EMERGING FOREIGN EXCHANGE MARKETS AND MONETARY POLICY IN EURO AREA: EVIDENCE FROM THE CRISIS

Milan Nedeljkovic[1]
Nikola Vasiljevic[2]

DOI: https://doi.org/10.31410/EMAN.S.P.2020.11

Abstract: *We examine how emerging market (EM) foreign exchange (FX) markets respond to innovations in the monetary policy in advanced economies over the crisis period. We focus on the case of the European Central Bank (ECB) which pursued a combination of different policies during the Eurozone sovereign crisis. In a new econometric framework, we identify responses of foreign exchange markets in three EM economies (Hungary, Poland and Turkey) to different types of ECB policies. We find weak effect of the ECB's Euro liquidity provisions on the EM foreign exchange markets. In contrast, while the ECB's foreign exchange liquidity provisions as well as government bond interventions and policy rate changes did not impact the FX levels, they led to higher uncertainty in the FX markets. The results are indicative of the additional, uncertainty channels through which monetary policy shocks in advanced economies may affect the business cycle fluctuations in the EM economies.*

Keywords: *Exchange rates, Monetary policy, Uncertainty, Conditional quantiles, MCMC.*

1. INTRODUCTION

The global financial crisis (GFC), which began in the summer of 2007, required central banks to respond on a scale they had not confronted since the Great Depression of the 1930s. Evaporating liquidity, particularly for Dollars, represented the primary short-term concern. The risk of economy falling into a recession with impaired financial markets and elevated uncertainty was the other, deeper worry. In Europe the crisis evolved into the sovereign debt crisis in which the government bond yields of five peripheral countries (Greece, Ireland, Italy, Portugal and Spain, GIIPS) reached unprecedented levels over the 2009–2012 period. The sovereign-bank nexus increased the uncertainty in the European financial sector and elevated the bank solvency and funding liquidity risks.

Central banks can respond to a worsening macro-financial environment with two principal types of polices.[3] The central bank can provide liquidity to stabilize financial markets and support bank lending. In addition, it can provide monetary stimulus through lower nominal interest rates. When the nominal interest rates reach the zero-lower bound, monetary stimulus includes some combination of forward guidance (a credible promise to keep interest rates low for an extended period) and the purchase of financial assets to lower the long-term interest rates.

In the post-2007 years, central banks implemented both types of policies. The major central banks opened up liquidity lines in the early phases of the subprime crises. The Fed also reduced its policy interest rate sharply, bringing it down to nearly zero by December 2008, at which point

[1] FEFA, Bulevar Zorana Đinđića 44, Belgrade, Serbia & CESifo Potschinger Strasse 5, Munich, Germany
[2] University of Zurich, Plattenstrasse 14, Zurich, Switzerland
[3] See e.g. Svensson (2010) for the discussion of different types of policies.

it began forward guidance and large-scale asset purchases. The Bank of England followed similar policy stance. The European Central Bank (ECB), in turn, used a combination of policies throughout the most intense phase of the crises. The ECB provided *Euro liquidity* through variety of measures which included: changes in the design of the open market operations; reduction in the required reserves ratio; changes in the collateral requirements for Euro borrowing; provision of long-term loans to banks and interventions in the covered bond market. The ECB also supplied *foreign currency liquidity* (mostly Dollar) through swap operations with the Fed and the Bank of England. Finally, the ECB provided direct *monetary stimulus* through policy rate changes and interventions in the sovereign bond market. The latter included direct purchase of the sovereign bonds of the stressed countries under the Securities Markets Programme (SMP), as well as the conditional commitment to purchase government bonds (Outright Monetary Transactions, OMT). The measures, in total, were expected to contribute to the reduction of elevated risks and easing of Euro area financial conditions with a positive effect on the real economy.

Over the past two decades the degree of trade and financial integration overall, and of emerging market economies (EM) in particular, has significantly increased. Higher integration of the global economy increased the potential that the impact of domestic shocks may spill over to other economies, especially if the shock originates in one of or several key advanced economies (AE). What is more, the deepening integration gives rise to views that financial conditions and growth worldwide may be driven by a global financial cycle, which in turn is largely driven by monetary policy conditions in the US and Europe (Rey, 2013). While the debate about the extent of monetary policy spillovers has a long history in international economics (being part of the Mundell-Fleming framework), (unconventional) monetary policies in AE over the post-2007 period and volatile capital flows in and out of integrating emerging markets over the same period have brought the spillovers back to the forefront of the policy and academic debate in recent years.

Spillovers to EMs may arise through several channels discussed in the literature (trade, portfolio rebalancing, signaling, liquidity and risk-taking), that are, to some extent, non-exclusive and overlapping. The transmission mechanism of the most of the channels is based on the changes in global investors' behavior and capital flow dynamics which, in the sum, can impact the exchange rate.

This paper studies empirically the importance of the exchange rate channel of monetary policy spillovers from advanced economies to the EM. We focus on the case of the Euro zone crisis and quantify the effect of the ECB monetary policy shocks on the neighboring EM exchange rates during the most intense phase of the Euro zone crisis, 2009-12. In particular, we want to identify any significant differences in foreign exchange (FX) market's reactions to different types of policy actions. The experience of the ECB over the Euro zone financial crisis provides a crucial empirical setup for achieving this goal. The fact that the ECB (unlike other AE central banks) pursued a combination of different policies over this period minimizes the learning bias in the data[4] and facilitates empirical comparison between the effects of different measures. In addition, the focus on the crisis period allows studying the spillovers in time of elevated uncertainty which is informative for the design of optimal policy response in the EM.

We use daily data between October 2009 and September 2012 and examine the changes in the foreign exchange rates vis-à-vis Euro for Hungary, Poland and Turkey. The choice of EM coun-

[4] The learning bias can arise if market participants adapt their actions to the prevailing mode of intervention.

tries reflects the prevailing exchange rate regime (floating) and the availability of sufficiently long data on the comparable measures of local sovereign risk.

