6. Return and Volatility Spillover between Stock Prices and Exchange Rates in Croatia: A Spillover Methodology Approach

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Abstract

The relationship between stock prices, returns and exchange rates is important for policymakers for tailoring macroeconomic policies that will promote economic growth. It is also important for potential investors who consider real investment projects and forecast asset returns and risks. This research focuses on the stock return and exchange rates co-movements in Croatia, by utilizing a VAR model and spillover index of Diebold and Yilmaz (2009). Empirical research is provided for the Croatian market, which has yet not been implemented in such a manner. Based on the results from the analysis, it can be concluded from a portfolio standpoint that return spillovers from exchange rates to stock returns were greater than volatility spillovers. This could have potential in hedging portfolio strategies. The same is true for the direction from stock to exchange rates returns and volatility.

Keywords: spillover index, return co-movements, variance decomposition, developing stock market, flow and stock-oriented model

JEL Classification: G12, F31, C1

1. Introduction

The relationship between stock returns and exchange rates has been in the spotlight for many years now. The research tries to obtain information on the direction of causality between movements in stock prices and exchange rates. The usual line of the approach is to examine the flow-oriented or stock-oriented model. The flow-oriented approach (Balance of Payment Approach, Dornbusch and Fischer, 1980) explains that changes in exchange

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rates influence changes in stock prices: depreciation of domestic currency improves local firms' competitiveness and stock prices move up as a response. Thus, it is believed that the exchange rate is predetermined by the current account of a country. Since stock prices can be defined as the present value of future cash flows, they have to adjust to changes in the economy and exchange rates. The stock-oriented model (Portfolio Approach, Branson, 1983; Frankel, 1983) assumes that changes in exchange rates are driven by changes in stock prices, as a consequence of changes in demand and supply of foreign and domestic assets in international portfolios. In that way, a negative relationship exists between the two financial series, since the rise in stock prices leads to the appreciation of the domestic currency. This is due to investor's wealth which increases and leads to increase in demand for money as well[4]. Researchers examine these concepts because the results are important to policymakers in order to tailor macroeconomic policies that will promote economic growth, but it is important to firms, (potential) investors and investment funds who consider real investment projects, forecast asset's return and risk, etc. This study mainly focuses on the investor's portfolio and diversification possibilities. In that way, the spillovers of shocks in return and volatility series can be dynamically evaluated over time in order to rebalance the portfolio. The macroeconomic approach of such modelling can be found in Dimitrova (2005). As this research allows observing whether the results will indicate the stock or flow-oriented model, the fundamental economic reasons for doing so are as follows. Many import and export-oriented firms are affected by changes in the exchange rates, which ultimately affects the stock value of such firms (Dornbuch and Fisher, 1980). This ultimately changes the international trade of the country through the profitability of the mentioned firms (Gregoriou *et al.*, 2009). Export-dominant economies can be very sensitive to such changes, as they face higher exchange rate changes exposure (Pan *et al.*, 2007). On the other hand, the stock-oriented model argues that shocks on the stock markets are the initial thing which triggers investors to come to a country, which would lead to changes in the exchange rates (Branson, 1983; Fankel, 1983). Previous research found that there is a bidirectional relationship between currency and stock markets (Guidolin, 2011; Engle and Colacito, 2006), it is reasonable to extend the empirical testing via a methodology which allows for a dynamic change in the spillover effects between both markets. There is a gap in the literature regarding the investor's point of view when structuring and rebalancing the portfolio. This is especially true for the market observed in this study, the Croatian market. There are only several studies in Croatia which deal with the mentioned issues. However, this research extends the existing literature. There is no other study which applies the spillover index methodology of Diebold and Yilmaz (2009) on the Croatian data, as well as the Balkan region. This research will focus on the stock return and exchange rates co-movements in Croatia, by utilizing VAR and MGARCH[5] approach for the stock market index CROBEX and three exchange rates relative to Croatian kuna: euro, American dollar and Swiss franc. The importance of CROBEX for the Croatian economy and vice versa is found in the following papers. Hsing (2011) found that real GDP and exchange rates have a positive impact on CROBEX; Ravnik (2014) demonstrated that including CROBEX in forecasting Croatia's GDP is relevant and should be included in similar future analysis as well. Finally, the percentage of total market capitalization on the Croatian market from 2010 until 2019 ranges from over 53% to over 66% of total GDP, which makes it relevant to conduct studies such as this one. In that way, the contributions of this study are twofold. Firstly, we give a concise

[4] More references to theoretical research can be found in Phylaktis and Ravazzolo (2005).

[5] Vector AutoRegression and Multivariate Generalized AutoRegressive Conditional Heteroskedasticity.

introduction and overview of the aforementioned topics (both theoretically and empirically); and secondly, empirical research is provided on the Croatian market, which has not yet been implemented up until writing this research. This study will observe volatility spillovers between each pair of time series of interest as well (not only return series). Finally, the study will apply the Spillover Index and Table as defined in Diebold and Yilmaz (2009, 2012), which has not yet been examined in the Croatian market.

