PANOECONOMICUS, 2022, Vol. 69, Issue 2 (Special Issue), pp. 315-332
Received: 27 January 2022; Accepted: 24 March 2022.

UDC 338.23:336.74]:336.748.12(497.11)
https://doi.org/10.2298/PAN2202315N
Original scientific paper

Milan Nedeljković
Corresponding author
Metropolitan University,
FEFA,
Belgrade,
Serbia
✉ mnedeljkovic@fefa.edu.rs

Nebojsa Savić
Metropolitan University,
FEFA,
Belgrade,
Serbia
✉ nsavic@fefa.edu.rs

Spillovers of Monetary Policy Shocks on Financial Markets during the Crisis: Serbia and Euro Zone

Summary: The position of developing countries (DC) in the international financial system is the topic on which Dragoslav Avramović worked throughout his successful scientific career. This paper extends his research towards an empirical analysis of the importance of spillovers from the changes in the monetary policy of the European Central Bank (ECB) on the country risk premium and exchange rate in Serbia over the most intense phase of the Euro crisis (2008-2012). Empirical results suggest that the ECB policy changes during the crisis significantly spilled over to financial markets only in several dimensions. The policies did not have a statistically significant effect on the level of the exchange rate and of the risk premium. However, they had a significant effect on the rise in uncertainty, especially in the case of ECB's foreign exchange liquidity and monetary stimulus measures. Our empirical results imply that the changes in monetary policy in advanced economies can drive uncertainty spillovers across the financial markets, thereby also affecting the business cycle fluctuations in emerging markets (EM).

Keywords: Monetary policy, Financial markets, Uncertainty, Conditional quantiles.

JEL: E44, E58, F31, F34.

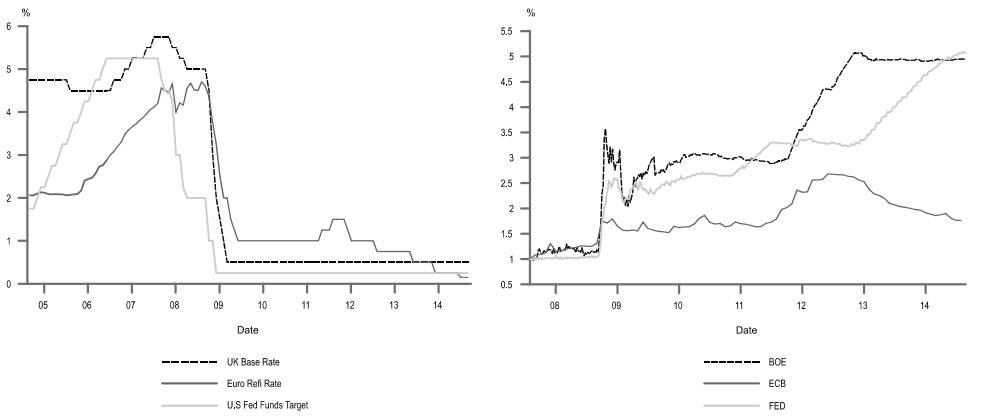
On the anniversary of the birth of Dragoslav Avramović, we prepared a study that corresponds to his lifelong research agenda – analysis of the position of a DC in the global financial system through the prism of its exposure to monetary policy spillovers. Debate on the level of spillovers of monetary policy measures between the countries has a long history. The implementation of unconventional monetary policy measures by advanced economies since the aftermath of the 2007-08 crisis and consequent volatile capital flows to and from the DC and EM have nevertheless propelled the study of the spillover effects of monetary shocks back in the focus of the debate.

This paper empirically analyses the impact of changes in the ECB's monetary policy on the country risk premium and exchange rate in Serbia during the most intense phase of the Eurozone crisis (2009-2012). Focusing on the crisis period (Eurozone) enables an analysis of the intensity and the type of spillovers during the period of major market disruptions, which is of the key interest for policymakers.

The paper analyses the ECB case which implemented several different measures, with different timing of implementation, and different expected direction of

effect on financial markets during the analysed period. The time variability regarding the applied measures separates the ECB from other key central banks (the FED and the Central Bank of England), which have implemented policies in a largely consistent timeline since the start of the global financial crisis – providing liquidity to the domestic financial system, aggressively lowering policy rate to levels close to zero, and early entry into the quantitative easing programme (Figure 1) On the other hand, the ECB lowered the policy rate more slowly and at the same time adopted various measures to provide additional euro and dollar liquidity to the financial system. The ECB also simultaneously intervened in the government bond market of peripheral Eurozone countries (Greece, Italy, Ireland, Portugal and Spain). Through direct purchases of these bonds within the Securities Markets Program (SMP) and through contingent liabilities on purchases of the same bonds through the Outright Monetary Transactions (OMT) policy.

The fact that the ECB has applied several measures that overlap over time is crucial for econometric identification and comparison of the effects of the different implemented measures. If the central bank applies one type of measure over one period and the second type during another (non-overlapping) period, market participants tend to adjust their behaviour to the prevailing measure (enhanced by the learning effect). In that case, an econometric analysis that includes both periods can, under suitable conditions, provide the estimate of the policy effectiveness within a period, but not a comparison of the effects of different measures (since the behaviour of market participants will be based on their learning that the central bank applies only one measure within a period)[1]. The time variability and overlap in the implementation of different measures by the ECB, therefore, allows us not only to evaluate the effects of individual measures but also to compare the effects between them.



Source: Andrea Buraschi and Paul Whelan (2015).

Figure 1 Interest Rate Movements and Balance Sheet Assets at the World's Leading Central Banks during the Crisis

[1] In the literature this is the example of the "learning bias".

The analysis used daily data between October 2009 and September 2012, which is the most intense period of the Eurozone crisis. The paper applies a new econometric framework that allows causal assessment of dynamic reactions of financial markets to shocks in the monetary policy of a particular country in the presence of other potential influences (Ashoka Mody and Milan Nedeljković 2018). More specifically, the augmented VAR model was applied to the quantiles of the conditional distribution of changes in the dinar exchange rate against the euro and the EMBI index for Serbia (QVARX). The QVARX model, proposed in Halbert White, Tae-Hwan Kim, and Simone Manganelli (2015) and Mody and Nedeljković (2018), has significant advantages over standard regression (and VAR) models or case studies. The model enables the analysis of the degree to which the ECB's policies affect changes in the level of financial variables (conditional median), but also the extent to which they affect uncertainty in a particular financial market (measured by the difference between the upper and lower quantiles).

In this way, a complete picture of the effects of monetary policy measures is provided while imposing weaker assumptions about the statistical process that generates data relative to alternative estimation methods. The model also enables the inclusion of potential control variables to more accurately isolate the impact of shocks that are subject to interest.

