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The spillover of shadow interest rate to the excess returns in emerging markets

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Abstract

Purpose — This study focuses on the monetary policy transmission of the U.S. on the excess returns in emerging markets by estimating the impacts of changes in the shadow interest rate in the U.S. on the Barclays Benchmark EM FX Trend Excess Return Index and the Barclays Cross Asset Trend Index.

Methods — To account for the spillover effects of the macroeconomic and financial variables, this study employs a bivariate VARMA–AGARCH approach. This study employs 206 daily observations, from February 22, 2002, to July 5, 2019 sourced from The Barclays database and the Reserve Bank of New Zealand.

Findings — This study finds that the shocks in shadow interest rates will decrease the Barclays Benchmark EM FX Trend Excess Return Index and the Barclays Cross Asset Trend Index in the short term. The results of VARMA–BEKK–AGARCH model show that changes/shocks in shadow interest rates will reduce the excess returns in the financial markets of emerging countries in the long term.

Implication — The study reveals that a high-interest rate policy could be used as a tool by the FED to prevent excessive returns on emerging countries' financial markets

Originality — This study contributes to the existing literature by addressing the issue of whether the monetary policy stance of the U.S. after the Global Financial Crisis (GFC) can be recognized as the primary source of the currency excess returns and multiple-asset class excess returns for emerging countries.

Keywords — shadow interest rates, excess returns, emerging countries, VARMA–BEKK–AGARCH model

Introduction

As a result of the unconventional policies implemented by major central banks, researchers have begun to derive shadow interest rates (Krippner, 2014; Wu & Xia, 2016). In this context, the assessment of the international spillover effect of monetary policy has come to the forefront of empirical analysis. More specifically, in the presence of unconventional monetary policies, the exchange rates and asset prices of emerging countries have become more sensitive to the interest rate decisions of the FED (Ammer, Claessens, Tabova, & Wroblewski, 2019; Inoue & Rossi, 2019). Thus, it has become essential to examining the relationship impacts of the U.S. shadow interest rate on excess returns in the financial markets of emerging countries.

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In the context of macroeconomics, the shadow interest rate is used as an indicator of unconventional monetary policy; for instance, Inoue and Rossi (2019) adopted a new approach to identifying monetary policy shocks. Their study defined monetary policy shocks as shifts in the entire term structure of interest rates on the day of a monetary policy announcement, and the relevant approach captured the effects of forward guidance and asset purchase program announcements. Using a Vector Auto Regression (VAR) model with daily data of the U.S., Inoue and Rossi (2019) found that expansionary monetary policy shocks caused the depreciation of exchange rates in both conventional and unconventional periods. The results highlighted the usage of time-varying models to assess the effects of the monetary policy on interest rates and exchange rates. However, it is well known that the monetary policy leads to news effects and other macroeconomic developments. Although news effects are considered in GARCH-type models, Cheung, Fatum, and Yamamoto (2019) considered whether the influence on the exchange rate of "good" versus "bad" news could be asymmetric. Using daily data, the authors evaluated the relative influence of U.S. and Japanese macro news on the JPY/USD rate before, during, and after the global financial crisis and revealed that U.S. macro news was more important than before the crisis and the influence of Japanese macro news started to disappear after the GFC.

Herein, it should also be noted that the relationship between exchange rates and interest rates may vary over time. In this respect, Hacker, Karlsson, and Månsson (2014) showed that the nominal interest rate differential was Granger cause the exchange rate as the wavelet time scale increased by proving evidence from the values of five major currencies against the Swedish krona (SEK). Moreover, by conducting impulse response analysis, they found that an increase in the Swedish interest rate compared with that of another country was associated with a lower Swedish krona price of the other country's currency in the short run. Most recently, Lee (2019) employed asset-pricing models for the cases of the UK, France, and the U.S. More specifically, the author considered smooth transition regimes in volatilities to examine the excess dollar returns and found that the expected excess returns could negatively correlate with the interest differential. Lee (2019) stressed the importance of uncertainty in macroeconomic variabilities and revealed that the uncovered interest parity theory could be explained if the economic agent achieved an early resolution of uncertainty. In a similar effort, Ames, Bagnarosa, and Peters (2017) considered the effects of capital flows on stochastic features in the joint behavior of the currency exchanges with respect to the level of short-term interest rates. Using daily data for developed and developing countries, they found that both upper- and lower-tail dependence features consequently displayed a significant association with and asymmetries to each other in periods of both financial stability and financial instability.

