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Volatility spillovers of Federal Reserve and ECB balance sheet expansions to emerging market economies

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Abstract

This paper examines volatility spillovers from changes in the size of the balance sheets of the Federal Reserve (FED) and European Central Bank (ECB) to emerging market economies (EMEs) from 2003 to 2014. We find that EME bond markets are most susceptible to positive volatility spillovers from both the FED and ECB in terms of magnitude. Positive volatility spillovers to EME currency markets are higher in the case of FED balance sheet expansions than those of the ECB by a factor of about ten. By contrast, we find that EME stock markets are subject to negative volatility spillovers. Moreover, we find only limited evidence of volatility transmission to the real economy of EMEs following the monetary policy actions of the FED and ECB. Finally, we show that the proportion of the volatility in EMEs that is accounted for by changes in FED and ECB balance sheets shifts over time.

JEL Classification: F3, F4, F16, G1

Keywords: unconventional monetary policy, central bank balance sheets, volatility spillovers, financial markets.

Non-technical summary

The expansion of international trade and a more pronounced increase in cross-border capital flows over the past decade or so means that countries are more interconnected, with developing countries receiving and sending substantial amounts of capital. The global financial crisis has reversed some of these capital flows to EMEs and has led to increased levels of financial and real volatility. The unprecedented actions by major central banks, which can affect the 'world' interest rate, are also likely to have had an impact on the volatility in EMEs. This paper examines volatility spillovers to EMEs from changes in the balance sheets of the Federal Reserve (FED) and the European Central Bank (ECB) over the period 2003 to 2014.

When the FED announced that it may slow its monetary stimulus in May 2013, emerging markets' currencies and asset prices became more volatile. The recent literature concentrated on the spillovers from unconventional monetary policies in developed countries and their effects on the levels of financial variables in other countries. However, the volatility that was observed in the financial and real variables of many developing countries has largely been ignored. The discontinuation on the one hand of unconventional monetary policies in the U.S., and the decision of the ECB on the other hand to embark on quantitative easing, have renewed interest in the volatility spillovers from these policies to EMEs. This paper estimates the extent to which the volatility across 13 EMEs can be explained by the changes in the FED and ECB balance sheets. In particular, we explore the dual transmission channel of monetary policy to domestic economies and spillovers to EMEs using a two-step specification to measure volatility spillovers to EMEs. Volatility spillovers are estimated with respect to financial variables such as the bilateral exchange rate, stock and bond markets, as well as macroeconomic variables such as inflation and industrial production.

Overall, our results indicate that the volatility of the FED and ECB balance sheets can explain some of the volatility in EMEs. We find that EME bond markets are most susceptible to positive volatility spillovers from both the FED and ECB in terms of the magnitude of the effect. Positive volatility spillovers to EME currency markets are higher in the case of FED balance sheet expansions than those of the ECB by a factor of about ten. By contrast, we find that EME stock markets are subject to negative volatility spillovers from both the expansion of the FED and ECB balance sheets, whereby volatility in EME stock markets is dampened due to this. Moreover, we find only limited evidence of volatility transmission to the real economy of EMEs following the monetary policy actions of the FED and ECB. Volatility spillovers from the ECB and the FED were generally more pronounced during the peak of the crisis in late 2008. Volatility spillovers from the FED have been diminishing since late 2008, due its exit from unconventional monetary policies but have not diminished as drastically for the ECB. Our results have policy implications for EMEs exposed to volatility spillovers from advanced economy central bank balance sheet expansions. These particularly pertain to calls for local currency bond markets, given that EME bond markets are most susceptible to negative volatility spillovers for both FED and ECB balance sheet expansions.