The structure of the paper is as follows. The second section reviews the previous research regarding the interrelationship of return and volatility within the spillover methodology context. The third section describes the methodology used in this study. The results of the empirical research are provided in the fourth section. The final, fifth section, concludes the paper.

2. Previous Related Research

By observing the literature which deals with interactions and spillovers between return and risk on the stock and exchange market, several conclusions may be drawn. First of all, a great deal of research applies the MGARCH and/or VAR methodology to observe interactions between stock returns and exchange rates. Some of the research includes Stavarek (2004), in which the Granger causality test and the VECM[6] model are applied on stock indices and real effective exchange rates in order to examine the direction of causality (stock or flow-oriented model) in the USA, Austria, France, Germany, UK, Poland, the Czech Republic, Hungary, and Slovakia (observed period differs depending upon the availability of data, ranging from 1969 to 2003). The majority of countries are characterized by the stock-oriented model as results suggest, with the relationship being tighter for the more developed countries in the sample. This has implications for the monetary policy, of course. Earlier empirical work in more developed countries can be found in this research. MGARCH approach of volatility spillovers can be found in Morales (2008), where Latin American countries and Spain are included in the study (1998–2006 time span). For each country, a bivariate model between stock returns and exchange rate changes was estimated in order to determine the direction of the spillover.

A smaller number of papers apply the methodology of Diebold and Yilmaz (2009, 2012). The majority of the papers apply the spillover methodology between stock indices (and/or other financial assets) of different countries. Since their theoretical base is different from this paper's, we just mention briefly some of the research. Diebold and Yilmaz (2016) in their extensive study observe volatility spillovers between major financial institutions in Europe and the USA in the period 2004-2014. Results indicated that the financial crisis period (2007-2008) was characterized by one-directional spillover from the USA to Europe. The bi-directional spillover occurs since 2011 when the health of European institutions became more deteriorated. Chow (2017) observed volatility spillovers between the US, UK, and 10 Asian stock markets for the period 1999-2016. The main findings include that the spillover has strengthened after the crisis; the more open the market was, the more of the spillovers occurred in the observed period and after the crisis, the Asian markets becoming bigger emitters of spillovers of financial shocks. The spillover methodology has been applied to bank connectedness (Yilmaz, 2014), financial firms (Diebold and Yilmaz, 2011), business cycles of different countries (Diebold and Yilmaz, 2013), etc. Thus, it is a versatile methodology and may be applied to different entities to explore the degree of

[6] *Vector Error Correction Model.*

connectedness. Exchange rate spillovers were examined in Bubak *et al*. (2011), who applied Granger causality tests and estimated the spillovers between 5-minute spot exchange rates of Euro against the American dollar, Czech koruna, Hungarian forint and the Polish zloty (2003-2009). The total sample was divided into two subsamples due to the financial crisis in 2007-2008. Authors showed that volatility spillovers increased in periods of market uncertainty.

There are not many papers that observe spillovers between the stock and exchange market, thus we believe that a gap in literature can be filled. Antonakakis (2012) examined co-movements and spillovers between returns on exchange rates of euro, British pound, Swiss franc and Japanese yen against the US dollar for the period 1986-2011. The author applied the spillover methodology in a VAR model and MGARCH and obtained the following results. In the observed period, significant spillovers between return series exist, with lower values of the spillover after the introduction of the Euro in the EU. Net receivers and transmitters were established as well (the pound and euro, respectively). Thus, the mentioned study only observed exchange rate spillovers. Kumar (2013) applied the VAR and MGARCH methodology firstly with the calculation of the spillover index afterward for the return and risk series for the IBSA countries. Daily data on stock indices and exchange rates in India, Brazil and South Africa for the period 2000-2011 was collected to evaluate the spillover intensity between return and risk series. Results indicated a presence of stronger spillover effects in return series as compared to volatilities. The author observed bivariate specification of each model (one exchange rate and one return series for each country). Kavli and Kotze (2014) observed several developed and developing markets (from the UK, USA, and Japan to Nigeria, Kenya and India, a total of 15 countries) for the period 1997-2011. The given results indicate that return spillovers have increased over time and volatility spillovers mainly reacted to economic events. Njegić *et al*. (2018) apply the MGARCH and spillover index on 7 emerging economies based upon their GPD growth (the Czech Republic, Hungary, Russia, Turkey, India and South Korea) for the period 2001-2016. This is the first study more linked to the Croatian market. The results indicate that Turkey had the strongest link to the more developed markets. Regarding the spillover methodology, in all of the countries, the spillovers are predominantly directed from exchange rates towards stock markets. Regarding research in Croatia, only several papers exist which deal with the stock market and exchange rates, but to the knowledge of authors, none of the existing research applies the spillover index methodology. Benazić (2008) was an explicit study of interactions between the stock index CROBEX and the real effective exchange rate of kuna, for the period from September 1997 to March 2008. The author used the VECM methodology to estimate short- and long-term interactions between level values of stock index and exchange rate. The results indicated that there is causality from stocks to exchange rates both on the short and long term, whilst the majority of variation in exchange rates is due to variations in changes in stock prices. Thus, this supports the stock-oriented model. As one may see, the literature was expanding only over the past several years, with many questions left unanswered.