Contrary to the studies in the scientific literature, Caraiani & Călin (2018) suggested that, when the shadow interest rate was included in the time-varying Bayesian VAR model, the impact of monetary policy shocks on asset prices was negative and the impact on asset price bubbles was smaller in the aftermath of the GFC. On the other hand, Sugimoto and Matsuki (2019) showed a significant international spillover effect of monetary policy on the asset price bubbles in emerging countries. More specifically, Sugimoto and Matsuki (2019) employed the measure of Diebold and Yilmaz (2012), and they found that both conventional and unconventional monetary easing raised the US-to-Asia and Japan-to-Asia stock return spillovers. Since they also found that the reaction of bubbles to shadow interest rate was lower than the federal funds rate, the importance of detecting the effects of shadow interest rates on financial variables was suggested.

The critical message found in the reviewed literature is that the conventional and unconventional monetary policy of the U.S. may cause considerable variations in the exchange rates and the asset prices of emerging countries and may lead to excess returns. The previous literature also indicated that the transmission of interest rates of the U.S. on the macroeconomic and financial variables of emerging countries could be exposed to non-linear effects. In this context, in line with Lee (2019), who considered excess returns, this study evaluates the effects of the shadow interest rates of the U.S. on the foreign exchange/currency and multiple-asset class excess returns in emerging countries in the presence of a decrease in the effectiveness of conventional monetary policies as a result of the expansionary monetary policies. More specifically, it investigates the effects of the shadow interest rate in the U.S. to the Barclays Benchmark EM FX

Trend Excess Return Index (FXERI) and the Barclays Cross Asset Trend Index – EM FX ER (CRASERI) in terms of volatility, shock, and asymmetric spillovers. However, this study differentiates itself from Lee (2019) in that it considers the roles of asymmetry and news effects. This study also differs from all studies available in the scientific literature, as the impact of the shadow interest rate of the U.S. on the multiple-asset class of the emerging markets is assessed through the international spillover effect of the monetary policy.

Additionally, this study assumes non-linear relationships among the variables for the time horizon and enhances the empirical approach (Hacker et al., 2014), who used wavelet analysis. In this context, firstly, this study employs the VARMA–BEKK–AGARCH model deriving from the VARMA–AGARCH model (McAleer et al., 2009). More specifically, by estimating the coefficients of the relevant model, thus study examines the relationships among the model variables and thus, assesses the roles of volatility and shock spillovers and asymmetric effects. The BEKK version captures both own-market and cross-market asymmetric effects. The BEKK version captures the asymmetric impacts both in the context of a variable of the model and between variables of the model. The BEKK version captures own-variable asymmetric impacts and also incorporates between variables of the model. The BEKK version captures the asymmetric effects in each variable on its volatility and incorporates asymmetric impacts between variables of the model. Herein, parallel to Cheung et al. (2019), it should be noted that the influence on the exchange rate of "good" versus "bad" news could be asymmetric. However, this study investigates whether the news effect related to one variable may induce higher (lower) volatility in another variable, unlike the CCC and DCC versions of the VARMA–AGARCH model. Hence, this study focuses on the probability of a financial crisis in emerging countries due to the changes in the monetary policy stance of the U.S. and the presence of asymmetric impacts and news effects. Secondly, this study uses the non-linear VAR model (Kilian & Vigfusson, 2011) and implement slope-based tests to ascertain the robustness of the VARMA–BEKK–AGARCH estimations in terms of asymmetry.

This study contributes to the existing literature by addressing the issue of whether the monetary policy stance of the U.S. after the Global Financial Crisis (GFC) can be recognized as the primary source of the currency excess returns and multiple-asset class excess returns for emerging countries. Within this theoretical and empirical framework, the main hypothesis of this paper aims to test whether the shadow interest rate has significant effects on financial stability and thus leads to changes in economic policy implementation.

Methods

To account for the spillover effects of the macroeconomic and financial variables, this study employs a bivariate VARMA–AGARCH approach. The conditional mean and conditional variance equations are derived below in the specification of a VARMA(1,1)–BEKK–AGARCH(1,1) model.

$$y_t = \Phi + \upsilon y_{t-1} + \Theta B_t + \varepsilon_t + \gamma \varepsilon_{t-1} \quad (1)$$

$$\varepsilon_t = D_t \eta_t \quad (2)$$

In equation (1), the vector y_t contains two variables that can be specified as $y_t = (y_t^1, y_t^2)'$ with the shadow interest rate of the U.S. and the excess returns in the emerging markets at time t, respectively. Additionally, υ corresponds to a (2×2) coefficient matrix as $\upsilon = \begin{pmatrix} \upsilon_{11} & \upsilon_{12} \\ \upsilon_{21} & \upsilon_{22} \end{pmatrix}$, Φ refers to a (2×1) vector including the constant variables of the model as $(\Phi^1, \Phi^2)'$, Θ is a (2×2) matrix of coefficients $\begin{pmatrix} \omega_{11} & \omega_{12} \\ \omega_{21} & \omega_{22} \end{pmatrix}$ and $B_t = (b_t^1, b_t^2)'$ refers to a vector of structural break dummies.[1] Additionally, the error terms from the mean equations are ε_t written as $\varepsilon_t = (\varepsilon_t^1, \varepsilon_t^2)'$, γ is also a (2×2) matrix as $\begin{pmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{pmatrix}$, and it shows the shock spillovers between the model variables. In terms of equation (2), the vector of independently and identically distributed errors is (2×1) can be specified as $\eta_t = (\eta_t^1, \eta_t^2)'$, while $D_t = diag\left(\sqrt{h_t^1}, \sqrt{h_t^2}\right)'$ with h_t^1 and h_t^2 as the conditional