We use exogenous (relative to the QVARX model) measures of shocks in the ECB's policy. Three types of ECB policies were analysed: *provision of additional EU liquidity, provision of additional dollar liquidity and monetary stimulus measures*. A specific measure, as in Mody and Nedeljković (2018), is defined as a daily change in the relevant monetary policy indicator on the day of the announcement of the policy by the ECB, which is further orthogonalised (cleaned) from the impact of current political and economic news in that day, as well as from all publicly available information up to that day. The resulting measure is, therefore, an exogenous component of monetary policy change that is not expected by market participants ("shock"). Estimates of the exchange rate and EMBI responses to policy shocks were obtained based on the estimated QVARX model using a simulated impulse and response function.

The results suggest that the three types of ECB policies implemented during the 2009-2012 crisis had a limited spillover effect on the level of the exchange rate and of the risk premium in Serbia, largely not statistically significant. At the same time, the results suggest that some of the policy measures had a statistically significant effect on increasing uncertainty in these markets. The euro liquidity measures have not significantly affected uncertainty in the foreign exchange market, while on some horizon, they did increase uncertainty about risk premium; the effect, however, is not long-lasting. On the other hand, dollar liquidity measures and monetary stimulus measures had a statistically significant effect on increasing uncertainty in both financial markets.

These results suggest that during a period of crisis and increased uncertainty in the financial markets of advanced economies (AE), expansionary monetary policy measures in AE may not affect exchange rate levels and risk premiums in EMs which are significantly linked to trade and financial flows with AE. This result differs from theoretical settings where expansionary monetary policy measures in one country lead to the depreciation of that currency relative to the other. The absence of a significant

effect[2] can be explained by the fact that the central bank's policy measures also provide a *signal* (Leonardo Melosi 2016) to market participants about the future character of monetary policy, as well as the signal about the current state of the economy at times of implementation of measures (not necessarily just the direction of policy action). In a crisis, central bank measures can therefore lead to increased uncertainty in the domestic financial market if interpreted differently by market participants (Lucas Husted, John Rogers, and Bo Sun 2019)[3]. The heightened uncertainty in AE financial markets can lead to lower capital flows towards EMs, leading to the absence of the effects of expansionary measures on risk premium levels and exchange rates in a less developed country, such as the result we find in the Serbia's case. Our results on the growth of uncertainty in financial markets further favour a spillover channel of uncertainty about monetary policy in the AE on financial markets in an EM economy.

To the extent that more uncertainty in the foreign exchange market and about the risk premium affects the behaviour of market participants, and through this, the level of investment and exports at the aggregate (Linda S. Goldberg 1993; Garret Binding and Andreas Dibiasi 2017) the empirical results point to an additional channel through which expansionary shocks in the monetary policy of advanced economies can affect economic cycles in EMs.

In addition to links to previous work by Avramović, our work fits into the wider and growing literature that analyses the spillovers of monetary shocks developed from advanced to DC and EM. Jiaqian Chen, Tommaso Mancini-Griffoli, and Ratna Sahay (2014), Diana Ayala, Nedeljković, and Christian Saborowski (2017), Elias Albagli et al. (2019), among others, find that unconventional US FED measures lead to the decline in long-term EM government bonds, as well as to the appreciation of their currencies. Mateo Falagiarda, Peter McQuade, and Marcel Tirpak (2015) and Martin Feldkircher, Thomas Gruber, and Florian Huber (2017) also find an appreciation of domestic currencies against the euro, increase in equity indices and a fall in domestic bond yields in Central and Eastern Europe (CEE) countries as a result of the implemented ECB's measures. Our work contributes to this literature in multiple dimensions. First, the paper assesses the causal reaction of risk and exchange rate premiums to different shocks in monetary policy in a more flexible econometric framework relative to the literature. In addition, we document a limited level of spillovers from the expansionary monetary policy measures in the AE to the level of exchange rates and the country's risk premiums in the EM during the crisis period. Finally, the significant estimated uncertainty reaction of financial markets indicates differences between the perception of financial participants with respect to the spillover of effects of monetary policy changes in AE and potentially emphasizes a new channel through which financial shocks in advanced economies can affect business cycles in DC and EM.

The following section briefly reviews the literature on spillovers in contemporary conditions. Section 2 presents data used in the paper, including a measure of the shocks in the ECB policy. Section 3 describes the econometric methodology, Section 4 displays empirical results, and Section 5 summarises the findings.

[2] The absence of a significant effect may also be due to the monetary policy response in the EM, which has been considered in the paper through inclusion of appropriate local control variables.
[3] For empirical analysis in the case of ECB see Mody and Nedeljković (2018).

1. Spillovers in Contemporary Conditions

The spillover effect relates to the impact events in one economy can have on other economies. The effects can be positive and negative, depending on the character of the initial shock and its direction. The spillovers can be amplified by the network effects which in the era of overall globalisation of trade and financial flows are gaining increasing importance.

The topic of monetary spillovers in economic literature has been thoroughly studied, both between the advanced economies and between the AE and EMs. The literature is too wide to be summarized here and we provide a very selective overview.

We particularly highlight the views of Raghuram Rajan. In several speeches, Rajan has stressed the need to address the monetary policy spillovers from advance economies to EMs (Raghuram Rajan 2014, 2015). He emphasized the need to look beyond a purely domestic mandate and take into account the first and the second-round effects of monetary policy changes in advanced economies on the global economy. In addition, he advocated strong international co-ordination in the conduct of monetary policies. The policymakers in the US, Canada, France, Germany, Italy, and Japan agreed for stronger cooperation following the Euro crisis. Nevertheless, they also reaffirmed that their fiscal and monetary policies will continue to be oriented towards meeting domestic goals using domestic instruments (Stephen Cecchetti et al. 2019).

The level and the intensity of spillovers indeed increased from the aftermath of the global financial crisis and with the implementation of unconventional monetary policy measures (Chen, Mancini-Griffoli, and Sahay 2014; Albagli et al. 2019). Falagiarda, McQuade, and Tirpak (2015) and Feldkirscher, Gruber, and Huber (2017), among others, documented the presence of the different types of spillovers in the financial markets. Isabella Modder (2017) showed the significant effect of ECB's unconventional monetary policy measures on price and industrial production dynamics in several Southeast Europe countries. She also showed that the exchange rate did not significantly contribute to price and production dynamics, implying that the exchange rates did not play the role of the shocks absorber in the case of the spillovers from the ECB's unconventional policy measures.