We study the exchange rate responses using a recently developed econometric framework that allows for the estimation of causal asset price reactions to multiple shocks in the presence of regional market spillovers and confounding (common) factors (Mody and Nedeljkovic, 2019). In particular, to evaluate the impact of the policy shocks on FX market expectations and uncertainty, we estimated the augmented vector autoregression for quantiles (QVARX, White et al., 2015; Mody and Nedeljkovic, 2019) of the conditional distribution of FX returns. The QVARX framework provides several advantages over the standard regression (vector autoregressive) or event study methodology. It delivers measures of both the market's central predictions (conditional median) and uncertainty (the difference between the upper and the lower conditional tail quantile), which are robust to outliers, departures from normality and misspecification of the volatility process. In addition, the framework features common and individual confounding factors and allows for a more general type of dynamic spillovers between the exchange rates without specifying whether they occur at the conditional mean, volatility or at higher moments of the conditional distribution. We follow Mody and Nedeljkovic (2019) and use an external (to the information embedded in QVARX) measure of policy interventions – the orthogonalized change in suitable policy indicators on the policy announcement days. The estimates of the changes in the FX market's predictions and uncertainty due to the ECB monetary policy innovations are obtained through simulated (generalized) impulse-response functions.

We find weak spillovers of the ECB's Euro liquidity provisions on the European EM foreign exchange markets. The conditional median responses are small and not statistically significant for all three exchange rates. The policy interventions did lead to higher uncertainty in the FX markets; however, the effects are statistically significant only in the case of Turkish Lira. The results are in line with Acharya and Steffen (2015) and Drechsler et al. (2016) who show that European banks that borrowed via the ECB liquidity programs tend to use the funding to invest in risky assets, primarily government bonds. In this way, the newly generated liquidity did not induce significant cross border capital flows to outside of the Euro area (rather, only within Euro area), thereby having a small effect on the neighbouring EM countries exchange rates.

The spillovers from the provisions of foreign currency (Dollar and Pound) liquidity were slightly stronger. The ECB FX policy measures led to appreciation of the EM currencies, though not by a statistically significant degree. In contrast, the measures led to higher FX market uncertainty as the estimated uncertainty responses are persistent and statistically significant for all three currencies. Similarly, monetary stimulus measures only had a marginal effect on the EM currency levels, yet they had stronger and statistically significant effect on the higher uncertainty in the FX markets.

The empirical results imply that in times of the crisis and of heightened financial stress in advanced economy, accommodative monetary policy innovation in that economy may not significantly impact the level of exchange rates in emerging markets which share close financial and trade ties with the AE. This is especially the case if the monetary policy innovations in AE provide uncertain signals about the underlying state of the economy to the market participants, increasing the risks in the AE financial markets (Husted et al, 2019; Mody and Nedeljkovic, 2019) which, in turn, impact the capital flows to EM. Our evidence of elevated uncertainty in the EM FX markets following the AE monetary policy innovations is consistent with the uncertainty spillovers arising from higher monetary policy uncertainty.

To the extent that higher FX uncertainty may dampen the trade flows and investment activity in a given economy (Goldberg, 1993; Darby et al, 1999; Binding and Dibiasi, 2017), our empirical results are indicative about less explored channel through which accommodative monetary policy innovations in AE may affect business cycle fluctuations in the EM economies.

This paper is related to a rapidly growing empirical literature that studies the effects of unconventional policy measures on financial asset prices. The literature's primary focus is on the effects on the US economy (see, inter alia, Krishnamurthy and Vissing-Jorgensen, 2011; Wright, 2012; and Hanson and Stein, 2015). A small subset of literature focuses on evaluating domestic effects of the ECB policy measures (Gambacorta et al, 2014; Falagiarda and Reitz, 2015; Eser and Schwaab, 2016; Krishnamurthy et al, 2017; Mody and Nedeljkovic, 2019). The question of international spillovers to EM economies has gained attention more recently. Chen et al. (2014), Albagli et al. (2018) showed that the US unconventional policy measures reduced longer-term yields and appreciated the EM currencies vis-à-vis US Dollar. Similarly, Falagiarda et al. (2015), Feldkirscher et al. (2017) found that the ECB unconventional measures outside the peak of the crisis led to an appreciation of local currencies against the Euro, rise in equity prices and, to a lesser extent, decrease in the long-term yields in Central and Eastern European countries. In addition, despite the importance of financial market uncertainty (Ludvigson, et al, 2019) for the business cycle fluctuations, the impact of the policy measures on changes in the market perceived uncertainty is largely unexplored in the literature.

We contribute to this literature in several ways. We study causal reactions of EM exchange rates to multiple policy shocks in advanced economy in a more general econometric framework which allows for cross EM market spillovers and confounding global and local factors. We highlight the absence of significant spillovers to the EM economies at the exchange rate level in crisis time. More importantly, estimated significant uncertainty reactions provide new evidence on the differences in which the markets interpreted the policy innovations and new channels through which the shocks can affect the EM economies.

The remainder of the paper is organized as follows: Section 2 presents the dataset. Section 3 discusses econometric approach. Section 4 presents empirical results. Section 5 concludes.

2. DATA

This section presents financial and other data used in empirical analysis (2.1) as well as the measure of the ECB policy changes (2.2).

2.1. Financial Data

We use daily data in all estimations. The sample runs between October 1, 2009 and September 28, 2012. The start date is chosen to match the beginning of the European sovereign crisis which can be traced to mid-October of 2009 when the Greek government officially announced the budget deficit in excess of 12% of GDP, the number more than double the previous forecast of the deficit. We take a more conservative approach and start the sample two weeks earlier allowing for the possibility that some of the movements were already anticipated by the markets. The end date of the sample matches the decrease in financial risks in the Euro zone, exemplified by the strong and continuous fall in the sovereign bond yields of the periphery countries (Greece, Ireland, Italy, Spain and Portugal).

Our primary variables of interest are exchange rates of the neighbouring European EM economies with flexible exchange rate regime – Czech Republic, Hungary, Poland, Turkey and Romania. The data comes from Bloomberg. Figure 1 shows plots of the exchange rate levels and of the corresponding daily changes. We see a general tendency of exchange rate appreciation in EM economies in the late 2009 and early 2010, which lasted relatively longer in the case of the Czech Republic. We also observe several depreciation periods, which largely coincide with periods of heightened stress in the Euro zone financial markets. At the daily changes level, the Hungarian Forint, the Polish Zloty and the Turkish Lira display larger volatility relatively to the Czech Koruna and Romanian Lei, the latter of which changes in a limited manner.