[1] In equation (2), $g_t = 1$ if $t \geq breakdate$.

variances of the model variables. Equations (1) and (2) constitute the conditional mean equation of the model, while the conditional variance equation can be written as below:

$$H_t = \Omega'\Omega + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + C'I_{t-1}\varepsilon_{t-1}\varepsilon'_{t-1}C + B'H_{t-1}B \quad (3)$$

where $A, B,$ and C correspond to the square matrices and Ω is a lower triangular matrix as $\begin{pmatrix} \varsigma_{11} & 0 \\ \varsigma_{21} & \varsigma_{22} \end{pmatrix}$. Accordingly, the volatility of the markets is incorporated into the conditional variance-covariance matrix H_t.[2] Matrix A includes the coefficients of the ARCH term and thus shows the effect of a shock in the shadow interest rate of the U.S. and a shock spillover from the variable reflecting the excess returns in emerging markets on the conditional volatility of the relevant variable. Similarly, the B matrix has the coefficients of the GARCH term, which represent the effect of past volatility in the shadow interest rate of the U.S. and the spillover of the remaining variable on the conditional volatility of the variable. Matrix C has asymmetric effect coefficients, indicating both the significance of an asymmetric effect for the shadow interest rate of the U.S. and the significance of asymmetric effect spillovers between the two variables of the model. It assumed that negative and positive shocks do not have identical effects on the conditional variance, while $I_t = diag(I_t^1, I_t^2)$ is a function of an independently and identically distributed error term. It should be noted that the BEKK–VARMA–AGARCH holds when matrix C is not null.[3] Moreover, there can be differences between the BEKK, CCC, and DCC types in their variance equations.[4]

This study focuses on the monetary policy transmission of the U.S. on the excess returns in emerging markets by estimating the impacts of changes in the shadow interest rate in the U.S. on the FXERI and the CRASERI. The analysis would be in the short run and long run. This study employs 206 daily observations, from February 22, 2002, to July 5, 2019. The data on the FXERI and the CRASERI are collected from The Barclays database, while the data on the shadow interest rate of the U.S. is collected from the Reserve Bank of New Zealand. Following Salisu and Oloko (2015), we employed the breakpoint unit root test.[5] In order to determine the break dates, the relationships between model variables were assessed using a VARMA–BEKK–AGARCH approach. Break dates are suggested for the model variables, and the unit root properties of the series are shown in Table 1.

Table 1. Breakpoint unit root test results

Variables	Test statistic	Number of lagged differences by the Akaike Information Criterion (AIC)	Suggested break date
sh_t^f	-2.10		July 7 6, 2007
gsh_t^f	-71.17	0	October 11, 2008
$fxeri_t^f$	-3.96		September 26 16, 2008
$gfxeri_t^f$	-60.29	0	December 3, 2008
$craseri_t^f$	-3.86		August 20 22, 2007
$gcraseri_t^f$	-57.30	0	August 3, 2008

Note: According to the 1%, 5%, and 10% significance levels, the critical values of the unit root with a structural break test are -4.94, -4.44, and -4.19, respectively.

According to Table 1, all the variables are not stationary at levels, while they became stationary when their first differences were taken. As a result of the Johansen cointegration test, no

[2] The parameterization of the VECH and the Diagonal VECH (DVECH) models does not enforce positive definiteness since the relevant models may have some (typically highly unlikely) sequences of residuals that may cause them to produce a non-positive definiteness covariance matrix. On the other hand, the BEKK model imposes positive definiteness by construction. More specifically, the BEKK specification guarantees that if the matrices $H_{t-i}, i = 1, \dots, p,$ are almost indeed positively definite, and thus is H_t. For details, please see Francq and Zakoïan (2010).

[3] For the details of VARMA–GARCH and VARMA–AGARCH, (please see McAleer et al. (2009).

[4] For the details of the specifications of CCC–VARMA–AGARCH and DCC–VARMA–AGARCH, please see Salisu and Oloko (2015) and Bala and Takimoto (2017).