Analysing the transmission of the unconventional monetary policy shocks by the FED and the ECB, Marek Jarociński (2019) showed that US monetary policy shocks exercise a very strong effect on the Eurozone, mainly through financial channels, but not on trade. In contrast, the ECB monetary policy shocks have no notable effect on the US.

2. Data and ECB Policy Changes

This section presents basic data used in the analysis (2.1), as well as a measure of ECB policy changes (2.2).

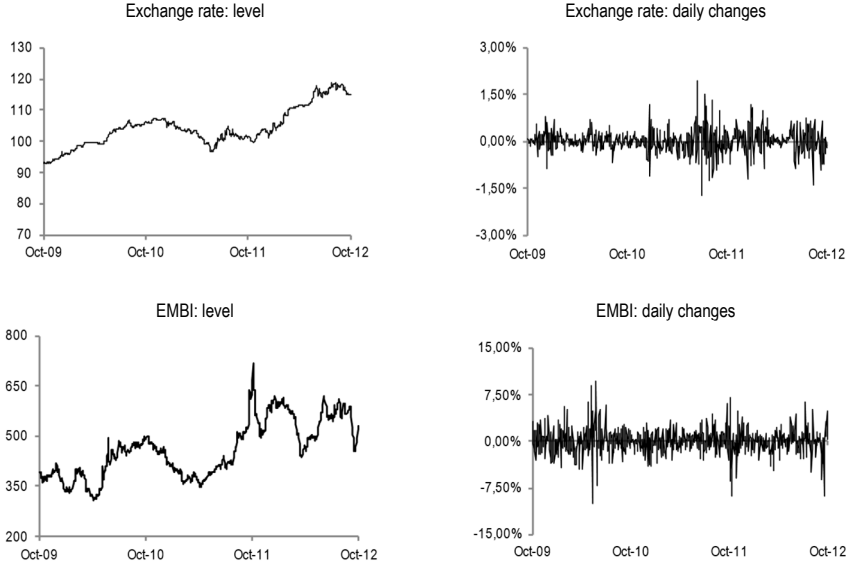
2.1 Data

Data used in the paper comes from multiple sources. All data are provided daily for the period from 1 October 2009 to 28 September 2012. The analyzed period covers the most intense phase of the Eurozone crisis. The beginning of the Eurozone crisis dates back to October 2009, when Greek officials for the first time publicly presented data on the high budget deficit, which produced the first wave of growing uncertainty in

European financial markets[4]. September 2012 was taken to complete our sample, when the stress in the European financial markets and the continuous fall of interest rates on government bonds of peripheral countries had already subsided.

Dependent variables used in the analysis are dinar/euro exchange rate (defined as the number of units of local currency for 1 EUR) and the Serbian Emerging market bond index (EMBI). The EMBI index is taken as a basic measure of the country's risk premium, which does not directly depend on the exchange rate of the dinar towards the euro (as it is calculated based on bonds expressed in the dollar). Data for both variables were retrieved from Bloomberg and are displayed in Figure 2.

To isolate the level of spillovers from the policy changes to dependent variables, several control variables are included in the analysis. To control the impact of global shocks, including the FED policy changes, the analysis includes data for the VIX index (a measure of the implied volatility of options on the S&P 500 index), as a measure of the risk aversion for global financial investors (which is also influenced by the FED's policies); and JP Morgan's VXY index (a measure of implied volatility of options on the foreign exchange rates of the EM countries) as a measure of the risk aversion of global investors in EMs, which includes Serbia. Both variables were retreived from Bloomberg, and their movements are shown in Figure 3 (top panel).



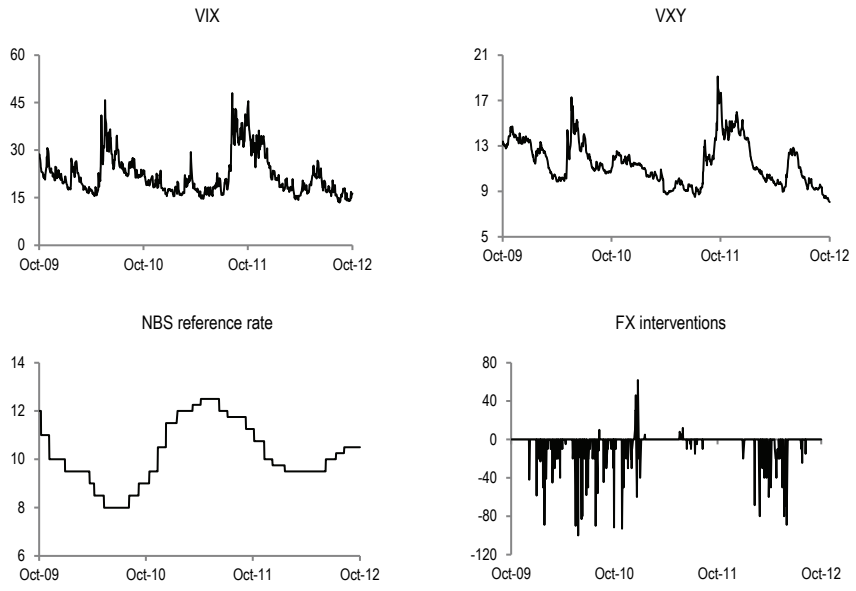
Source: National Bank of Serbia and Bloomberg.

Figure 2 Dinar/Euro Exchange Rate and EMBI

[4] Two key statements during this period with a strong impact on financial markets were the statement by the Governor of the Central Bank of Greece that the budget deficit in that year could exceed 12% of GDP (October 9) and the statement of the new Greek Finance Minister that the current budget deficit year amounted to about 12.5% of GDP, which was almost twice as much as the percentage communicated by the government (October 20).

Data on changes in government bond ratings, news of political and economic changes at the European Union level, and important political and economic news in peripheral economies were used for additional control at the eurozone level. The data source for credit rating changes is again Bloomberg. Based on the source data, an artificial rating variable is constructed that takes a zero value on the days when there was no change in ratings for eurozone countries, while on the days of the change in ratings, the value of the variable is equal to the number of rating categories for which the ratings have been changed (positive values for rating growth, negative for decline), which is in line with the approach in existing literature (Amar Gande and David Parsley 2005). News data was retrieved from Mody and Nedeljković (2018), where the news series was manually constructed through a detailed analysis of individual news from the Bloomberg platform and through several validation checks from alternative news sources to ensure its comprehensiveness and consistency. Based on the news series, dummy variables are constructed that take a non-zero value on days with important news.