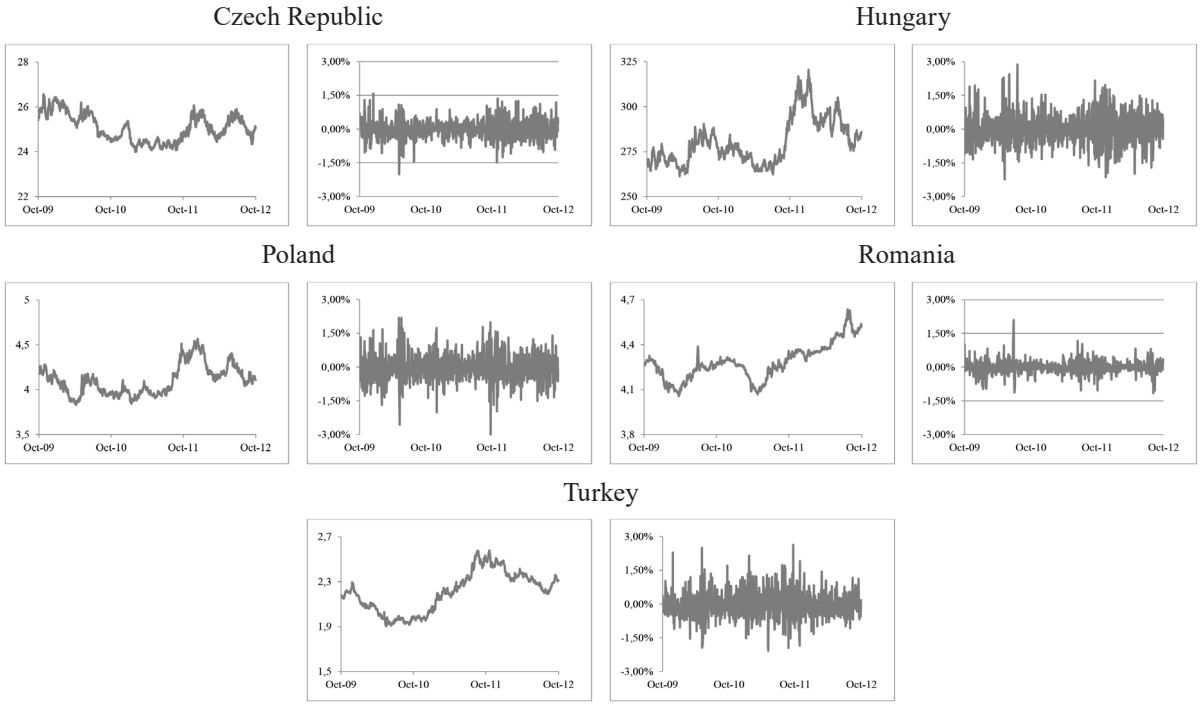


Figure 1. Exchange rate: levels and daily changes

Source: Bloomberg

To control for confounding effects, we include several proxies at the global/Euro zone level, as well as the individual country level. At the global level we include: (i) the VIX index of the implied volatility of S&P 500 stock market index options as a proxy for the general risk aversion of global investors; (ii) JP Morgan's EM VXY index of implied volatility in emerging market currencies (based on at-the-money currency options) as a proxy for the risk aversion of EM currency investors. Both variables are obtained from Bloomberg. The top panel in Figure 2 shows plots of the variables and their daily changes.

At the Euro zone level, we use data on country rating changes, major Euro zone/EU-wide (non-monetary) policy announcements, and economic and political news in the Euro zone periphery countries. The information on rating changes is used from Bloomberg and data are coded following the literature (Gande and Parsley, 2005): the variable takes value zero on days with no rating change for the Euro zone sovereigns and takes the value equal to the number of notches in the downgrade (minus sign for upgrade) on the rating changes days. The changes in the credit outlook and credit watch received value 0.5 (assigned to credit watch / negative outlook) and -0.5 (taken out from credit watch / positive outlook). The data on major Euro zone/EU-wide (non-monetary) policy announcements, and local economic and political news in the

periphery countries is taken from Mody and Nedeljkovic (2019). The authors compiled the narrative dataset over the 2009-2012 period using information from the Bloomberg newswire and performing multiple validation cross-checks to ensure its consistency and coverage.

We complement the global/EU level data with a proxy for the local financial conditions. In order to use a comparable measure across the countries we use country-level EMBI spreads. The data is available from Bloomberg. The EMBI spreads provide a proxy for the sovereign risk premium that is not directly influenced by the exchange rate movements.

The variable, however, is not available for the Czech Republic and Romania for the period of study and we focus our analysis only on the remaining three currencies. Figure 2 (lower panel) reports plots of the available EMBI series, which display slightly higher volatility over the first part of the sample.