[5] The breakpoint unit root test is a modified augmented Dickey-Fuller test, allowing for levels and trends that differ across a single break date., EViews 10.0 was employed in this study in order to perform the relevant test.

cointegration is found in terms of the $(sh_t, fxeri_t)'$ and $(sh_t, craseri_t)'$; thus, the variables used in the empirical exercise are in percentage changes from the previous observation and are denoted as gsh_t, $gfxeri_t$and $gcraseri_t$. On the other hand, the break dates for the relevant variables are in the second half of 2008, which coincides with the GFC. Thus, this splits the entire sample into a particular subsample in line with the break dates found in Table 1, and model estimations are carried out for both the entire sample and in the presence of structural breaks. In this respect, this study generates the mean equation of the multivariate GARCH model by including dummy variables to capture the identified break dates. The impacts of the shadow interest rate of the U.S. on the FXERI and the CRASERI are examined within the $(gfxeri_t^f, gsh_t^f)'$, $(gfxeri_t^s, gsh_t^s)'$, $(gcraseri_t^f, gsh_t^f)'$ and $(gcraseri_t^s, gsh_t^s)'$ vectors, respectively.

In line with equations (1)–(3), the elements of the resulting variance and covariance equations for the estimates of the bivariate VARMA–BEKK–AGARCH can be evaluated using the equations below:

$$h_{11,t} = \varsigma_{11}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + a_{21}^2\varepsilon_{2,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + c_{11}^2\varepsilon_{1,t-1}^2 I_{1,t-1} + c_{21}^2\varepsilon_{2,t-1}^2 I_{1,t-1} + 2c_{11}c_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1}I_{1,t-1} + b_{11}^2 h_{11,t-1} + b_{21}^2 h_{22,t-1} + 2b_{11}b_{21}h_{21,t-1} \quad (4)$$

$$h_{21,t} = \varsigma_{21}\varsigma_{22} + a_{11}a_{22}\varepsilon_{1,t-1}^2 + a_{21}a_{22}\varepsilon_{2,t-1}^2 + (a_{21}a_{12} + a_{11}a_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1}c_{11}c_{22}\varepsilon_{1,t-1}^2 I_{1,t-1} + c_{21}c_{22}\varepsilon_{2,t-1}^2 I_{1,t-1} + (c_{21}c_{12} + c_{11}c_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1}I_{1,t-1} + b_{11}b_{22}h_{11,t-1} + b_{21}b_{22}h_{22,t-1} + (b_{21}b_{12})h_{12,t-1} \quad (5)$$

$$h_{22,t} = \varsigma_{22}^2 + a_{12}^2\varepsilon_{1,t-1}^2 + a_{22}^2\varepsilon_{2,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + c_{12}^2\varepsilon_{1,t-1}^2 I_{1,t-1} + c_{22}^2\varepsilon_{2,t-1}^2 I_{1,t-1} + 2c_{12}c_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1}I_{1,t-1} + b_{12}^2 h_{1,t-1} + b_{22}^2 h_{22,t-1} + 2b_{12}b_{22}h_{21,t-1} \quad (6)$$

Results and Discussion

In the context of equations (1) and (6), this study exposes the impacts of the shadow interest rate on the FXERI and the CRASERI by focusing on the short-run return impacts in terms of the coefficient matrices υ and γ. Long-run effects of the shadow interest rate of the U.S. are also assessed in terms of the coefficient matrices $A, B,$ and C, indicating the shock, volatility, and asymmetric spillovers, respectively.

In this study, following Salisu and Oloko (2015), the effects of the shadow interest rate in the U.S. on excess returns in the currency and multiple-asset classes were analyzed within separate vectors as $(sh_t, fxeri_t)'$ and $(sh_t, craseri_t)'$, respectively. In this context, since the statistical criteria revealed that the BEKK version of the VARMA–AGARCH model is superior to the CC and DCC variations, the results obtained in Table 2 were evaluated. The VARMA–BEKK–AGARCH model was estimated for the entire sample and the subsample by dividing the whole sample according to the structural break date as found in Table 1.

Within this empirical framework, the mean equation of model 1 showed that past changes in the shadow interest rate of the U.S. have a little immediate impact on the FXERI. However, the coefficient of υ_{12} is negative, and it can be said that the tight monetary policy in the U.S. reduces the net capital inflows to emerging countries and, consequently, decreases the FXERI. Similar findings have been obtained for the CRASERI in the context of model 2. The argument is that the high interest rate environment in the U.S. may lower the asset prices of emerging market countries, but this effect may be limited. Since this study uses the VARMA–BEKK–AGARCH model, the short-run effects of the FXERI on the shadow interest rate of the U.S. can also be examined. Considering the coefficient symbolized by υ_{21}, it became apparent that the increase in the FXERI causes the shadow interest rate to increase in the U.S. The detected return spillover may be attributed to the fact that the capital inflows into the financial markets of emerging countries cause excessive returns in the foreign exchange market and, as a result of this, the FED, which wants to reverse the direction of capital movements, may start to implement a high-interest policy. However, following the evaluation of the relationship between the shadow interest rate of the U.S. and the CRASERI, it can be claimed that the excess returns in the multiple-asset class of emerging markets do not have immediate effects on the shadow interest rate in the U.S. due to a statistically insignificant coefficient. In other words, it can be asserted that the effects of the returns of various financial instruments on U.S. interest rates may occur in the longer term.