3. Methodology

Basics of the methodology is the VAR(p) model, where we follow Lütkepohl (2006) and Diebold and Yilmaz (2009). VAR(p) in the matrix form is given as:

$$\boldsymbol{y}_t = \boldsymbol{v} + \boldsymbol{A}_1 \boldsymbol{y}_{t-1} + \boldsymbol{A}_2 \boldsymbol{y}_{t-2} + \ldots + \boldsymbol{A}_p \boldsymbol{y}_{t-p} + \boldsymbol{\varepsilon}_t , \tag{1}$$

where: $\boldsymbol{y_t} \in R^K$ is random vector, $\boldsymbol{A_i} \in R^{K \cdot K}$ are matrices of coefficients, $\boldsymbol{\nu} \in R^K$ vector of intercept terms and $\boldsymbol{\varepsilon_t} \in R^K$ vector of white noise processes, $E(\boldsymbol{\varepsilon}_t) = \mathbf{0}$, $E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t') = \sum_\varepsilon < \infty$ and $E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_s') = 0$ for *t≠s*. We can write the VAR(*p*) model in a VAR(1) form, by denoting $\boldsymbol{Y}_t = [\boldsymbol{y}_t \quad \boldsymbol{y}_{t-1} \quad \cdots \quad \boldsymbol{y}_{t-p}]'$, $\mathbf{v} = [\boldsymbol{\nu} \quad \mathbf{0} \quad \cdots \quad \mathbf{0}]'$, $\boldsymbol{A} \in R^{Kp \cdot Kp}$ matrix as defined in Lütkepohl (2006:15) and $\boldsymbol{\varepsilon}_t = [\boldsymbol{\varepsilon}_t \quad \mathbf{0} \quad \cdots \quad \mathbf{0}]'$, so that:

$$\boldsymbol{Y}_t = \mathbf{v} + \boldsymbol{A}\boldsymbol{Y}_{t-1} + \boldsymbol{\varepsilon}_t . \tag{2}$$

If the model given in (1) or (2) is stable[7], it has an MA(∞) representation:

$$\boldsymbol{Y}_t = \boldsymbol{\mu} + \sum_{i=1}^{\infty} \boldsymbol{A}^i \boldsymbol{\varepsilon}_{t-i} , \tag{3}$$

$\boldsymbol{\mu} \equiv (\boldsymbol{I}_{Kp} - \boldsymbol{A})^{-1} \mathbf{v}$; which can be written compactly in a polynomial form:

$$\boldsymbol{Y}_t = \Phi(L)\boldsymbol{\varepsilon}_t , \tag{4}$$

where: $\boldsymbol{\mu}$ is assumed to be a zero vector and $\Phi(L)$ is a polynomial in the lag operator *L*. Coefficients $\phi_{jk,i}$ in Φ are impulse responses of the system. In practice, the innovation processes in $\boldsymbol{\varepsilon}_t$ are usually correlated for *t≠s*. Thus, the matrix $\sum_\varepsilon$ can be ortogonalized via the Cholesky decomposition, with a lower-triangular matrix $\boldsymbol{P}^{-1}$, such that $\boldsymbol{P}^{-1} \boldsymbol{\varepsilon}_t$ is a vector of ortogonalized innovations, where $E(\boldsymbol{P}^{-1}\boldsymbol{\varepsilon}_t \boldsymbol{P}^{-1}\boldsymbol{\varepsilon}_s') = 0$ for *t≠s* and $E(\boldsymbol{P}^{-1}\boldsymbol{\varepsilon}_t \boldsymbol{P}^{-1}\boldsymbol{\varepsilon}_t') = \boldsymbol{I}_{Kp}$. Now, the model in (4) can be re-written as:

$$\boldsymbol{Y}_t = \Phi(L)\boldsymbol{P}\boldsymbol{P}^{-1}\boldsymbol{\varepsilon}_t = \Theta(L)\boldsymbol{u}_t , \tag{5}$$

$\boldsymbol{u}_t = \boldsymbol{P}^{-1}\boldsymbol{\varepsilon}_t$. By using model (5) for forecasting in order to obtain variance decomposition, the error of the *h*-step forecast is calculated as follows:

$$\boldsymbol{Y}_{t+h} - E(\boldsymbol{Y}_{t+h}) = \sum_{i=0}^{h-1} \Theta_i \boldsymbol{u}_{t+h-i} , \tag{6}$$

and for the *j*-th element of $\boldsymbol{Y}_t$:

$$\begin{aligned} y_{j,t+h} - E(y_{j,t+h}) &= \sum_{i=0}^{h-1} (\theta_{j1,i} u_{1,t+h-i} + \ldots + \theta_{jK,i} u_{K,t+h-i}) \\ &= \sum_{k=1}^{K} (\theta_{jk,0} u_{k,t+h} + \ldots + \theta_{jk,h-1} u_{k,t+1}) \end{aligned} , \tag{7}$$

where: $\theta_{m,n,i}$ is element of Θ_i . The variance decomposition of each element in $\boldsymbol{Y}_t$ is then defined as:

[7] *$\boldsymbol{Y}_t$ is stable if det($\boldsymbol{I}_{Kp}$-$\boldsymbol{A}$z)≠0 for |**z**|≤**1**.*

$$\omega_{jk,h} = \sigma_j^{-1} \sum_{i=0}^{h-1} \left(e_j^{'} \Theta_i e_k \right)^2 / \sum_{i=0}^{h-1} \sum_{k=1}^{K} \theta_{jk,i}^2 \, , \tag{8}$$

where: numerator is contribution of innovations in variable *k* to forecast error variance of variable *j*, and denominator is the mean squared error of the forecast in (7) of variable *j*; e_k is the *k*-th column of matrix I_{Kp}. $\omega_{jk,h}$ is interpreted as the proportion of the *h*-step forecast error variance of the *j*-th variable due to innovation shocks in variable *k*. The corresponding matrix of mean squared error *h*-step forecast is

$$\sum_y h = \sum_{i=0}^{h-1} \Theta_i \Theta_i^{'} = e_j^{'} \Phi_i \sum_{\varepsilon} \Phi_i^{'} e_j \, , \tag{9}$$

so we can rewrite (8) as

$$\omega_{jk,h} = \sigma_j^{-1} \sum_{i=0}^{h-1} \left(e_j^{'} \Theta_i e_k \right)^2 / \sum_{i=0}^{h-1} e_j^{'} \Phi_i \sum_{\varepsilon} \Phi_i^{'} e_j \, . \tag{10}$$

The Spillover index defined by Diebold and Yilmaz (2009:159) is calculated as the fraction of the *h*-step error variance of y_j forecast due to shocks to the *k*-th variable (*k≠j*) (cross variance shares) and the total forecast error variation:

$$S = \left(\sum_{\substack{j,k=1 \\ j \neq k}}^{K} \omega_{jk,h} / \sum_{i=0}^{h-1} \sum_{j,k=1}^{K} \omega_{jk,h} \right) 100\% \, , \tag{11}$$

and by construction of $\omega_{jk,h}$, it follows that the denominator in (11) is equal to *K*. Thus, the Spillover index in (11) is essentially given by:

$$S = 100\% \frac{1}{K} \sum_{\substack{j,k=1 \\ j \neq k}}^{K} \omega_{jk,h} \, . \tag{12}$$

It is also called the total spillover because it measures the contribution of spillovers of all shocks to the total forecast error variance. On the other hand, directional spillovers can measure spillovers received to variable *j* from shocks in other variables *k*:

$$S_{j\square,h} = 100\% \frac{1}{K} \sum_{\substack{k=1 \\ j \neq k}}^{K} \omega_{jk,h} \tag{13}$$

and spillover from variable *j* to other variables:

$$S_{\square j,h} = 100\% \frac{1}{K} \sum_{\substack{k=1 \\ j \neq k}}^{K} \omega_{kj,h} \, . \tag{13}$$

To make everything easier to follow, spillover tables are constructed. For more details, see Urbina (2013) or the original article of Diebold and Yilmaz (2009). Since return and volatility series will be included in the VAR model, volatilities will be estimated via univariate and multivariate GARCH models. This methodology is widely known in the literature, thus interested readers are referred to the following sources: Alexander (2008, 2009), Bauwens *et al.* (2006), Bauwens *et al.* (2012), Francq and Zakoian (2010), Franses and van Dijk (2000) or Silvennoinen and Teräsvirta (2008).