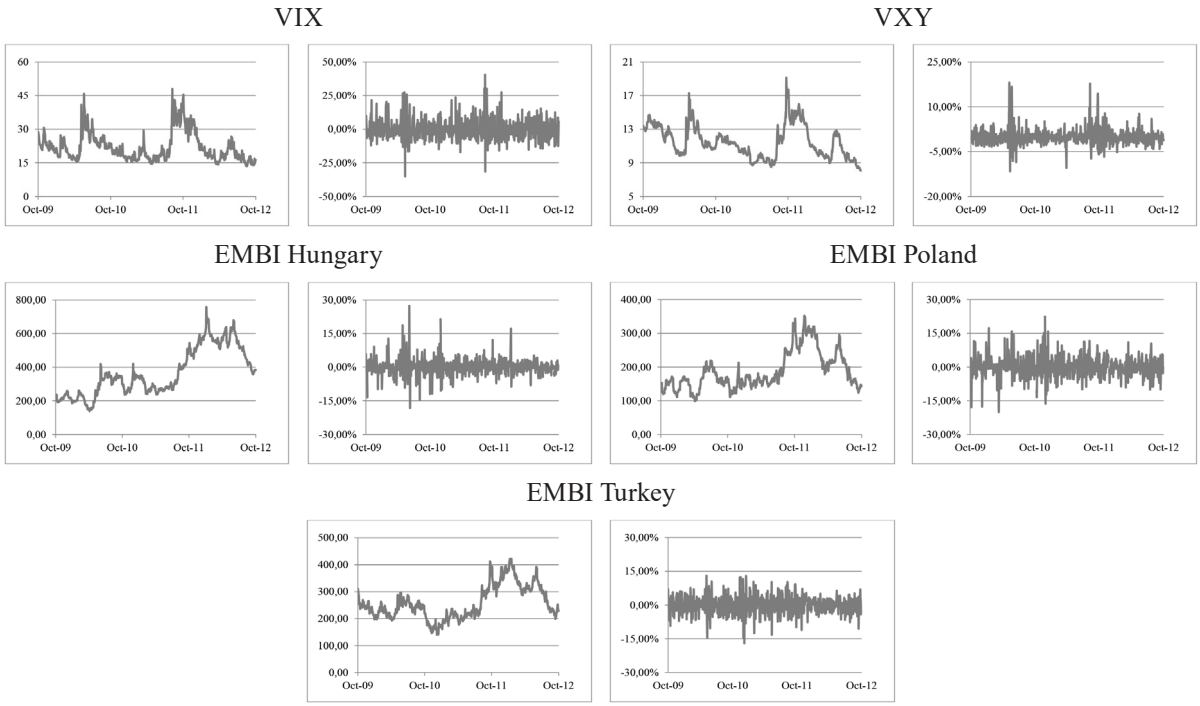


Figure 2. Control variables: levels and daily changes
Source: Bloomberg

2.2. Measure of Monetary Policy Changes

As a last building block of the data framework we use data on the ECB monetary policy innovations from Mody and Nedeljkovic (2019). Their approach builds upon the so-called high frequency approach to identification of monetary policy shocks (Kuttner, 2001) in using changes in financial variables on the policy announcement days as an exogenous measure of policy innovations. The authors distinguish between three types of policy changes – Euro liquidity provision, Dollar liquidity provision and monetary stimulus by using suitable financial variables ("policy indicators") that tend to co-move only with the type of the policy measure of interest. They identify the ECB policy shocks from the daily variation in the policy indicators by cleaning the daily changes from the impact of other (observed) news and public information about the state of the economy through additional orthogonalization step. The obtained series are then a meas-

ure of the component of the specific type of the policy change that is unexpected by the financial markets given their pre-announcement information set. In this way, the constructed measure of the policy change can be included to the empirical specification as an exogenous variable.

3. ECONOMETRIC FRAMEWORK

We are interested in understanding the broader effect of monetary policy innovations in advanced economies on the EM foreign exchange markets that goes beyond their effects on the conditional mean of the univariate distribution of FX changes. Rather, we are interested in studying the effects on the key features of the multivariate conditional distribution. The econometric methodology is based on vector autoregressive model for conditional quantiles, introduced in White et al (2015) and later extended in Mody and Nedeljkovic (2019).

Empirical specification is given in (1):

$$Q_t^{\theta} = \alpha + AQ_{t-1}^{\theta} + B\Delta y_{t-1} + CMP_t + Dx_{t-1} + GN_t \tag{1}$$

where Δy_{t-1} is the K-dimensional vector of the exchange rate changes (in our case K =3), α is the K-dimensional vector of intercepts, MP_t is the vector of the ECB policy changes, x_{t-1} is p-dimensional vector of global and local covariates (p=*2*) and N_t is the *3*-dimensional vector of the news variables (EU-level policy actions, Euro zone country-level rating changes and local news). Q_t^{θ} is the θ^{th} quantile of the conditional distribution $P(\Delta y_t < y \mid \Delta y_{t-1}, MP_t, x_{t-1}, N_t)$. To mitigate the endogeneity concerns the variables x_{t-1} are included with a lag. The specification can arise from a simple VARX model with spillovers in conditional volatility:

$$\Delta y_t = \Psi + \Phi \Delta y_{t-1} + \Pi MP_t + \Lambda x_{t-1} + \Xi N_t + \Sigma_t^{1/2}(\Delta y_{t-1}, MP_t, x_{t-1}, N_t)u_t$$

where the errors u_t come from asymmetric Laplace distribution and the monetary policy innovations, global and local factors and other news can also impact the conditional volatility matrix $\sum_t^{1/2}$. The specification (1) can also arise in various ways from spillovers at higher moments of the conditional distribution or from a VAR with time-varying parameters (White et al, 2015); we therefore do not assume a specific underlying data generating process and focus on directly estimating (1).

The empirical framework offers several advantages. First, it yields a parsimonious framework for studying different types of asymmetries in the FX reactions with weaker distributional assumptions on the underlying data generating process. Second, the VAR allows for dependence of the conditional quantiles of the exchange rate on lagged quantiles and past values of other exchange rates, thereby capturing dynamic spillovers between the regional exchange rates at the distributional level. Third, despite the fact that individual quantile estimates may be of separate interest, we use them to construct the robust measure of the market's central prediction of the exchange rate changes (conditional median) and the robust measure of uncertainty (the difference between the corresponding upper and lower quantile).

We are interested in tracing the contemporaneous and dynamic impact of policy innovations on the proposed measures. The contemporaneous responses can be recovered from estimates of corresponding elements of matrix C. Dynamic responses can be obtained following the dynamic simulation procedure outlined in Mody and Nedeljkovic (2019).

The simulation procedure builds upon the representation of the quantile impulse-responses in the form of the quantile treatment effects. Denote by Z_t^{SH} the state of the variable Z_t following the realization of a specific monetary policy shocks, while Z_t^{NO} denotes the state of the variable when the shock does not hit the system. Given the representation in equation (1), the quantile impulse-responses (QIR) at time t+1 can be represented as[5]:

$$Q_{t+1}^{SH} - Q_{t+1}^{NO} = A\left(Q_t^{SH} - Q_t^{NO}\right) + B\left(\Delta y_t^{SH} - \Delta y_t^{NO}\right) + D\left(x_t^{SH} - x_t^{NO}\right) \quad (2)$$

where we see that QIR depend on the history (the time t at which we evaluate the response) and on the paths of endogenous and other weakly exogenous variables after the shock $\{\Delta y_t^{SH} - y_t^{NO}\}$ and $\{x_t^{SH} - x_t^{NO}\}$. The latter property implies that unless one is willing to assume that paths of these variables are independent of the policy innovation, the QIR cannot be recovered directly from VAR or using local projection methods (Jorda, 2005). The idea that we follow is to simulate the paths $\{\Delta y_t^{SH}, x_t^{SH}\}$ and $\{\Delta y_t^{NO}, x_t^{NO}\}$ from the empirical distribution of the variables within and outside of the time band around the actual time of policy announcements which, in combination with the estimated parameters allows recovering QIR at various horizons h.

