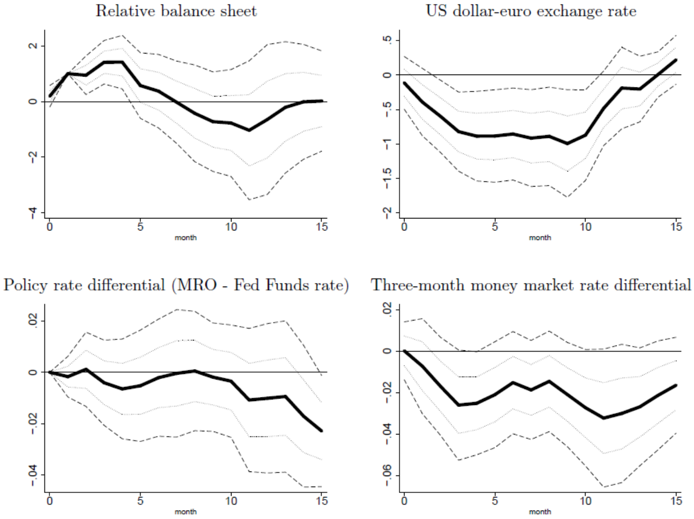
Future balance sheet change



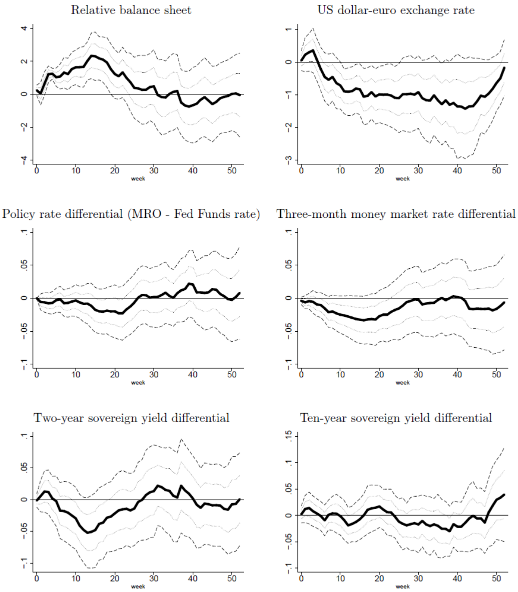
OLS estimation



Excluding APP announcements



Weekly data



Relative balance sheet
US dollar-euro exchange rate
Policy rate differential (MRO - Fed Funds rate)
Three-month money market rate differential
Two-year sovereign yield differential
Ten-year sovereign yield differential
week

Conclusions and open issues

- Evidence of dynamic effects of QE in foreign exchange markets
  - Increase in ECB relative balance sheet leads to euro depreciation, decline in money market rates differential
  - Reduction in CIP deviations, little role for signaling, but large effects from risk premia
- Caveats
  - Empirical model good approximation of markets' expectations
  - Not easy to control for ECB, Fed private info and forecasts
- Room for improvement
  - Instead of 0-1 dummies, weigh announcements differently
  - Other currency pairs