At this point, the fact that the monetary policy implementation is subject to a rule emerges as an influential factor for the dynamics of the financial markets of emerging countries and the expectations of economic agents. More specifically, the coefficient expressed by γ_{12} of the VARMA–BEKK–AGARCH model showed the shock spillovers among the variables in the short-run, parallel to Sugimoto and Matsuki (2019). Accordingly, it can be argued that shocks in the shadow interest rate of the U.S., in other words, unexpected developments that were not in line with the monetary policy rule, deteriorated the expectations related to the financial markets of the emerging markets and reduced the value of the FXERI and the CRASERI in line with Ammer et al. (2019), Caraiani and Călin (2018), Inoue and Rossi (2019), and Lee (2019). Since the reduction in excess returns can be considered as a factor reducing the likelihood of a financial bubble and thus the likelihood of a financial crisis, it can be argued that monetary policy shocks/contractionary monetary policy in the U.S., in terms of the shadow interest rate, contribute to the financial stability of emerging countries. On the other hand, it was revealed by the γ_{21} coefficients of the relevant model that the shocks in the FXERI will raise the interest rates in the U.S. Thus, the VARMA–BEKK–AGARCH model showed that the shocks in the FXERI are taken into consideration by the FED, while the shocks in the CRASERI do not create immediate short-term effects on the shadow interest rate of the U.S.

When the results of the model estimated for the entire sample were evaluated within the context of the conditional variance equation discussing the shock, volatility, and asymmetric spillovers in the long run, there was a significant interaction between the shadow interest rate of the U.S. and the FXERI and the shadow interest rate of the U.S. and the CRASERI. In terms of a_{12}^2, it was indicated that shocks in the shadow interest rate of the U.S. reduce the FXERI, in line with Caraiani and Călin (2018). Similar findings were obtained for the increase in the shadow interest rate for the CRASERI, and it can be suggested that contractionary monetary policy shocks in the U.S. can reduce the excess returns in the multiple-asset class in the long run. Considering the entire sample framework, it was also found that there are long-term asymmetric shock spillovers between the shadow interest rate of the U.S. and the FXERI and between the shadow interest rate of the U.S. and the CRASERI over the positive statistically significant c_{12} and c_{22} coefficients, in line with Ames et al. (2017) and Sugimoto and Matsuki (2019). In the light of these findings, it can be suggested that high shock and asymmetric information shocks in the shadow interest rate of the U.S. will have crucial effects on both variables. In other words, unexpected bad news about the shadow interest rate of the U.S. and unconventional monetary policy in the U.S. are exposed to higher rates of an impact than good news.

This study determined the break dates for all the variables used in our empirical models in line with the structural break unit root tests shown in Table 1. The break dates determined for each variable coincided with the GFC period; therefore, this study evaluated the effects of shadow interest rates on emerging countries' financial markets in the presence of quantitative easing and macro-prudential policies implemented by major central banks. The subsample models did not also include dummy variables, which were generated depending on the structural break dates of each variable. In this context, the coefficients obtained for the after-break model differ from those obtained for the entire sample with respect to the size, direction, and statistical significance levels. In terms of υ_{12}, it was shown that the increase in the shadow interest rate in the U.S. adversely affects the excess returns in the multiple-asset class of emerging countries. Within this framework, it was confirmed that the contractionary monetary policy implemented in the U.S. reduces the capital inflows to emerging markets and that investors even started to leave emerging countries due to the rising interest rates in the U.S. Despite the argument that there may be immediate interaction between the shadow interest rate of the U.S. and the CRASERI in the context of model 4, the statistically insignificant coefficient of the υ_{12} in model 3 showed that the effects of the monetary policy changes in the U.S. on the FXERI do not occur immediately. Although this finding is not parallel to the entire sample model, the negative and statistically significant values of the γ_{12} coefficients of both models suggested that the excess returns on the assets of emerging countries decrease, since the shocks in the shadow interest rate of the U.S. are perceived as a high interest rate environment in the U.S.