Data on changes in the National Bank of Serbia's policy rate (NBS) and foreign exchange market interventions were used to control the impact at the local level. Both data types were retrieved from the NBS. Based on the source data, FX intervention variable is constructed to take positive value on the days of net purchase of the euros by the NBS, a negative value on the days of euro sales and zero value on days without the intervention. The sample dynamics of these variables are displayed in Figure 3 (lower panel).



Source: National Bank of Serbia and Bloomberg.

Figure 3 Control Variables

2.2 Monetary Policy Changes

The last data type used in the analysis is the data on the ECB policy shocks. Data were taken from Mody and Nedeljković (2018). The main challenge in the econometric assessment of the response of a given dependent variable to changes in monetary policy is how to isolate/identify the actual measure of policy change from the influence of many other factors (which can affect both dependent variables and the central bank's decision). The measure we want should represents an exogenous (relative to other variables in the model) and an unexpected policy change, that is, a "shock". There are several approaches in the literature, starting with setting certain types of restrictions on the existence or the sign of the relationships between the included variables, which enables the identification of structural (exogenous) shocks from the estimated residuals of the reduced form model; through the use of external proxies (instruments) to identify the structural component based on the estimated residuals from the reduced model form; to the construction of a direct measure of shocks using historical sources (the so-called narrative approach, popularised initially in Christian D. Romer and David H. Romer 2004) or by using a change of a certain financial variable at (ultra) high frequency. The latter approach, initially proposed in Kenneth N. Kuttner (2001), is based on the idea of observing the change of a certain financial variable (federal funds rate in his paper) in the short-time horizon around the central bank announcement of policy change. In that case, if the variable summarises all publicly available information that can impacts the character of monetary policy, then its change in the short window surrounding the announcement (half-hour or one day depending on the approach) will reflect a part of the policy that is unexpected and exogenous for market participants based on their prior information (i.e., a shock). An additional assumption of this approach is that during the period in which the change of the variable is measured, there is no new news on the financial market that could affect its movement and thus contaminate the calculated measure of shock.

The shock measure proposed in Mody and Nedeljković (2018) modifies the high-frequency approach to shock identification. The process consists of two steps. The first step calculates daily changes in the selected policy indicators. Policy indicators are financial variables that are not directly controlled by the central bank[5] but are changing in a direction consistent with changing a certain type of central bank policy, so their daily variability allows for the identification of shock in a certain type of policy. Following existing literature (Carlos Garcia-de-Andoain et al. 2016), a total bank liquidity surplus in the European monetary system was used as an indicator of the policy of additional Euro liquidity. The variable grows when banks prefer to deposit funds with the ECB relative to alternative placements, hence measures of *additional Euro liquidity* that reduce stress in the European interbank market represent a negative daily innovation in this variable. As an indicator of *additional dollar liquidity* policy, the authors use a deviation from the dollar's covered parity of interest rates on the three months horizon (Viral V. Acharya, Diane Pierret, and Sascha Steffen 2018, so-called euro-dollar swap base). Measures of additional dollar liquidity that reduce stress in the banking dollar market, represent a daily innovation in this variable. Finally, as an indicator of monetary stimulus policy, the authors use yields on Belgium's two-year

[5] Unlike the policy rate which is under the direct control of the central bank.

government bonds. Monetary stimulus measures represent a negative daily change in this series.

In order to obtain an exogenous measure of changes in ECB policy, an additional step was taken to "clean-up" the observed daily changes in policy indicators from: (a) all other available news in the days when the ECB issued policy statements; and (b) all publicly available information about the state of the Eurozone economy that was not necessarily contained in indicator values. In this step, the daily series of indicators is regressed to a large set of different financial variables and collected news series. The final measure of the ECB's monetary policy changes was obtained as a residual from these regressions on the days of the ECB's measures. Mody and Nedeljković (2018) have also shown that the constructed variables pass various validity checks.

3. Econometric Framework

The standard econometric approach (in the form of regression models or case studies) allows (under certain assumptions) to assess the effects of policy changes on financial markets at the "average" level, that is, looking at the changes in the mean of a conditional distribution of the variable. The aim of the econometric analysis of this paper is a causal assessment of the wider effects of the spillovers from the changes in the ECB's monetary policy on financial markets in Serbia, which includes various characteristics of the conditional distribution, not just the mean. For this purpose, the methodology of the augmented quantile vector autoregressive model (QVARX), proposed in White, Kim, and Manganelli (2015) and further modified in Mody and Nedeljković (2018), was used. The empirical specification is given in Equation (1):

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

where Δy_{t-1} is a two-dimensional vector of changes in the dependent variables (exchange rate and EMBI index), α is intercepts vector, MP_t is a vector of ECB policy changes, x_{t-1} is a p-dimensional vector of global and local control variables (p = 3 in the basic specification), and N_t is a three-dimensional vector of artificial variables with news (about rating changes, political and economic changes at the European Union level, as well as important political and economic news in individual countries). Q_t^{θ} is 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 avoid the possibility of reverse causality, all control variables are included with the lag. Changes in monetary policy and news are innovations (shocks) relative to dependent variables and are included as exogenous variables in the specification.

The QVARX model shown in Equation (1) has several advantages over standard regression (and VAR) models or case studies. The model automatically includes different types of asymmetric (nonlinear) reactions that can come due to spillovers effects at the conditional variance level or at higher moments of the conditional distribution, which manifest through different behaviours of certain quantile(s) of the conditional distribution. Compared to alternative estimation methods, the quantile model also makes weaker assumptions about the statistical process that generates data and allows for the presence of more extreme data and deviation of random errors from the normal distribution. QVARX also enables the direct inclusion of control variables in

the specification, the dependence of conditional quantiles on the quantiles of the conditional distribution from the previous period, and on the previous exchange rate and EMBI values, thus enabling dynamic relations between variables over time. Finally, although the QVARX model enables estimating reactions at the level of individual quantiles, in our analysis, we use two overarching measures – *changes in the conditional median* as robust measures of changes in the central tendency and *changes in the level of uncertainty* in the market, given by the difference between the quantile reaction in the upper and lower part of the distribution function.

Based on the estimated matrix of model parameters, one can directly obtain the immediate reactions of the exchange rate and EMBI to policy changes (matrix C). Dynamic reactions of these variables can be obtained using a simulated function of quantile impulse and response, proposed in Mody and Nedeljković (2018)[6].

4. Results

4.1 Basic Specification

The basic specification is estimated for conditional median and 10^{th} and 90^{th} quantile of the conditional distribution. As weakly exogeneous variables, x_{t-1}, the specification includes the VIX implicit volatility index (global variable), a change in the NBS policy rate changes and intervention variables for the NBS interventions in the foreign exchange market (local variables). In addition, the empirical model also includes three categories of variables related to news in the Eurozone, N_t.