1 Introduction

> "...frankly the ECB has not done anything to increase volatility in the markets. If you think that the ECB has done anything that is comparable to what is happening in the other central banks, we would not agree with this perception...But, certainly, we have observed an increase in global volatility, coming from major monetary policy decisions or announcements of decisions that may be taken in the coming months. However, I do not think that the ECB has in any way been a source of this; I cannot really find any data to support this." (Mario Draghi, June 2013)[1]

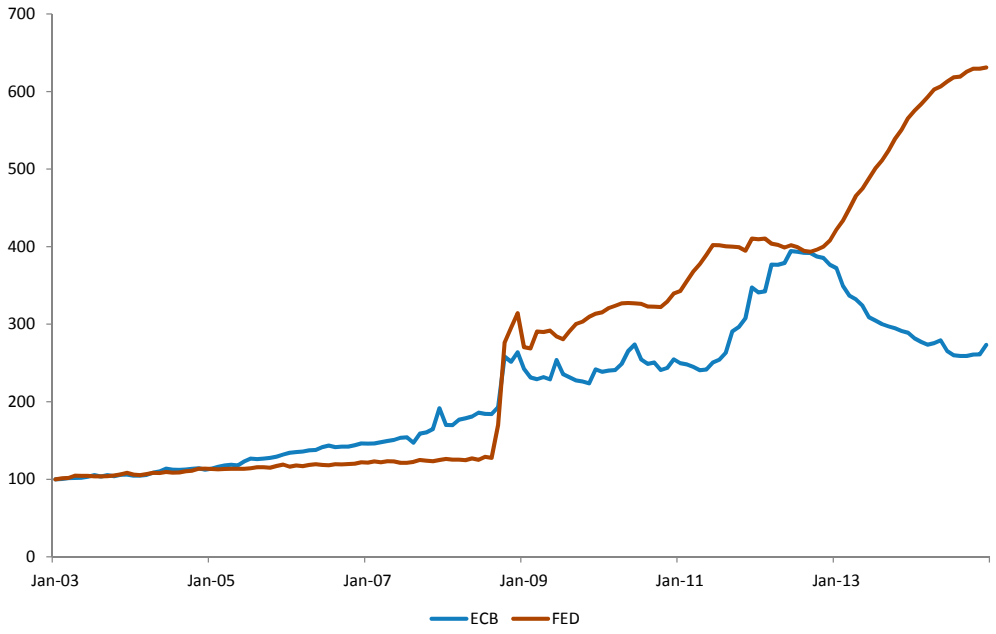
The May 2013 announcement by the FED that it may slow down its monetary stimulus led to considerable volatility in EME currencies and other asset markets. Nonetheless, the recent literature has concentrated on the effects of unconventional monetary policies in developed countries on the levels of financial variables in other countries. The recent discontinuation, on the one hand, of unconventional monetary policies in the U.S., and the decision on the other hand of the ECB to embark on quantitative easing, have renewed interest in volatility spillovers from these policies to EMEs. Figure 1 shows that the expansion of both the FED and the ECB balance sheets since the crisis has been significant and it is likely to have encouraged capital outflows from their respective economies to other countries especially emerging markets, where interest rates remained significantly higher.

This paper measures the volatility of economic and financial variables in EMEs that can be explained by the volatility spillovers from the balance sheets of the FED and the ECB. Using a two-step specification to measure volatility spillovers to EMEs, we investigate the *volatility* spillovers from the monetary policies of the FED and ECB, while most of the recent literature, such as Fratzscher, Lo Duca and Straub (2016), investigates the *level* of spillovers. Focusing on the period from 2003 to 2014, volatility spillovers are estimated for 13 EMEs with respect to financial variables such as the bilateral exchange rate, stock and bond markets, as well as macroeconomic variables such as inflation and industrial production. Our analysis incorporates the following EMEs: Brazil, Russia, India, China and South Africa, Poland, Hungary, Croatia, the Czech Republic, Colombia, Chile, Mexico and Peru.

The expansion of international trade and the pronounced increase in cross-border capital flows over the past decade or so means that countries are more interconnected, with developing countries receiving and sending substantial amounts of capital. The global financial crisis reversed some of these capital flows to and from EMEs and has increased levels of financial and real volatility. The unprecedented actions by major central banks, which can affect the 'world' interest rate, are also likely to have had an impact on the volatility of financial and macroeconomic variables in emerging markets. This paper measures volatility spillovers from monetary policies as the volatility in emerging market financial and macroeconomic variables that can be explained

[1] Mario Draghi, President of the ECB, Introductory statement to the press conference (with Q&A), Frankfurt am Main, 6 June 2013.