4. Empirical Results

For the purpose of empirical evaluation of the spillovers between returns and volatilities in Croatia, daily data on CROBEX from the Zagreb Stock Exchange (2019) and daily values of euro (EUR), American dollar (USD), and Swiss franc (CHF) in kunas were obtained from Croatian National Bank (2019) for the period January 4th, 2010, until July 16th, 2018. The three selected exchange rates are chosen due to diversification possibilities for the potential portfolio. Returns for each series were calculated as monthly averages of daily returns, to reduce potential problems of daily data in the VAR analysis. Unit root tests have rejected the null hypothesis of a unit root in every return series on usual levels of significance. Thus, return series are used in the following procedure. Based upon the information criteria, VAR(1) was chosen as the optimal model; with no problem of autocorrelation and heteroskedasticity up to lag 12. Granger causality test resulted only with the conclusion that USD caused EUR on 5%, thus this was taken into account in the Cholesky decomposition of the variance-covariance matrix[8]. In the next step, we calculate the spillover indices for the whole sample period and construct the spillover table, shown in Table 1. The spillover indices were calculated based upon the 10-day horizon of the forecast error variance. As one may see, the shocks in return on CROBEX explain 0.1%, 0.6%, and 3.6% of the forecast error variance of return on EUR, CHF, and USD, respectively. Moreover, shocks in return on EUR explain 1.7%, 9.1%, and 13.56% of the forecast error variance of return on CROBEX, CHF and USD, respectively. Other interpretations for CHF and USD can be similarly made. Thus, it may be concluded that shocks in stock return series do not have a great spillover to the exchange rate returns, which is favorable for the portfolio construction. Shocks in return on EUR have the greatest spillover to other return series, with the greatest spillover to the USD return forecast error variance. The USD return series had the least spillover effects on other return series from the exchange rate group (it can be seen in the row *contribution to others*), as well as it received the most spillovers from others (column *from others*). Thus, if an investor anticipates shocks in a return series, he can use results in Table 1 to estimate the degree of the spillover effects on other returns. The total spillover index in the grey cell is equal to 47.40%, calculated via formula (12).

Table 1

Spillover Table for Return Series in the Full Sample, in %

	CROBEX	EUR	CHF	USD	From others
CROBEX	91.205	1.749	6.786	0.260	8.795
EUR	0.095	95.913	0.103	3.890	4.087
CHF	0.629	9.076	87.846	2.449	12.154
USD	3.561	13.455	5.344	77.640	22.360
Contribution to others	4.285	24.280	12.233	6.599	47.397

[8] Thus, the approach of Diebold and Yilmaz (2009) was taken, with the ordering of variables based on the Granger causality tests. However, we re-estimated the results via the generalized error decomposition variances of Diebold and Yilmaz (2012) paper, and the results were very similar to those in this paper. Detailed results are available upon request.

To obtain a dynamic interpretation that is important in portfolio optimization, the rolling spillover index was calculated based upon 24-month windows. The results are shown in Figure 1. One may see that at the end of the period the index value is higher as compared to the beginning of the period. This reduces diversification possibilities for the investor. Moreover, the spike at the beginning of 2015 is due to the shock in the CHF return series, when the central bank of Switzerland declined to defend its exchange rate. The consequence in Croatia was a great depreciation of the CHF rate and the shock in the return series spilled over to other return series.

Next, we examine the dynamic spillovers from exchange rate return shocks to the CROBEX return in Figure 2. The most favorable in terms of diversification was the spillover from USD return, due to the spillover index being the smallest in the observed period in the majority of the time, especially from 2015. On a trade-weighted basis, the US dollar increased in value by about 6% between early December 2014 and early March 2015. The appreciation of the US dollar was also notable with respect to a large number of emerging market currencies as well as the euro. (Malkhozov and Rixtel, 2015). The CHF return series shocks have the greatest spillover index to stock return series. This can be explained by the controversies around the franc exchange rate in Croatia since 2011; due to problems with the housing loans denominated in CHF. Thus, investors are more prudent towards the CHF changes. Figure 3 depicts the spillover from the shocks in stock return series to exchange rate series. The shocks in stock return series had the greatest spillover to USD returns in the first half of the sample; whilst in the second half, this is true for the EUR returns. Moreover, after the accession of Croatia to the European Union in July 2013, it may be seen that the spillover index to EUR gets greater onwards until the beginning of 2015 and the infamous CHF depreciation.