The QVARX model parameters were estimated using Laplace type estimator (LTE) proposed in Victor Chernozhukov and Han Hong (2003). Following Mody and Nedeljković (2018), the parameters are obtained using the Monte Carlo Markov chains (MCMC) methods, details on the algorithm are available in that paper. Specifically, we use 600,000 iterations with 100,000 burn-in and sampling each 200 realization from the final sample to minimize the potential impact of autocorrelation in the algorithm.

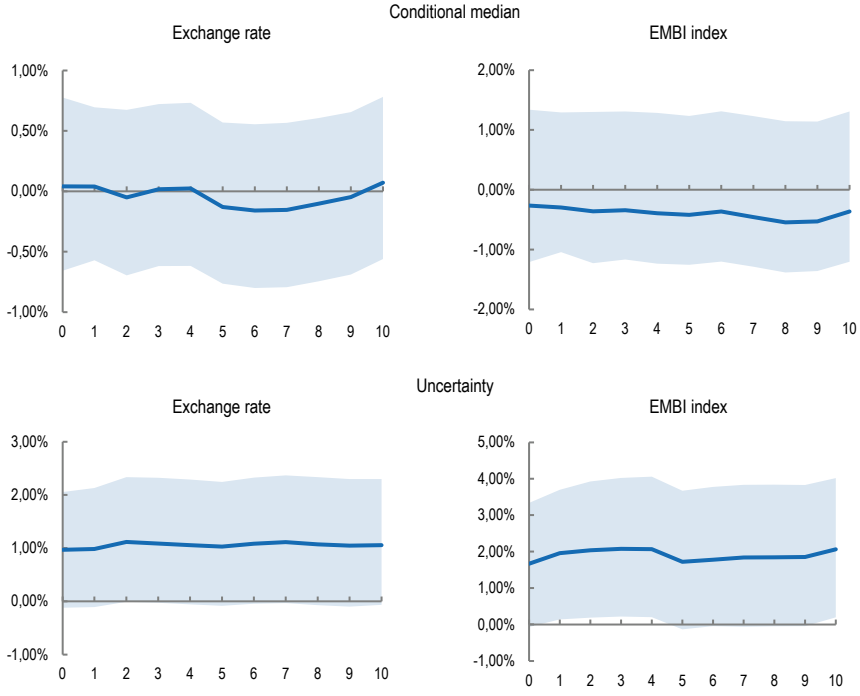
Confidence intervals for the function of quantile impulse and response are obtained using the sampled value of the parameters from the chain. Specifically, 2500 realizations of parameter values were sampled from the quasi-posterior distribution, and for each of these realizations, the function of quantile impulse and response was evaluated by the method described in the previous section. The confidence intervals (68-percent, as standard in literature) correspond to 16^{th} and 84^{th} quantile of the quasi-posterior distribution.

The Figures 4-6 show the results of the model's basic specification. Each figure separately shows *the conditional median reaction* after the realization a certain type of shock (a change in the level of the variables, the upper part of the figure) and *the difference between reactions 90^{th} and 10^{th}* quantile (a change in the level of uncertainty after the realization of a certain shock, lower picture) on the horizon of 10 days from the moment of policy change[7].

[6] The steps to obtain quantile impulse responses (QIR) are provided in Mody and Nedeljkovic (2018).
[7] Reactions over a longer horizon (10+ days) are not shown as the effect is difficult to disentangle from other shocks that hit financial markets over a longer period of time.

It should be noted that the reactions of variables to all three types of shock in the model are simultaneously estimated, but for the overview, we show them in separate figures. To obtain relatively comparable measures, the magnitude of the policy shock has been normalised to the level of the tenth quantile of the empirical distribution of the daily changes in policy indicators (total surplus liquidity of banks in the European monetary system, deviation from the covered dollar parity of interest rates, yields on Belgium's two-year government bonds), corresponding moderately to a stronger level of expansiveness.

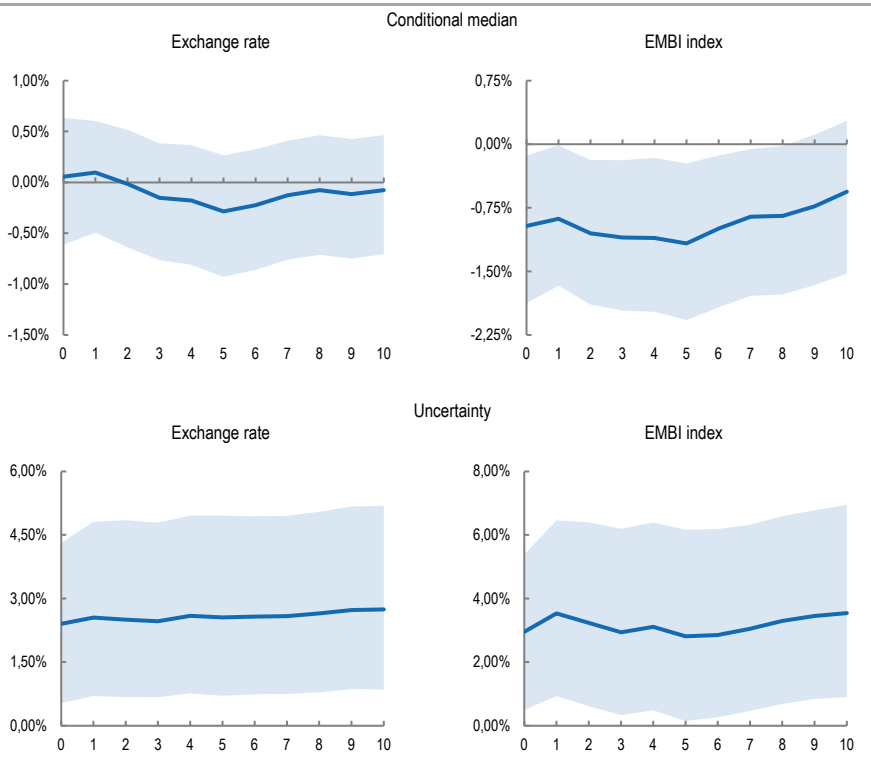
The ECB measures of *additional Euro liquidity* had little impact on the risk premium and the dinar exchange rate (Figure 4). The conditional median reaction shows slight dinar appreciation on the horizon five days after the policy change, while risk premiums gradually and slightly decline in the post-change period. Both reactions, however, are not statistically significant. Measures of additional EU liquidity also affect the growth of uncertainty in financial markets, primarily in the initial period. However, the effect in the exchange rate case is not statistically significant throughout the period. In the case of risk premium, the cumulative effect on uncertainty is short-term and statistically significant only during the first four days since the ECB policy change.