The procedure generates dynamic impulse responses at the specific quantile level. The uncertainty responses at horizon h are then constructed as the difference between the two (upper and lower) quantile responses:

$$UNC_{t+h} = \left(Q_{t+h}^{UP,SH} - Q_{t+h}^{UP,NO}\right) - \left(Q_{t+h}^{LOW,SH} - Q_{t+h}^{LOW,NO}\right), h = 0,1....H)$$

4. RESULTS

4.1. The Baseline Specification

The baseline specification is estimated for the conditional median and two tail quantiles (10 and 90). The vector of weakly exogenous variables includes the VIX index of implied volatility and the local EMBI spreads. Matrix A is assumed to be diagonal in estimations for parsimony reasons. In this way, the dynamics of conditional quantile of a particular exchange rate capture the persistence in quantiles (matrix A), spillovers from past changes in all exchange rates (matrix B), the impact of monetary policy innovations in the Euro area (matrix C), the impact of weakly exogenous variables (global and regional factors, matrix D) and the effect of financial and economic news (matrix G).

We estimate the parameters of the model following Mody and Nedeljkovic (2019) which use a Laplace type estimator (LTE) introduced in Chernozhukov and Hong (2003). The LTE is based on the integral transformation of the so-called quantile check (criterion) function, which provides a quasi-posterior distribution of parameters. The estimates are computed as the mean of the quasi-posterior distribution. The quasi-posterior distribution is approximated using Markov Chain Monte Carlo method (MCMC). The MCMC sampling is based on the block adaptive Random Walk Metropolis Hastings algorithm introduced in Roberts and Rosenthal (2009).[6] The starting values of the parameters are based on the estimates from quantile autoregressions for each exchange rate. We run 600,000 iterations of the algorithm with the burn-in of 100,000. We then select every 200th observation to minimize the sampler's autocorrelation. We confirm the good

[5] See Mody and Nedeljkovic (2019) for simple recursion that lead to equation (2).

[6] For details of the algorithm please see Appendix D in Mody and Nedeljkovic (2019).

convergence properties of the sampler following the procedures in Cowles and Carlin (1996). The confidence intervals for QIR are computed using the generated MCMC chain of parameter values. In particular, 2500 parameter values are drawn from the quasi-posterior distribution and, for each draw, the impulse response paths were constructed. The 68-percent confidence intervals are then obtained as the corresponding quantiles of the response paths distribution.

Figure 3-5 present the results from the baseline specification. While all three types of policy innovations are included jointly in the QVARX specification, we present the results in separate figures for each type of the policy change. Each figure presents: 1) shift in the FX market's prediction of the changes in the exchange rate level (conditional median responses, top panel); (2) shifts in the FX market's uncertainty (uncertainty responses, lower panel), both in response to a given change in the ECB monetary policy.

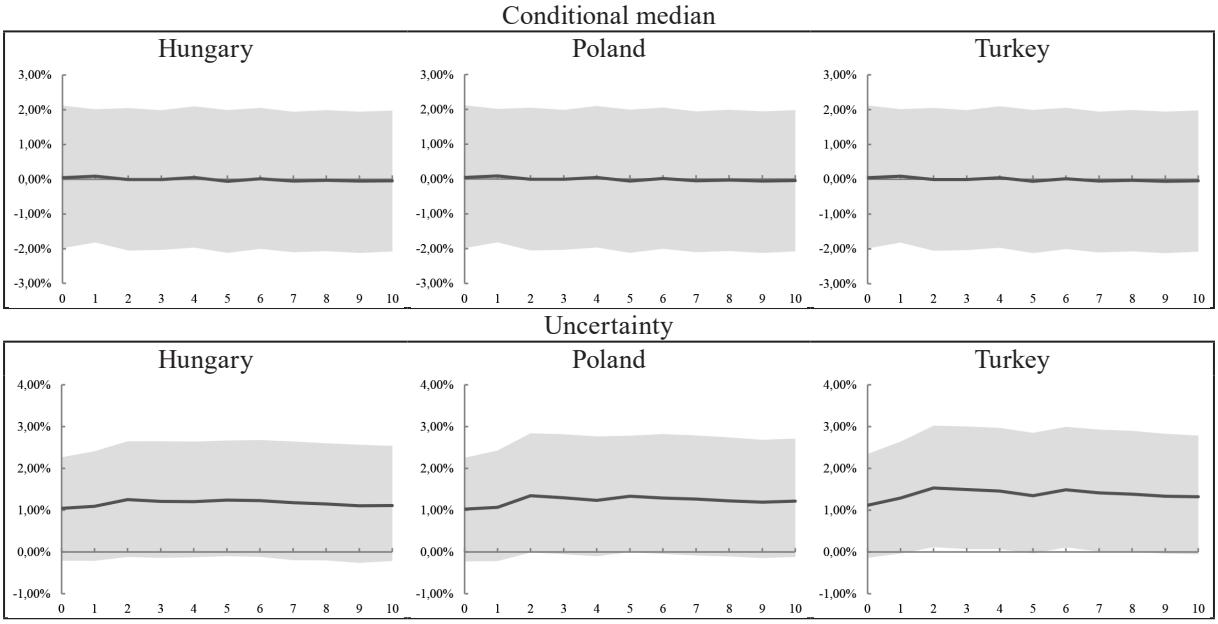
Following Mody and Nedeljkovic (2019) we normalize the size of the ECB policy innovations in order to obtain a broadly comparable measure of responses between different types of policy measures. The size of innovation is normalized at 10^{th} quantile of the empirical distribution of the policy indicators which captures a moderate level of expansionary monetary policy effect. Following the literature we use the excess bank liquidity in the Euro-system as a policy indicator for Euro liquidity innovations (Garcia de Andoain et al., 2016), the Euro-Dollar swap basis as an indicator for Dollar liquidity innovations (Acharya et al. 2018) and the yield on two year Belgium sovereign bond as an indicator of monetary stimulus policy innovations. The use of the latter follows the literature (Hanson and Stein, 2015; Gertler and Karadi, 2015) that advocates the use of changes in sovereign yields at longer maturities (2 year) to capture the information about the expected path of interest rates revealed in the policy change; the use of Belgium sovereign bond is motivated by the fact that this bond remained outside direct purchases by the ECB, yet it displayed some variability over the empirical sample that allows extracting the information about the policy change.

For each type of policy innovation and each exchange rate, we report the contemporaneous and ten-day cumulative reactions (solid line). The shaded areas display the confidence intervals.

The ECB's Euro liquidity provisions had a marginal spillover effect on the EM foreign exchange markets (Figure 3). The conditional median responses are not statistically significant, and in the case of Poland and Turkey suggest small depreciation. The uncertainty in all FX market increases following the Euro liquidity measures. However, the effect is statistically significant only in the case of Turkish Lira, where it tends to decelerate over time and becomes insignificant after nine days.