Figure 1: Scaled Assets of the FED and the ECB (June 2007=100)



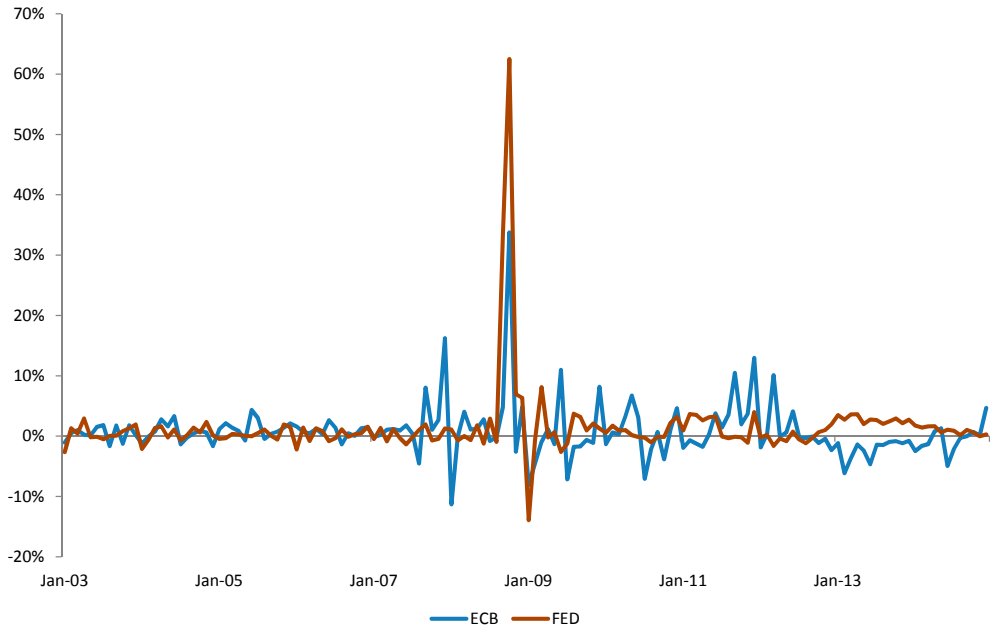
Data:FED and ECB

by the volatility in the FED and ECB balance sheets.

The actions of the FED and the ECB are of particular importance not only because of the size of their respective economies, and the size of their balance sheets, but also because of the international role of the U.S. dollar and the euro, and their influence on international interest rates. Given the volume of trade and the significant current account surpluses and deficits in a much more globalised world, combined with the activist stance of major central banks the issue of volatility spillovers from monetary policies has come to the forefront of international policy discussions. In addition, the increase in foreign reserves held by EMEs, has coincided with substantial cross border asset holdings and gross capital flows. Foreign reserves are mainly denominated in U.S. dollars and euros because these currencies are considered to be safe and liquid. Countries issuing these currencies are the most financially developed countries and therefore attract a large share of foreign reserves. The global crisis and the fall in some asset prices, have prompted central banks in developed countries to take unprecedented measures that are likely to have had an impact beyond bilateral exchange rates, to affect the prices of assets held by emerging market central banks and private individuals. Interventions by central banks probably can explain part of the observed volatility in asset prices and may have induced investors to shift to other asset classes thereby affecting portfolio allocation decisions.

The exit of the FED from unconventional policies has coincided with volatility in exchange rates, macroeconomic variables and in various asset classes. The turmoil following the May 2013

Figure 2: Changes in the FED and the ECB's balance sheets



Data:FED and ECB

announcement of 'tapering' of unconventional monetary policies by the FED and the market reactions after the ECB's quantitative easing programme announcement shows that central banks remain important players in international markets, even when policy rates have reached the zero lower bound.