Figure 1

Total Spillover Index, 24-month Rolling Windows, Return Series

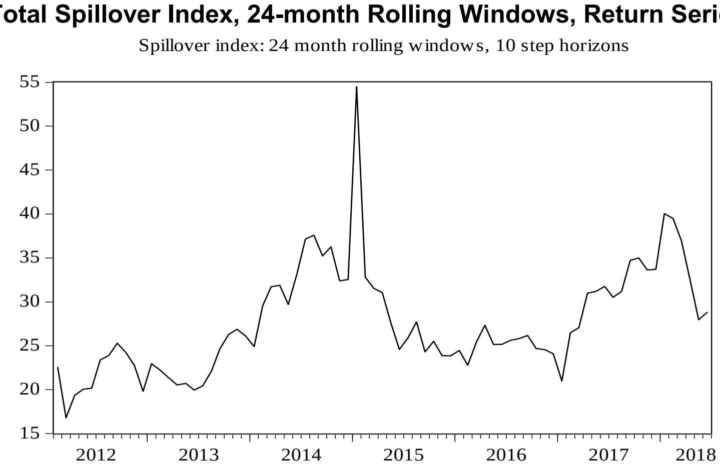


Figure 2

Spillover Indices from Exchange Rates Returns to CROBEX Return

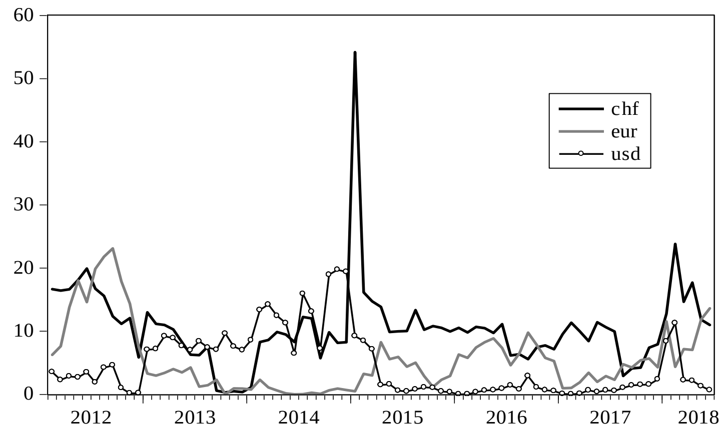
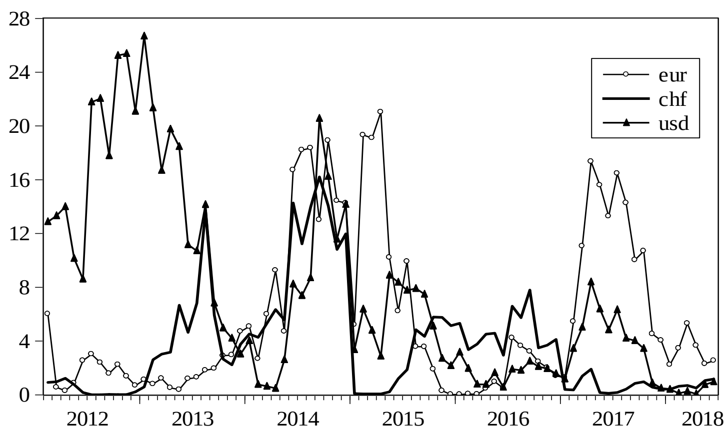


Figure 3

Spillover Indices from CROBEX to Exchange Rate Returns



Now, we explore the spillovers between volatility series. We follow a parsimonious approach by estimating each volatility series as a univariate GARCH process, with GARCH(1,1) being the appropriate model to estimate each series. Additional specifications were included as well (such as E-GARCH, component, M-GARCH, etc.), but the original model was best in terms of information criteria and statistical significance of parameters. Since no heteroskedasticity was detected in the monthly return series, GARCH models were estimated on weekly data. Each conditional variance series was extracted from the model and, again, a VAR(1) model was determined to be suitable in case of volatilities. Before the estimation of the VAR model, a unit root test was performed for each conditional variance series. All of the series, except for the USD volatility, were determined to be stationary. Thus, we use the first difference of dollar volatility in the analysis. Estimated spillover indices are given in Table 2. Several conclusions may be drawn by observing Table 2[9]. First of all, the spillover effects are much less prominent in the volatility series as compared to the return series. The total spillover index is lower than 3% for the whole period. This is in favor of diversification possibilities from a portfolio standpoint. Now, shocks in stock market volatility explain 1.04%, 0.03% and 0.26% of forecast error variance of the volatility of EUR, USD and CHF, respectively. Thus, the spillovers are very small in the observed period. The greatest spillovers to other volatility series were from the EUR and the smallest was from CHF. The greatest receiver of spillovers was again USD. However, this is again a static measure based upon the whole sample. Dynamics are more important in portfolio management. Thus, the rolling spillover index was estimated based upon a 24-week window length. It is shown in Figure 4. The value of the index is more or less constant for the majority of the observed period, with some spikes throughout 2011-2017. From the beginning of 2017 onwards, the value of the index is increasing. This means that volatility spillovers are getting bigger and diminish the diversification possibilities. Next, Figure 5 shows spillovers from exchange rate volatilities to the CROBEX risk. It is not surprising that the EUR spillovers were the greatest in the majority of the observed period. However, they are diminishing over time and the spillover from CHF had the least impact on stock volatility, except for 2015 (again, due to controversies).

Table2

Spillover Table for Volatility Series in the Full Sample, in %

	CROBEX_V	EUR_V	D_USD_V	CHF_V	From others
CROBEX_V	99.896	0.001	0.076	0.026	0.104
EUR_V	1.038	98.797	0.144	0.021	1.203
D_USD_V	0.026	4.447	94.650	0.878	5.350
CHF_V	0.264	0.573	4.216	94.947	5.053
Contribution to others	1.328	5.021	4.437	0.925	11.710

Stock markets were more volatile at the beginning of 2015 than at the end of 2014. Differences in monetary policies, in part, was responsible for increases in the exchange rate volatility which became more pronounced after the Swiss monetary authorities abandoned the SF/Euro exchange rate cap. The reaction of the financial markets was expectedly strong: bond yields declined as stock prices in the euro area countries rose an average of 2 percent. As inflation expectations rose both five-year and five-year forward inflation swap rate followed suit while the euro depreciated vis.a.vis the US dollar by about 1.5 %, following spikes in both volatility and risk aversion in global markets. (see for details Malkhozov and Rixel, 2015). Equity markets always react actively to political and economic decisions. In 2016, the victory of Emmanuel Macron raised investors' confidence and strengthened euro against dollar and pound. On the other hand, BREXIT impacted the currency market and weakened investors' confidence. Economic and political events mentioned above affected exchange rates and capital markets in Croatia, too (Figures 4, 5, 6).