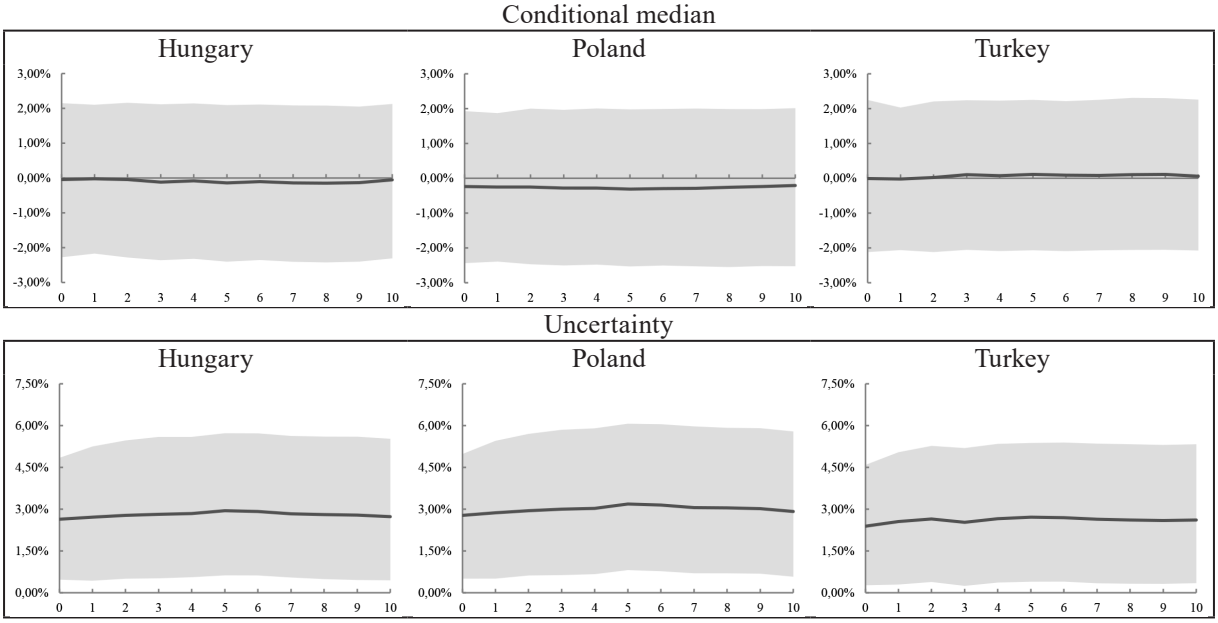
The ECB's FX (Dollar and Pound) liquidity provisions tend to lead to appreciation pressures in the range between 0.1% and 0.5% daily change for the three currencies, yet the estimated effect is not statistically significant (Figure 4). In turn, the FX provision measures exacerbate uncertainty in the FX market. Estimated uncertainty in the EM currencies spikes on the day of policy innovation, and remains elevated throughout the following two weeks. The magnitude and the shape of the response are quite similar in the case of the Hungarian Forint and the Polish Zloty; it is further pronounced in the case of Turkish Lira. The estimated effects are also economically meaningful. While the unconditional daily sample standard deviation ranges between 0.62% (Turkey) and 0.71% (Hungary), estimated uncertainty reactions to (relatively large) ECB policy changes reach between 2.33% (Poland) and 2.92% (Turkey).

Similarly, the *ECB's monetary stimulus measures* did not have a statistically significant effect on the conditional median of the exchange rate changes (Figure 5). However, they also led to a significant increase in the uncertainty. The estimated effect in the case of Forint and Zloty is comparable in magnitude to the effects of the ECB's FX liquidity provisions. In the case of Lira, the estimated uncertainty response to monetary stimulus measures, on the other hand, is lower relative to FX provisions.



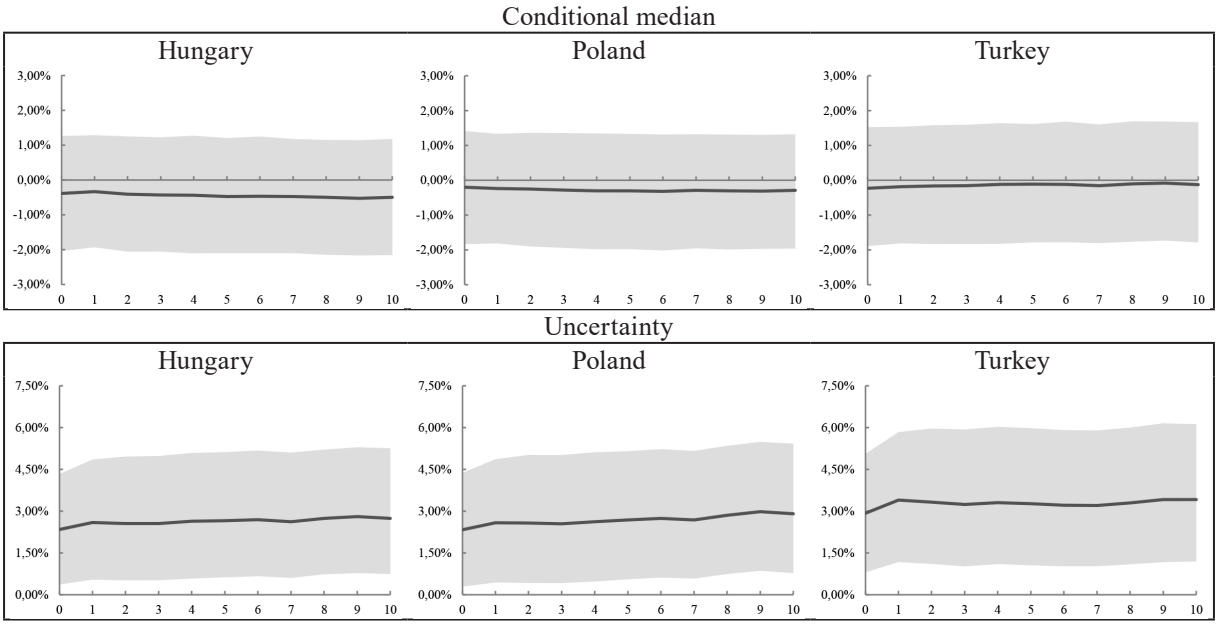
Notes: The figure reports estimated daily cumulative conditional median (top row) and uncertainty (bottom row) response of the change in exchange rates vis-à-vis Euro to the ECB euro liquidity intervention that decreases the Eurosystem excess liquidity by 11.5 bn EUR. The uncertainty is the difference between the 90th and the 10th conditional quantile. The shaded areas are 68% confidence intervals.