Notes: The Figure shows the 10-day reaction (line) of conditional median and uncertainty (the difference between the 90th and 10th quantile of the conditional probability schedule) of the given variables to the shock in the ECB's additional EURO liquidity proportional to reducing the total bank surplus liquidity in the European monetary system by EUR 11.5 billion. Reactions are shown based on the estimated QVARX model described in Section 2. The shaded surface indicates a 68-percentage point confidence interval.

Source: Authors' calculations.

Figure 4 Estimated Cumulative Reactions: Additional EU Liquidity Measures



Notes: The Figure shows the 10-day reaction (line) of conditional median and uncertainty (the difference between the 90th and 10th quantile of the conditional distribution) of given variables to the shock in the ECB's additional dollar liquidity proportional to reducing the deviation from the covered dollar parity of interest rates by 1.2 basis points. Reactions are shown based on the estimated QVARX model described in Section 2. The shaded surface indicates a 68-percentage point confidence interval.

Source: Authors' calculations.

Figure 5 Estimated Cumulative Reactions: Dollar Liquidity Measures

The ECB measures of *additional dollar liquidity* had a limited effect on the risk premium and the exchange rate (Figure 5). The exchange rate appreciates in the first five days since the shocks; the effect, however, is not statistically significant. The fall in the risk premium reaches its biggest effect after five days. The cumulative effect, however, ceases to be statistically significant after eight days. On the other hand, cumulative reactions of uncertainty are statistically significant even after ten days since the policy change. In the case of the exchange rate, uncertainty increases on the day of the policy change and remains at that level for all other days. In the case of the risk premium, the reaction of uncertainty is most pronounced during the first day, and after a gradual reduction, there is a slight growth again after five days. The assessed effects are significant in economic terms as well. While the daily standard deviation in the sample is 0.57% (exchange rate) and 1.98% (EMBI), the estimated growth of uncertainty on a daily basis due to a (relatively significant) change in the ECB policy is 2.4% (exchange rate) and 2.9% (EMBI).

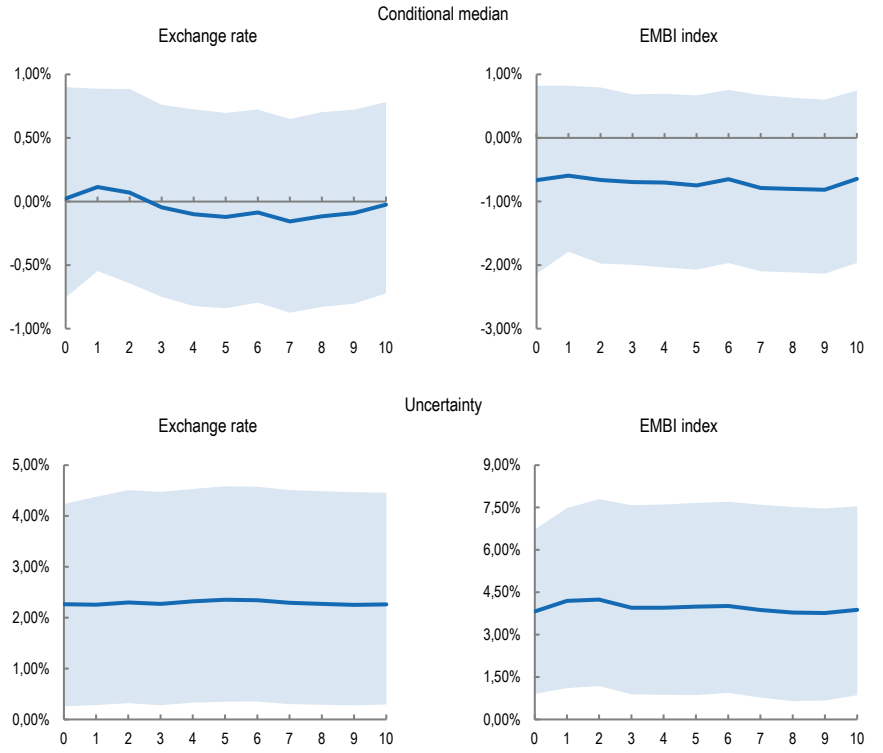
Exchange rate reactions and risk premiums to the *ECB's monetary stimulus measure* indicate a very slight appreciation in the exchange rate and a drop in risk premiums by about 0.75%. (Figure 6). Reactions are also not statistically significant on any day. On the other hand, the measures have statistically significant effect on the heightened uncertainty throughout the entire period. Uncertainty in the foreign exchange market is rising on the day of the ECB's policy change and remains high over the next ten days. The level of change is slightly lower compared to the reaction to shocks in dollar liquidity. Uncertainty about risk premiums is also rising significantly on the day of the ECB's policy change but continues to rise further over the next two days. The assessed effects are also significant in economic terms – the estimated daily growth of uncertainty due to a (relatively significant) change in ECB policy is 2.2% (exchange rate) and 3.8% (EMBI).

The results indicate that changes in the ECB policy during the crisis had a significant effect on financial markets only in certain dimensions. The policies did not significantly affect the level of the dinar exchange rate, nor the level of the risk premium in Serbia. However, they had a potentially significant effect on the uncertainty in these markets. Measures to provide additional EU liquidity had the lowest effect among the implemented measures. The result is consistent with the documented fact (Acharya and Steffen 2015) that the core beneficiaries of these measures, European banks, used liquidity primarily to purchase government bonds from European countries, which did not, in turn, lead to higher capital flows towards Serbia during this period, nor to improving the growth prospects in the Eurozone.

The absence of the significant effect of other types of measures on the levels of the considered variables, as well as the growth of uncertainty about their future movements (beyond the impact of measures implemented by the NBS included as the control variables in the empirical model), differs to some extent from the theoretical settings where expansive monetary policy measures in one (developed) country lead to the depreciation of that currency compared to others (Richard Clarida and Jordi Gali 1994, model, for example) and to the decline of the general risk premium. The results differ from other Central and Eastern European countries for which previous studies (Falagiarda, McQuade, and Tirpak 2015; Feldkircher, Gruber, and Huber 2017) find domestic currency appreciation against the euro in relation to the ECB measures implemented *outside the crisis period*. The literature typically studies the currency reactions and risk premiums in other advanced economies and/or during the full phase of the business cycle. Our results indicate that during a period of crisis and greater uncertainty in the financial markets of advanced economies, expansionary monetary policy measures in AE may not affect exchange rate levels and risk premiums in EM countries which are significantly linked to trade and financial flows with developed countries.