[9] *Besides the 24-rolling window length provided in the text, a robustness checking was done by changing the length to 20 and 50 weeks, as a referee asked. The results are very similar. This makes the results robust. Detailed results are available upon request.*

Figure 4

Total Spillover Index, 24-week Rolling Windows, Volatility Series

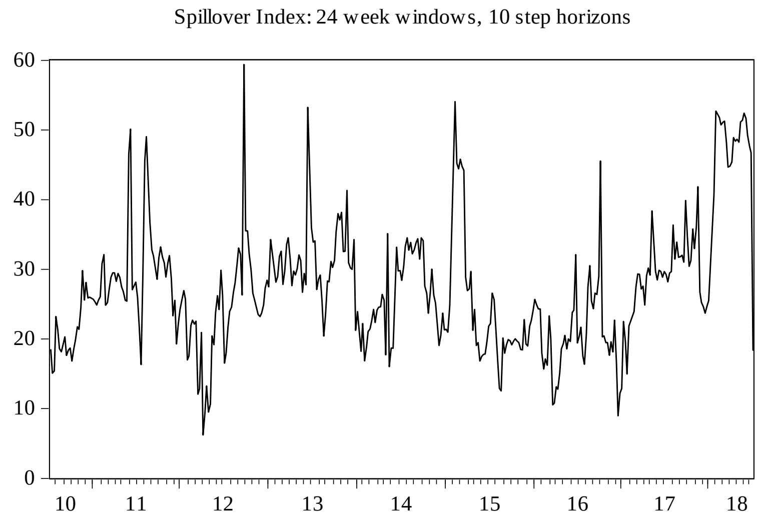


Figure 5

Spillover Indices from Exchange Rates to CROBEX Volatility

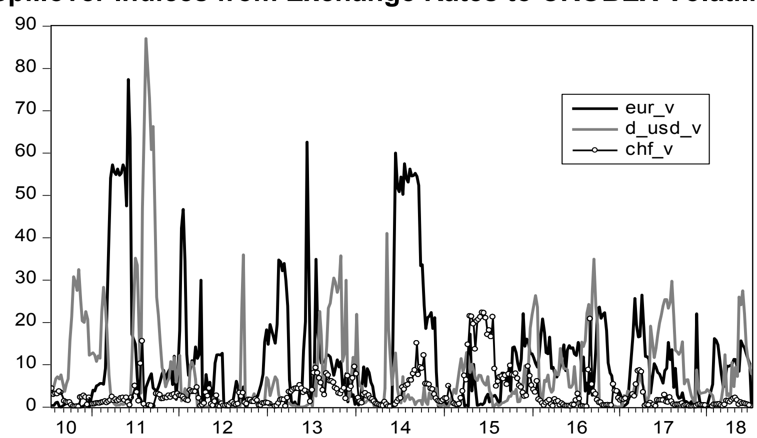


Figure 6

Spillover Indices from CROBEX to Exchange Rate Volatility

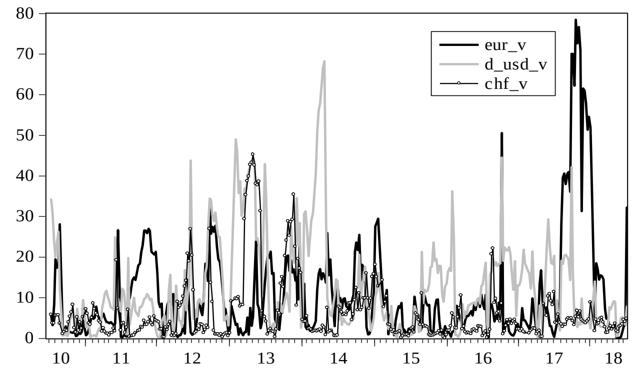


Figure 7

Stock- or Flow-oriented Model on Croatian Market, Returns Left Panel, Volatility Right Panel