Figure 3. Euro liquidity interventions: exchange rate responses (in percentage)



Notes: The figure reports estimated daily cumulative conditional median (top row) and uncertainty (bottom row) response of the change in exchange rates vis-à-vis Euro to the ECB monetary stimulus intervention that decreases the Belgium 2Y sovereign bond yield by 7 basis points. The uncertainty is the difference between the 90th and the 10th conditional quantile. The shaded areas are 68% confidence intervals.

Figure 4. Monetary stimulus interventions: exchange rate responses (in percentage)



Notes: The figure reports estimated daily cumulative conditional median (top row) and uncertainty (bottom row) response of the change in exchange rates vis-à-vis Euro to the ECB foreign exchange liquidity intervention that increases the three months euro-dollar swap basis by 1.2 basis points. The uncertainty is the difference between the 90th and the 10th conditional quantile. The shaded areas are 68% confidence intervals.

Figure 5. Foreign exchange liquidity interventions: exchange rate responses (in percentage)

The obtained results suggest that different types of policy innovations pursued by the ECB during the crisis period had a relatively similar effect on the emerging European foreign exchange markets. The policies did not affect the exchange rate levels in a significant way in these economies. Yet they have led to higher uncertainty in the FX markets. Among the polices, the effects of Euro liquidity provisions are the weakest in line with the notion that that European banks that borrowed via the ECB liquidity programs tend to use the funding to invest in risky assets, primarily Euro zone sovereign bonds (Acharya and Steffen, 2015; and Drechsler et al., 2016). In this way, the newly generated liquidity did not affect capital flows to outside of the Euro area (rather, only within Euro area), thereby having a small effect on the exchange rates of the neighbouring EM countries.

The absence of a significant reaction of the exchange rates contradicts the conventional wisdom that expansionary monetary policy shocks lead to depreciation of the currency of the country that conducts such policy (see Clarida and Gali, 1994 and the subsequent literature). The conventional view typically considers advanced economies and the periods of "normal" business cycle. Our empirical results suggest that in times of the crisis and of heightened financial stress in advanced economy, accommodative monetary policy innovation in that economy may not significantly impact the level of exchange rates in emerging markets which share close financial and trade ties with the AE. This is especially the case if the monetary policy innovations in AE provide uncertain signals about the underlying state of the economy to the market participants, increasing risks in the AE financial markets (Husted et al, 2019; Mody and Nedeljkovic, 2019) which, in turn, impact the capital flows to EM. Our evidence of elevated uncertainty in the EM FX markets following the AE monetary policy innovations is consistent with the uncertainty spillovers arising from higher monetary policy uncertainty. To the extent that higher FX uncertainty may dampen the trade flows and investment activity in a given economy (Goldberg, 1993; Darby et al, 1999; Binding and Dibiasi, 2017), our empirical results are indicative about less explored channel through which accommodative monetary policy innovations in AE may affect business cycle fluctuations in the EM economies.

4.2. Specification Checks

We evaluate the baseline specification from various perspectives. First, we perform formal specification checks of the empirical specification. Second, we study the importance of control variables for the obtained results: we look at the responses to the ECB policy innovations when the set of global confounding factors is alternated. Third, we examine the importance of the choice of the tail quantiles in uncertainty calculations.

We start with the model fit. Table 1 shows the general fit of the model. For each currency/quantile pair, Table 1 reports empirical frequency of the events when the sample exchange rate change is smaller than the estimated conditional quantile (in-sample fit, left part of the cell), as well as the p-values from the general dynamic conditional quantile specification test (Escanciano and Velasco, 2010, right part of the call). Empirical frequencies are close to their population values and the null hypothesis of no misspecification is not rejected for all country/quantile pairs, implying a satisfactory performance of the baseline specification.
Next, we evaluate the choice of the control variables. Taken into account relatively high sample correlation between the VIX, and VXY (above 0.5), we include only one in estimations. The main results are not sensitive to the choice of control variables. Finally, we examine the sensitivity of the estimates of the uncertainty reactions to the selection of baseline quantile levels. We test for this by re-estimating the baseline specification at other quantile levels (15, 20, 80, 85) and constructing an alternative set of uncertainty estimates. The results with VXY (instead of VIX) in the specification and with different quantile levels do not differ qualitatively and often quantitatively from the baseline estimates and for space considerations are not reported (they are available on request from the authors).

In sum, additional specification checks do not detect any significant deficiencies in the baseline specification.

Table 1. QVARX model fit

Quantile	10		50		90	
	Hits	DCQ test	Hits	DCQ test	Hits	DCQ test
Hungary	8.59%	0.12	50.48%	0.37	91.48%	0.19
Poland	8.73%	0.17	50.75%	0.21	92.09%	0.14
Turkey	9.14%	0.28	49.39%	0.35	91.41%	0.22

Notes: For each currency in row and each quantile level in column, Table 1 reports: the percentage of times the actual exchange rate change was below the estimated quantile level (first column); the p-value of the dynamic conditional quantile (DCQ) specification test (second column) of Escanciano and Velasco (2010). The conditioning set under the alternative for each currency in the row includes regressors from equation (1) and up to four lags of the corresponding change in the exchange rate. Critical values of the test statistic are obtained using the approximation procedure outlined in Escanciano and Jacho-Chavez (2010). In calculations we use 2000 draws from 10 independent (m=10 in notation of their paper) standard normal random variables.

5. CONCLUDING REMARKS

This paper examined the response of EM foreign exchange markets to innovations in the monetary policy in advanced economies over the most intensive phase of the crisis. We focused on the case of the European Central Bank which pursued a combination of different policies during

the Eurozone sovereign crisis, which facilitates empirical comparison between the effects of different measures. We applied a recently developed econometric framework that allows identification of causal responses of foreign exchange markets to different types of the shocks across the entire conditional distribution of foreign exchange rates.

We found weak effect of the ECB's Euro liquidity provisions on foreign exchange markets in three neighbouring EM economies (Hungary, Poland and Turkey). In contrast, while the ECB's Dollar and Pound liquidity provisions as well as government bond interventions and policy rate changes did not impact the FX levels, they led to higher uncertainty in the FX markets.