The interconnectedness between developed and emerging countries has led to comovements of output during the crisis. Nonetheless, the growth differentials among countries are noticeable. Therefore, central banks in the countries where growth is rising such as the U.S. and U.K have tended towards monetary policy normalisation while other central banks such as the ECB and Bank of Japan (BOJ) have expanded or promised to expand their balance sheets. These unsynchronised policies are likely to affect the volatility of asset prices and macroeconomic variables in the global economy. The interventions by the FED and ECB are analysed by looking at changes in the size of their balance sheet, which has been volatile (Figure 2), because policymakers have adjusted their policies as information about the state of their economies became known. These interventions are likely to have some volatility spillovers to EMEs.

Overall, our results indicate that the volatility of the FED and ECB balance sheets can explain some of the volatility in EMEs. We find that EME bond markets are most susceptible to positive volatility spillovers from both the FED and ECB in terms of the magnitude of the effect. Positive volatility spillovers to EME currency markets are higher in the case of FED balance sheet expansions than those of the ECB by a factor of about ten. By contrast, we find that

EME stock markets are subject to negative volatility spillovers from both the expansion of the FED and ECB balance sheets, whereby volatility in EME stock markets is dampened due to this. Moreover, we find only limited evidence of volatility transmission to the real economy of EMEs following the monetary policy actions of the FED and ECB. Volatility spillovers from the ECB and the FED were generally more pronounced during the peak of the crisis in late 2008. Spillovers from the FED have been diminishing since late 2008, due its exit from unconventional monetary policies but have not diminished as drastically for the ECB. Negative volatility spillovers are found in the case of EME stock markets, implying balance sheet expansions by the FED and ECB have had a mitigating effect on EME stock market volatility.

The remainder of the paper is structured as follows. Section 2 reviews the related literature that guides the analysis. Section 3 presents the empirical methodology and the data used and Section 4 summarises the results. Section 5 concludes, providing some policy implications.

2 Related literature

This paper contributes mainly to the growing literature on the effects of unconventional monetary policies, and it is closely related to both the theoretical and empirical aspects of the literature. On the theoretical side, our work is related to that of Fernández-Villaverde et al. (2011), which examines the effect of changes in the volatility of interest rates in emerging markets, sometimes due to shocks from foreign monetary policy, and the effect on macroeconomic and financial variables. Fernández-Villaverde et al. (2011) build a dynamic stochastic general equilibrium model and find that an increase in real interest rate volatility leads to a decrease in output, consumption, investment, and hours worked when calibrated with data from EMEs. This is driven by households changing their precautionary holdings of foreign debt, dominated by US dollar and euro denominated assets that also form a large part of the portfolios of international investors.

The effects described by Fernández-Villaverde et al. (2011) are slightly different to the transmission of monetary shocks in levels as regards the basic IS/LM model interpreted by Burda and Wyplosz (2012); the IS/TR model with a Taylor Rule (TR) guiding monetary policy and an international market interest rate.[2] The results of Fernández-Villaverde et al. (2011) are particularly relevant to our modelling approach given the focus on volatility spillovers, providing a theoretical underpinning to our empirical strategy. The detrimental effects of volatility spillovers in interest rates are distinct from level effects. Volatility can still be detrimental even if the level of interest rate is beneficial for the domestic economy. A further related paper by Uribe and Yue (2006) finds that interest rate shocks emanating from the US contribute to volatility in EMEs (see also Neumeyer and Perri (2005) who find that the international interest rate ampli-

[2] See Appendix for further details.

fies shocks to EMEs).