Table 2. Estimation results for the VARMA–BEKK–AGARCH model

	Full sample		After break	
Mean equation	Model 1: $(gfxeri_t^f, gsh_t^f)'$	Model 2: $(gcraseri_t^f, gsh_t^f)'$	Model 3: $(gfxeri_t^{ab}, gsh_t^{ab})'$	Model 4: $(gcraseri_t^{ab}, gsh_t^{ab})'$
ϕ_{10}	0.036*** (0.000)	0.032*** (0.000)	0.039*** (0.000)	0.035*** (0.000)
υ_{11}	0.094*** (0.000)	0.132*** (0.000)	0.114*** (0.000)	0.112*** (0.000)
υ_{12}	-0.000 (0.205)	-0.000 (0.000)	-0.000 (0.815)	-0.008 (0.034)
γ_{11}	0.063*** (0.000)	-0.025*** (0.000)	0.001*** (0.000)	0.032*** (0.000)
γ_{12}	-0.082*** (0.000)	-0.118*** (0.000)	-0.007*** (0.000)	-0.017*** (0.000)
φ_{11}	-0.331** (0.036)	0.619** (0.035)	–	–
φ_{12}	-0.522 (0.180)	-0.949** (0.047)	–	–
ϕ_{20}	-0.101*** (0.000)	-0.107*** (0.000)	0.032** (0.025)	0.025* (0.066)
υ_{21}	0.034*** (0.000)	-0.011 (0.592)	0.032 (0.453)	0.018 (0.422)
υ_{22}	0.644*** (0.000)	0.664*** (0.000)	0.396*** (0.000)	0.404*** (0.000)
γ_{21}	0.044*** (0.000)	-0.038*** (0.000)	0.029*** (0.000)	0.002*** (0.000)
γ_{22}	-0.001*** (0.000)	-0.013*** (0.000)	0.006*** (0.000)	0.008*** (0.000)
ω_{22}	-0.699** (0.038)	0.468** (0.0449)	–	–
ω_{21}	0.272* (0.088)	-0.384** (0.0491)	–	–
Variance equation	Model 1: $(gfxeri_t^f, gsh_t^f)'$	Model 2: $(gcraseri_t^f, gsh_t^f)'$	Model 3: $(gfxeri_t^{ab}, gsh_t^{ab})'$	Model 4: $(gcraseri_t^{ab}, gsh_t^{ab})'$
ς_{11}	-0.058*** (0.000)	-0.081*** (0.000)	0.088*** (0.000)	0.087*** (0.000)
ς_{21}	0.024 (0.579)	-0.001 (0.952)	0.011 (0.592)	0.017 (0.112)
ς_{22}	-0.173*** (0.000)	-0.192*** (0.000)	0.000 (0.999)	-0.000 (0.999)
a_{11}	0.308*** (0.000)	0.441*** (0.000)	0.381*** (0.000)	0.490*** (0.000)
a_{12}	-0.151 (0.001)	-0.119*** (0.003)	-0.043 (0.447)	-0.060*** (0.000)
a_{21}	0.000 (0.020)	0.000 (0.062)	0.003 (0.152)	0.016*** (0.000)
a_{22}	0.537*** (0.000)	0.494*** (0.000)	0.089 (0.001)	0.088*** (0.000)
b_{11}	0.939*** (0.000)	0.886*** (0.000)	0.885*** (0.000)	0.866*** (0.000)
b_{12}	-0.045 (0.072)	-0.065*** (0.002)	-0.020 (0.597)	-0.028*** (0.000)
b_{21}	0.000 (0.031)	0.000 (0.010)	0.002** (0.014)	0.003*** (0.001)
b_{22}	0.688*** (0.000)	0.695*** (0.000)	0.973*** (0.000)	0.973*** (0.000)
c_{11}	-0.098 (0.000)	-0.148*** (0.000)	-0.039 (0.660)	-0.147** (0.041)
c_{12}	0.660*** (0.000)	0.494*** (0.000)	0.244*** (0.000)	-0.011 (0.721)
c_{21}	-0.000 (0.100)	-0.000 (0.011)	0.004 (0.298)	0.009 (0.139)
c_{22}	2.438*** (0.000)	2.421*** (0.000)	0.324*** (0.000)	0.309*** (0.000)

Note: The values in parentheses refer to the p-values.
***, **, * denote significance at 1%, 5%, and 10% repectivelly.

Regarding the maintenance of global financial stability, it was revealed that the FED does not give an immediate reaction to shocks in the FXERI and the CRASERI since the υ_{21} in both models is statistically insignificant. Within the after-break models, the finding that the υ_{21} of both models was statistically insignificant suggests that the Fed does not immediately respond to changes in extreme returns on financial assets of emerging countries. Nevertheless, the γ_{21} of both models showed that excess return shocks are perceived as an increase in the risk of a financial crisis in emerging countries in the short run and thus have an increasing effect on the shadow interest rate of the U.S.