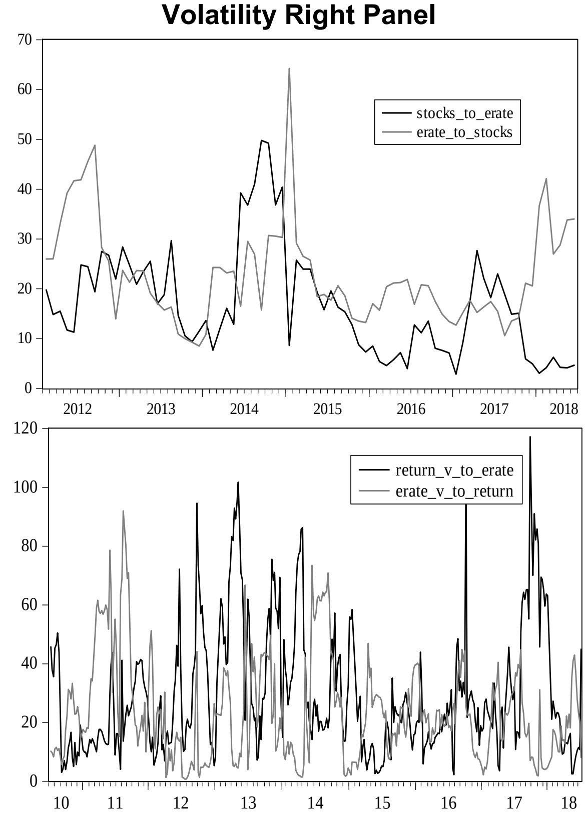


Table3

Stock-flow or Oriented-flow Model on Croatian Market

Statistics	Stock return to erate	Erate to stock return	Stock volatility to erate	Erate to stock volatility
Mean	17.001	**22.746**	**29.949**	23.794
Median	15.119	**20.633**	**23.143**	19.950
Maximum	49.797	**64.227**	**117.251**	91.989
Minimum	2.851	**8.518**	**2.295**	0.714
Standard deviation	10.820	10.079	22.119	17.388

Figure 6 shows the opposite spillovers, how the shocks in stock volatility affect the exchange rate volatility. One may see that these volatilities are more sensitive to shocks in the stock market volatility, with the greatest spillover to the EUR. Based upon the discussion, it may be concluded from a portfolio standpoint that returns spillovers from exchange rates to stock returns were greater than volatility spillovers in the observed period. This could have potential in the hedging portfolio strategies. The same is true for the direction from stock to exchange rate returns and volatility. However, to determine whether there is more evidence in favor of stock- or flow-oriented model, total spillover from stock return and volatility to exchange rates and vice versa was calculated. The dynamics are shown in Figure 7, with the descriptive statistics shown in Table 3. As one may see, the stock oriented model is supported in the volatility series, whilst the flow-oriented approach in the return series. This partially coincides with Benazić's (2008) research. To check for robustness of results, for the return spillover indices, we change the length of forecast window in the VAR model from 10 to 5, 15 and 20. The resulting rolling spillover indices almost overlap in the whole period, meaning that the initial results are robust[10]. Moreover, to examine the robustness of volatility spillover indices, in the first step, we estimate an MGARCH model. Several specifications have been considered and, in the end, we choose the CCC model based upon the information criteria, the statistical significance of parameters. Other models did not result in a positive semi-definite variance-covariance matrix (BEKK or VECH) and the DCC model resulted in parameters of the dynamics of covariances not being statistically significant. Based upon estimated conditional variances in the CCC model, spillover indices were calculated and the dynamic spillover was again very close to the index depicted in Figure 4[11]. Thus, the results provided in the study can be interpreted with reliability.

5. Conclusion

This study observes the spillover effects of shocks in return and volatility series on the Croatian financial market within the methodology of Diebold and Yilmaz (2009). The importance to observe such interactions lies upon the tailoring process of macroeconomic policies to promote economic growth, (potential) investors and investment funds who consider real investment projects, forecast asset's return and risk, etc. The main results indicate that the spillover between stock and exchange returns in Croatia is larger as compared to volatility spillovers. This is in favour of diversification possibilities in the financial market. Moreover, the volatility spillover is strongest between the Euro and CROBEX, a

[10] Results are omitted due to limited number of pages but are available upon request.
[11] Again, detailed results are available upon request.

result that is not surprising. The spillovers between dollar and CROBEX were the least in the observed period, which means that when forming future portfolios, investors could take the dollar more into account for hedging purposes.

Some of the pitfalls of the study were as follows. A relatively short period was observed in the study when compared to some developed markets. This is a usual problem for markets under development, such as the Croatian market. Thus, future research should expand the period of variables in the study. Furthermore, only stock and exchange rate returns and risks were observed. Thus, this limits the investor's possibilities to diversify the portfolio. However, the analysis was done in the stock- and flow-oriented models which use only the mentioned variables. Future research can expand on other financial assets as well. Moreover, the generalized error decomposition variance error models have been developed as well (see Diebold and Yilmaz, 2012; Koop *et al*., 1996 or Pesaran and Shin, 1998). Since we focused mostly on the interpretations from a portfolio standpoint, future research could empirically investigate how to incorporate the results from this paper into trading strategies on the financial markets. As far as this research was written, no such study exists. Since this methodology can be used to forecast future returns and risks, as well as the spillovers, it can be investigated if this methodology can enhance portfolio performance in terms of risk and return. So, much work needs to be done in the future as well. However, this research was the first step towards providing answers regarding issues dealing with this paper. Basic questions regarding diversification possibilities and directions of spillovers were given. Presented research can provide valuable information to international investors interested in the emerging markets.

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