The absence of a significant effect can be explained by the fact that the central bank's policy measures provide a signal to market participants about the future character of monetary policy, as well as the signal about the state of the economy at the time of the implementation of the measures (not necessarily just the direction of policy action). During the crisis, if interpreted differently by market participants, the central bank's measures can therefore lead to increase in uncertainty in the domestic financial

market (Husted, Rogers, and Sun 2019)[8]. The heightened uncertainty in advanced financial markets can lead to lower capital flows towards EMs, which can mute the traditional channel through which expansionary measures affect the risk premium level and the exchange rate in an EM country. Our results on the growth of uncertainty in financial markets further speak in favour of an uncertainty channel through which monetary policy shocks in the advanced economy can spillover on financial markets in a less developed economy.



Notes: The Figure shows the 10-day reaction (line) of conditional median and uncertainty (the difference between the 90th and 10th quantile of the conditional distribution) of given variables to the shock in the ECB's stimulus measured proportional to reducing yields on Belgium's two-year government bonds by seven basis points. Reactions are shown based on the estimated QVARX model described in Section 2. The shaded surface indicates a 68-percentage point confidence interval.

Source: Authors' calculations.

Figure 6 Estimated Cumulative Reactions: Monetary Stimulus Measures

To the extent that heightened uncertainty in the foreign exchange market and in the risk premium affects the behaviour of market participants, and through this, the level of investment and exports at the aggregate (Goldberg 1993; Binding and Dibiasi 2017), the empirical results point to an additional channel through which expansionary

[8] For an empirical analysis in the case of the ECB, see Mody and Nedeljković (2018).

shocks in the monetary policy of developed countries can affect economic cycles in EMs.

4.2 Specification Checks

The robustness of the result presented in the basic specification has been examined in several ways. First, formal specification tests were conducted. Then we assess the impact of the included control variables on the obtained results – we estimated new specifications with alternative global variables and when individual control variables at the Eurozone level are excluded. Finally, we use alternative quantile levels for the estimation of uncertainty responses.

Table 1 displays the results from the specification testing. For both dependent variables and all quantiles analyzed, the table shows: (1) the percentage number of times in the sample when the actual daily change in the dependent variable was less than the estimated conditional quantile (a model performance measure in the sample); (2) *p*-value of general dynamic quantile specification test (DCQ, Juan Carlos Escanciano and Carlos Velasco 2011). As expected, the percentage of events based on the estimated conditional quantile model does not deviate significantly from its population value for both variables. Also, the null hypothesis of the correctly specified model was not rejected on the basis of the statistical test. All together, the results point to the satisfactory statistical performance of the model.

Table 1 Specification Tests

Quantile	10		50		90	
	Event %	DCQ	Event %	DCQ	Event %	DCQ
Exchange rate	8.8%	0.11	49.5%	0.34	91.3%	0.17
EMBI	9.5%	0.22	49.7%	0.47	90.5%	0.28

Notes: Each row displayes: the percentage number of times in the sample when the actual daily change of the variable in the first column was less than the estimated conditional quantile (second, fourth and sixth column) and the *p*-value of the general dynamic quantile specification test (third, fifth, and seventh columns).

Source: Authors' calculations.

The impact of control variables on the results was then analyzed. Taking into account significant empirical correlation between global proxies (the correlation between VIX and -VXY in the sample is about 0.5), only VIX measurements are included in the basic specification. In an alternative specification, it has been replaced by a VXY measurement, and the QVARX model has been re-eestimated. In addition, individual variables at the Eurozone level are excluded from the specification, one by one, and the QVARX model has been re-estimated to see if any of them have a decisive impact on the results. The results from all these checks are qualitative and almost entirely quantitatively similar to the results from the basic specification.

Finally, we examined whether the uncertainty reaction results received are driven by the concrete choice of quantles (90^{th} and 10^{th}) on which they were calculated. For this purpose, the model has been re-evaluated, but now for alternative quantiles (15, 20, 80, 85), and a new set of reactions have been estimated. The obtained result

are not significantly different from the results in the basic specification and are available from the authors.

In summary, different specification checks do not indicate significant deficiencies in the presented results.

5. Conclusion

This paper was prepared for the Serbian Academy of Science and Arts marking the 100th anniversary of the birth of Dragoslav Avramović, with whom one of the authors of this paper had the honour of working closely together in the process of preparing a program to tackle hyperinflation in 1993-1994, which was the second-largest hyperinflation in economic history.

On the traditions of Avramović's contribution in addressing the debt problem of DC and the commodity prices in the 1960s and 1970s, (Dragoslav Avramović et al. 1964; Avramović 1987, 1992) for which he was recognised as one of the leading economists of his time, we analysed the currently burning topic for EMs, and in particular Serbia, which is the issue of spillovers of the effects of unconventional monetary policies by the leading central banks (FED and ECB).

The paper empirically analyzed the impact of changes in the European Central Bank's monetary policy on the country's risk premium and exchange rate in Serbia during the most intense phase of the Eurozone crisis (2009-2012). A new econometric framework has been applied in the paper that allows for a causal assessment of financial markets' dynamic reactions to different shocks (changes) in a particular country's monetary policy in the presence of other confounding effects.

The results indicate that changes in the ECB policy during the crisis had a significant spillover effect on Serbia's financial markets only in certain dimensions. The policies have not significantly affected the level of the exchange rate level and of the risk premium. However, they had a potentially significant effect on the growth of uncertainty in these markets, especially in the case of ECB measures that provided additional dollar liquidity and monetary stimulus. The results indicate that during a period of crisis and increased uncertainty in the financial markets of advanced economies, expansionary monetary policy measures in AE may not affect exchange rate levels and risk premiums in EMs which are significantly linked to trade and financial flows with developed countries. In addition, if changes in monetary policy lead to growing uncertainty in the financial markets of AE, the uncertainty can spillover to higher uncertainty in the EM's financial markets. To the extent that increased uncertainty in the foreign exchange market and in the risk premium affects the behaviour of market participants, and through this, the level of investment and exports at the aggregate, empirical results point to an additional channel through which expansionary monetary policy shocks in advanced economies can affect business cycles in EM.

References

Acharya, Viral V., and Sascha Steffen. 2015. "The Greatest Carry Trade Ever? Understanding Eurozone Bank Risks." *Journal of Financial Economics*, 115(2): 215-236. http://dx.doi.org/10.1016/j.jfineco.2014.11.004

Acharya, Viral V., Diane Pierret, and Sascha Steffen. 2018. "Lender of Last Resort versus Buyer of Last Resort: Evidence from the European Sovereign Debt Crisis." Swiss Finance Institute Discussion Paper 18-035.