Long-term interactions were assessed through variance equations; more precisely, it can be said all the models are stationary due to the satisfaction of the $(a_{11}^2 + b_{11}^2) < 1$ and $(a_{22}^2 + b_{22}^2) < 1$ condition and the statistical significance. Thus, it was indicated that the volatility among the model variables exhibits weak mean reversion. It was also revealed that, except for model 3, the volatility of the model variables is significantly influenced by lagged own conditional variance (b_{11}^2, b_{22}^2), lagged own shocks (a_{11}^2, a_{22}^2), and own asymmetric shocks (c_{11}^2, c_{22}^2). In terms of the c_{12}^2 and $c_{22}c_{12}$ of the relevant models, it was indicated that asymmetric shock spillovers exist between the shadow interest rate of the U.S. and the FXERI. However, the finding that a_{12} and b_{12} were statistically insignificant in the relevant model does not confirm a long-term relationship between the shadow interest rate and the FXERI for the post-GFC period in terms of shock and volatility spillovers. The VARMA–BEKK–AGARCH estimations showed that there might be long-term impacts of the shadow interest rate of the U.S. on the CRASERI in terms of a_{12} and b_{12}, whereas the asymmetric shock spillover did not persist. These findings may be interpreted as the effects of the FED's interest rate policy on emerging markets being mitigated by the country-specific macroeconomic vulnerabilities of emerging countries after the GFC.

On the other hand, the relevant empirical models determined that bad news about the shadow interest rate of the U.S. does not tend to influence the excess returns in the multiple-asset class of emerging countries more than good news. In terms of a_{21}, b_{11}, and b_{21}, the model results also implied the long-term effect of excess returns in the financial markets of emerging countries on the shadow interest rate of the U.S. and the volatility transition between variables both in the post-GFC period and in the entire sample. Accordingly, the long-term effect of the change in the value of financial assets of emerging countries on U.S. financial markets and the FED interest rate policy was confirmed, in line with Ammer et al. (2019). Since the results obtained for c_{21} and c_{11} for all the models did not strongly support asymmetric effects, it can be said that the developments in the financial markets of emerging countries have a very weak probability of triggering a financial crisis in the U.S. economy.

In this study, the robustness of the estimated VARMA–BEKK–AGARCH-type models was also tested with the Ljung–Box, and McLeod–Li tests. Of all the models, the Ljung–Box test results generally revealed that the null hypothesis of no serial correlation could not be rejected. The McLeod–Li statistics also supported the adequacy of the ARCH and GARCH terms in the model. On the other hand, the slope-based Mork test was conducted to evaluate the presence of asymmetric relationships between the variables of the models within the scope of the non-linear VAR model (Kilian & Vigfusson, 2011). The Mork test was chi-square based, and p-values greater than 0.05 indicated the validity of the non-asymmetric relationship. This study estimated the non-linear VAR model for the full sample and the subsample in accordance with the vectors indicated in Table 3. At the confidence level of 95%, it can be accepted that there can be asymmetric effects in the impacts of gsh_t^f on $gfxeri_t^f$, while gsh_t^{ab} also has asymmetric effects on $gcraseri_t^{ab}$. Similarly, this study used Mork tests to investigate whether FXERI and CRASERI have asymmetric effects on the U.S. shadow interest rate, and it was strongly confirmed that shocks in the FXERI have asymmetric effects on the shadow interest rate of the U.S. Thus, it can be suggested that the positive and negative shocks in the FXERI will not be weighted with the same importance by the FED. On the other hand, since I found that the CRASERI does not have an asymmetric effect on the shadow interest rate of the U.S., it can be argued that the monetary policy in the United States gives significant responses to positive and negative shocks in the multiple-asset class.