The empirical results suggest that in times of the crisis and of heightened financial stress in advanced economy, accommodative monetary policy innovation in that economy may not significantly impact the level of exchange rates in emerging markets which share close financial and trade ties with the AE. However, if the monetary policy innovation increase uncertainty in the AE financial markets, the potential for uncertainty spillovers to emerging FX markets increases, as documented in our results. The observed rise in FX uncertainty is indicative of the additional, uncertainty channels through which monetary policy shocks in advanced economies may affect the business cycle fluctuations in the EM economies. Further work can explore in more detail the connection between the foreign exchange uncertainty and the real outcomes in the crisis context.

REFERENCES

Acharya, V. V., i S. Steffen (2015). "The Greatest Carry Trade Ever? Understanding Eurozone Bank Risks". *Journal of Financial Economics*, 115(2), 215- 236.

Acharya, V. V., D. Pierret, S. Steffen, (2018). "Lender of Last Resort versus Buyer of Last Resort. Evidence from the European Sovereign Debt Crisis". Discussion Paper 18-035, Swiss Finance Institute.

Albagli, E., Ceballos, L., Claro, S., i D. Romero (2019). "Channels of US monetary policy spillovers to international bond markets". *Journal of Financial Economics (forthcoming)*

Binding, G. and Dibiasi, A., 2017. "Exchange rate uncertainty and firm investment plans evidence from Swiss survey data". *Journal of Macroeconomics* 51, 1–27.

Chen, M. J., Griffoli, M. T. M., R. Sahay, (2014). "Spillovers from United States monetary policy on emerging markets: different this time?". International Monetary Fund Working Paper 14-240.

Chernozhukov, V., H. Hong (2003): "An MCMC Approach to Classical Estimation". *Journal of Econometrics*, 115(2), 293-346.

Clarida, R., J. Gali (1994). "Sources of real exchange-rate fluctuations: How important are nominal shocks?", in: *Carnegie-Rochester conference series on public policy* (Vol. 41, pp. 1-56). North-Holland.

Darby, J. Hughes Hallett, A. Ireland, J. and Piscatelli, L. 1999. "The impact of exchange rate uncertainty on the level of investment". *Economic Journal* 109, 55-67.

Drechsler, I., T. Drechsel, D. Marques-Ibanez, and P. Schnabl (2016): "Who Borrows from the Lender of Last Resort?" *The Journal of Finance*, 71(5), 1933-1974.

Escanciano, J. C., C. Velasco (2010). "Specification Tests of Parametric Dynamic Conditional Quantiles". *Journal of Econometrics*, 159(1), 209-221.

Eser, F., and B. Schwaab (2016): "Evaluating the Impact of Unconventional Monetary Policy Measures: Empirical evidence from the ECB's Securities Markets Programme". *Journal of Financial Economics*, 119(1), 147-167.

Falagiarda, M., and S. Reitz (2015): "Announcements of ECB Unconventional Programs: Implications for the Sovereign Spreads of Stressed Euro Area Countries". *Journal of International Money and Finance*, 53, 276-295.

Falagiarda, M., P. McQuade, M. Tirpak. (2015). "Spillovers from the ECB's Non-standard Monetary Policies on Non-euro area EU Countries: Evidence from an Event Study Analysis". *ECB Working Paper Series 1869*. Available at:
(https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1869.en.pdf)

Feldkircher, M., Gruber, T., F. Huber (2017). "Spreading the word or reducing the term spread? Assessing spillovers from euro area monetary policy". Working Paper 248, Wien University (https://epub.wu.ac.at/5554/1/wp248.pdf)

Gambacorta, L., B. Hofmann, and G. Peersman (2014): "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-country Analysis". *Journal of Money, Credit and Banking*, 46(4), 615-642.

Gande, A., D. C. Parsley (2005): "News Spillovers in the Sovereign Debt Market". *Journal of Financial Economics*, 75(3), 691-734.

Garcia-de Andoain, C., F. Heider, M. Hoerova, S. Manganelli (2016). "Lending-of-last-resort is as Lending-of-last-resort Does: Central Bank Liquidity Provision and Interbank Market Functioning in the Euro Area". *Journal of Financial Intermediation*, 28, 32-47.

Gertler, M., P. Karadi (2015). "Monetary Policy Surprises, Credit Costs, and Economic Activity". *American Economic Journal: Macroeconomics*, 7(1), 44-76.

Goldberg, L.S. 1993. "Exchange rates and investment in United States industry". *Review of Economics and Statistics* 75, 575-589.

Husted, L., Rogers, J. and Sun, B., 2019. "Monetary policy uncertainty". *Journal of Monetary Economics forthcoming*

Hanson, S. G., J. C. Stein (2015). "Monetary Policy and Long-term Real Rates". *Journal of Financial Economics*, 115(3), 429-448.

Jorda, O. (2005): "Estimation and Inference of Impulse Responses Local Projections". *American Economic Review*, 95(1), 161-182.

Krishnamurthy, A., and A. Vissing Jorgensen (2011): "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy." *Brookings Papers on Economic Activity,* 42, 215-287.

Krishnamurthy, A., S. Nagel, and A. Vissing-Jorgensen (2017): "ECB Policies Involving Government Bond Purchases: Impact and Channels". *Review of Finance*, 22(1), 1-44.

Kuttner, K. N. (2001). "Monetary Policy Surprises and Interest Rates: Evidence from the Fed funds Futures Market". *Journal of Monetary Economics*, 47(3), 523-544.

Mody, A., and M. Nedeljkovic. 2019. "Central Bank Policies and Financial Markets: Lessons from the Euro Crisis". CESifo Working Papers 7400, Munich". (https://sites.google.com/site/mnedelj/research)

Rey, H. 2013. "Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence." In: Federal Reserve Bank of Kansas City Jackson Hole Economic Policy Symposium proceedings, 285–333.

Roberts, G. O., J. S. Rosenthal (2009). "Examples of Adaptive MCMC". *Journal of Computational and Graphical Statistics*, 18(2), 349-367.

Svensson, L. E. (2010): "Monetary Policy and Financial Markets at the Effective Lower Bound." *Journal of Money, Credit and Banking*, 42, 229-242.

White, H., T.-H. Kim, and S. Manganelli. 2015. "VAR for VaR: Measuring Tail Dependence Using Multivariate Regression Quantiles." *Journal of Econometrics* 187(1), 169-188.

Wright, J. H. (2012): "What Does Monetary Policy Do to Long-term Interest Rates at the Zero Lower Bound?". *Economic Journal*, 122(564), 447-46.