Albagli, Elias, Luis Ceballos, Sebastian Claro, and Damian Romero. 2019. "Channels of US Monetary Policy Spillovers to International Bond Markets." *Journal of Financial Economics*, 134(2): 447-473. http://dx.doi.org/10.1016/j.jfineco.2019.04.007

Avramović, Dragoslav, Shahid S. Husain, Jan De Weille, Johan Froland, J. P. Hayes, and Hans Wyss. 1964. *Economic Growth and External Debt*. Washington, D. C.: Johns Hopkins University Press.

Avramović, Dragoslav. 1987. "Commodity Problem: What Next?" *World Development*, 15(5): 645-655. http://dx.doi.org/10.1016/0305-750X(87)90008-8

Avramović, Dragoslav. 1992. "Developing Countries in the International Economic System: Their Problems and Prospects in the Market for Finance, Commodities, Manufacturers and Services." United Nations Development Programme Occasional Paper 3.

Ayala, Diana, Milan Nedeljković, and Christian Saborowski. 2017. "What Slice of the Pie? The Corporate Bond Market Boom in Emerging Economies." *Journal of Financial Stability*, 30(C): 16-35. http://dx.doi.org/10.1016/j.jfs.2017.03.003

Binding, Garret, and Andreas Dibiasi. 2017. "Exchange Rate Uncertainty and Firm Investment Plan Evidence from Swiss Survey Data." *Journal of Macroeconomics*, 51(C): 1-27. http://dx.doi.org/10.1016/j.jmacro.2016.11.004

Buraschi, Andrea, and Paul Whelan. 2015. "Bond Markets and Unconventional Monetary Policy." In *Handbook of Fixed-Income Securities*, ed by Pietro Veronesi, 93-116. New Jersey: John Wiley & Sons.

Cecchetti, Stephen, Tommaso Mancini-Griffoli, Machito Narita, and Ratna Sahay. 2019. "U.S. or Domestic Monetary Policy: Which Matters more for Financial Stability?" *IMF Economic Review*, 68(1): 35-65. http://dx.doi.org/10.1057/s41308-020-00108-2

Chen, Jiaqian, Tommaso Mancini-Griffoli, and Ratna Sahay. 2014. "Spillovers from United States Monetary Policy on Emerging Markets: Different This Time?" International Monetary Fund Working Paper 14-240.

Chernozhukov, Victor, and Han Hong. 2003. "An MCMC Approach to Classical Estimation." *Journal of Econometrics*, 115(2): 293-346. http://dx.doi.org/10.1016/S0304-4076(03)00100-3

Clarida, Richard, and Jordi Gali. 1994. "Sources of Real Exchange-Rate Fluctuations: How Important Are Nominal Shocks?" *Carnegie-Rochester Conference Series on Public Policy*, 41: 1-56. http://dx.doi.org/10.1016/0167-2231(94)00012-3

Escanciano, Juan Carlos, and Carlos Velasco. 2010. "Specification Tests of Parametric Dynamic Conditional Quantiles." *Journal of Econometrics*, 159(1): 209-221. http://dx.doi.org/10.1016/j.jeconom.2010.06.003

Falagiarda, Matteo, Peter McQuade, and Marcel Tirpak. 2015. "Spillovers from the ECB's Non-Standard Monetary Policies on Non-Euro Area EU Countries: Evidence from an Event Study Analysis." European Central Bank Working Paper 1869.

Feldkircher, Martin, Thomas Gruber, and Florian Huber. 2017. "Spreading the Word or Reducing the Term Spread? Assessing Spillovers from Euro Area Monetary Policy." Wien University Working Paper 248.

Gande, Amar, and David Parsley. 2005. "News Spillovers in the Sovereign Debt Market." *Journal of Financial Economics*, 75(3): 691-734. http://dx.doi.org/10.1016/j.jfineco.2003.11.003

Garcia-de-Andoain, Carlos, Florian Heider, Marie Hoerova, and Simone 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. http://dx.doi.org/10.1016/j.jfi.2016.01.003

Goldberg, Linda S. 1993. "Exchange Rates and Investment in the United States Industry." *Review of Economics and Statistics*, 75(4): 575-589.

Husted, Lucas, John Rogers, and Bo Sun. 2020. "Monetary Policy Uncertainty." *Journal of Monetary Economics*, 115(C): 20-36. http://dx.doi.org/10.1016/j.jmoneco.2019.07.009

Jarociński, Marek. 2019. "International Spillovers of the FED and ECB Monetary Policy Surprises." *DIWBerlin*, June 05. https://www.diw.de/en/diw_01.c.613242.en/events/international_spillovers_of_the_fed_and_ecb_monetary_policy_surprises.html.

Kuttner, Kenneth N. 2001. "Monetary Policy Surprises and Interest Rates: Evidence from the FED Funds Futures Market." *Journal of Monetary Economics*, 47(3): 523-544. http://dx.doi.org/10.1016/S0304-3932(01)00055-1

Melosi, Leonardo. 2016. "Signalling Effects of Monetary Policy." *The Review of Economic Studies*, 84(2): 853-884. http://dx.doi.org/10.1093/restud/rdw050

Modder, Isabella. 2017. "Spillovers from the ECB's Non-Standard Monetary Policy Measures on South-Eastern Europe." European Central Bank Working Paper 2095.

Mody, Ashoka, and Milan Nedeljković. 2018. "Central Bank Policies and Financial Markets: Lessons from the Euro Crisis." Center for Economic Studies Ifo Working Paper 7400.

Rajan, Raghuram. 2014. "Global Monetary Policy: A View from Emerging Markets." *Brookings Institutions*, April 10. https://www.brookings.edu/events/global-monetary-policy-a-view-from-emerging-markets/.

Rajan, Raghuram. 2015. "Rules of the Game in the Global Financial System." *House of Finance*, November 10. https://www.hof.uni-frankfurt.de/news-media/news/article/article/rules-of-the-game-in-the-global-financial-system.html.

Romer, Christian D., and David H. Romer. 2004. "A New Measure of Monetary Shocks: Derivation and Implications." *American Economic Review*, 94(4): 1055-1084. http://dx.doi.org/10.1257/0002828042002651

White, Halbert, Tae-Hwan Kim, and Simone Manganelli. 2015. "VAR for VaR: Measuring Tail Dependence Using Multivariate Regression Quantiles." *Journal of Econometrics*, 187(1): 169-188. http://dx.doi.org/10.1016/j.jeconom.2015.02.004