Table 3. Residual diagnostics for the model variables and Mork test results

	$(gfxeri_t^f, gsh_t^f)'$		$(gcraseri_t^f, gsh_t^f)'$		$(gfxeri_t^{ab}, gsh_t^{ab})'$		$(gcraseri_t^{ab}, gsh_t^{ab})'$	
	$gfxeri_t^f$	gsh_t^f	$gcraseri_t^f$	gsh_t^f	$gfxeri_t^{ab}$	gsh_t^{ab}	$gcraseri_t^{ab}$	gsh_t^{ab}
Ljung–Box Q(20)	14.526 (0.796)	21.399 (0.374)	11.280 (0.871)	14.359 (0.811)	12.377 (0.871)	15.480 (0.748)	47.335*** (0.000)	23.856 (0.248)
Ljung–Box Q(40)	33.080 (0.524)	40.864 (0.432)	15.665 (0.974)	27.207 (0.938)	15.344 (0.912)	32.566 (0.791)	97.542*** (0.000)	39.109 (0.510)
McLeod–Li(20)	25.289 (0.145)	33.155** 0.032	11.265 (0.915)	14.475 (0.805)	10.536 (0.957)	19.820 (0.469)	11.368 (0.936)	10.661 (0.954)
McLeod–Li(40)	47.400 (0.157)	55.036* 0.057	21.383 (0.951)	29.162 (0.897)	22.693 (0.987)	43.673 (0.318)	21.252 (0.993)	27.298 (0.936)
	$gsh_t^f \rightarrow gfxeri_t^f$		$gsh_t^f \rightarrow gcraseri_t^f$		$gsh_t^{ab} \rightarrow gfxeri_t^{ab}$		$gsh_t^{ab} \rightarrow gcraseri_t^{ab}$	
Mork's test of symmetric coefficients and p-values	3.993** (0.045)		2.725* (0.098)		3.683** (0.054)		18.383*** (0.000)	
	$gfxeri_t^f \rightarrow gsh_t^f$		$gcraseri_t^f \rightarrow gsh_t^f$		$gfxeri_t^{ab} \rightarrow gsh_t^{ab}$		$gcraseri_t^{ab} \rightarrow gsh_t^{ab}$	
Mork's test of symmetric coefficients and p-values	9.139*** (0.002)		0.325 (0.568)		14.128*** (0.000)		0.084 (0.770)	

Note: The values in parentheses refer to the p-values.
***, **, * denote significance at 1%, 5%, and 10% repectivelly.

Conclusion

In this study, the VARMA–BEKK–AGARCH models were divided into two segments. More specifically, the mean equation reflects the short-run interactions between model variables, and the variance equation provides the opportunity to examine the shock, volatility, and asymmetric spillovers in the long run. The estimated for the entire sample revealed the relationship between the shadow interest rate and the FXERI, and shadow interest rates do not have immediate effects on the FXERI. It was also found that the changing economic conditions and the economic structure after the GFC do not change the transition of U.S. interest rates to emerging countries' exchange rates. In addition, the increases in the shadow interest rates in the U.S. will reduce the CRASERI. Therefore, it can be said that the level of integration between the changes in the U.S. money market conditions and the financial markets of emerging countries has increased. In this study, short-term shock spillovers were also evaluated among the variables of the models, and it was revealed that the shocks in shadow interest rates will decrease the value of the FXERI and CRASERI. In other words, it was determined that monetary policy changes that do not comply with the monetary policy framework pursued by the FED may cause capital flows to shift from emerging countries to the U.S. financial markets. Therefore, it can be argued that shocks in U.S. shadow interest rates are perceived by economic agents as the FED's interest rate increase and the tightening of money market conditions. Although the FED's policy rate cut is a sign of the strong performance of the U.S. economy, it is suggested by the models' results that the high interest rate environment in the U.S. can prevent excessive returns on the financial markets of emerging countries and can contribute to meeting the global financial stability target.

The results of VARMA–BEKK–AGARCH model showed that changes/shocks in shadow interest rates will reduce the excess returns in the financial markets of emerging countries in the long term. Additionally, the country-specific macroeconomic developments have gained weight in emerging countries' exchange rates in the post-GFC period and the relationship between the foreign exchange market the U.S. shadow interest has weakened. At this point, it can be argued that issues such as a high debt level and level of foreign exchange reserves, which cause macroeconomic and financial vulnerabilities in these countries, dominate the FXERI by affecting the country risk. The long-term response of the money and capital markets of emerging markets is negative and statistically significant to the country-specific macroeconomic and financial fragilities as well as the foreign interest rates. Moreover, there exposes the long-term relationship between the U.S. shadow interest rate and the CRASERI. The asymmetric impact of shadow interest rates on the FXERI and the CRASERI were implied. Accordingly, it can be suggested that bad news about the shadow interest rate of the U.S. has a greater impact than good news.

The long-term effect of excess returns in the financial markets of emerging countries on the U.S. shadow interest rate was also analyzed with the VARMA–BEKK–AGARCH models. The shocks in the FXERI and the CRASERI can cause the interest rates to rise in the U.S. in the short term. In other words, due to excessive returns in emerging countries, it can be argued that the FED may soon pursue policies that reduce the abundance of global liquidity. As a result of the estimated values, it can also be assumed that these inferences are partially valid for the long term.

Furthermore, the excess returns in emerging countries have volatility spillovers to the U.S. shadow interest rates in the post-GFC period. However, it was suggested that bad news in the FXERI and the CRASERI does not influence the shadow interest rates in the U.S. more than good news. Although excess returns in the emerging countries did not have asymmetric effects on the shadow interest rate in the U.S., the results of the slope-based Mork test performed under the non-linear VAR model emphasized that the FED will give asymmetric responses to shocks in the FXERI.

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