Prior to the global financial crisis, there was little mention made of the term spillovers. Early work carried out by Bernanke and Reinhart (2004), inspired by the case of Japan, examined the policy options for central banks in the face of a zero lower bound: one, forward guidance for low interest rates, two, changing the central bank balance sheet composition and, three, expanding the central bank balance sheet or quantitative easing. The unintended side-effects of implementing these types of policies, however, was not a feature of the early literature. Unconventional monetary policy interventions reduce the risk of future asset price declines and thus tend to increase the price of assets today. The CAPM has provided the theoretical background for pricing risky assets, and papers by Sharpe (1964), Lintner (1965) and Merton (1973) are the bases for most asset pricing methods. However, asset pricing models are not conclusive regarding the impact of volatility on overall asset prices because a reduction in the volatility of economic fundamentals can affect some asset classes negatively and some positively. Hence, there is no clear theoretical direction of how asset prices will move if interventions by central banks reduce or increase macroeconomic variables volatility.

As regards to the empirical literature, the analysis of unconventional monetary policy spillovers came to the fore after the crisis, with the majority of papers tending to focus on the different effects of types of policies on the levels as opposed to the volatilities of financial variables. For example, we build on the findings of Fratzscher, Lo Duca and Straub (2016), who find that the FED's unconventional monetary policy announcements had a smaller effect than the actual operations of the FED. The authors find that the actual operations, which increased its balance sheet, affected the portfolio decisions and asset prices outside the US, and spilled over to EMEs. Their findings suggest that investors did not fully adjust their portfolios at the time of the monetary policy announcements, and it was the operations that had the dominant effect on investor behaviour. The authors argue that announcements are not enough to repair dysfunctional markets and actual operations could contain new information to encourage investors to change their behaviour. The authors argue that the unconventional monetary policy actions of the ECB had similar effects, specifically the 3-year longterm refinancing operations (LTROs) in 2011 and 2012, where the amounts borrowed by the banks were the determinants of the success of the policy. Our paper builds on the work of Fratzscher, Lo Duca and Straub (2016) by focusing on volatility spillovers using changes in the value of assets in the FED and ECB balance sheets as the instrument for monetary policy spillovers.

A range of other papers have analysed the effects of quantitative easing. For example, Ait-Sahalia et al. (2012) examines the market response to unconventional monetary policy announcements on financial variables. Hattori, Schrimpf and Sushko (2013) find that quantitative easing by the FED decreased the perceived risks both in response to announcements and actual operations. Our results are consistent with Hattori, Schrimpf and Sushko (2013), who find that the effect of the actual purchases of assets is most pervasive when there is an expansion and a duration ex-

tension of the balance sheet. Bekaert, Hoerova and Lo Duca (2010) find similar results, whereby loose monetary policy decreases risk aversion and uncertainty, conditional on business cycle movements. Their results reinforce our empirical strategy, to focus on the volatility of both financial and macro variables, building on the changes in risk aversion and uncertainty that may have been contributed to by the monetary policies of the FED and the ECB. Consistent with our findings, Gambacorta, Hofmann and Peersman (2014), using a panel VAR approach, find that the effects of unconventional monetary policies in different countries contribute to a temporary rise in economic activity and the price level. Therefore, the monetary policy tools utilised by the FED and ECB are likely to have temporary positive effects on their domestic economies but are likely to have asymmetric effects on developing countries that do not share the same macroeconomic characteristics. Analysis of international spillovers of central bank balance sheet policies have also been carried out by Chen et al. (2013). Finally, a useful review of the literature on unconventional monetary policy developed during the recent crisis is provided by Cecioni, Ferrero and Secchi (2011).

Our paper is also closely related to the literature on volatility spillovers more broadly. For example, Diebold and Yilmaz (2009), focusing on equity returns, find that there are bursts to volatility spillovers that have no trend. This is in line with our findings that the burst in unconventional monetary policies by the FED and ECB had an asymmetric impact on the financial and macroeconomic variables in EMEs. In addition, consistent with our findings, Yilmaz (2010), using an equity volatility spillover index, finds that the interdependence among East Asian equity markets pushed the index to its highest levels during the current crisis. Moreover, Devereux and Yetman (2010) and others have developed the mechanisms underpinning the interconnectedness between countries financial assets. Devereux and Yetman (2010) propose a model of the international transmission of shocks due to interdependent portfolio holdings among leverage-constrained investors. When the leverage constraints bind, the diversified portfolios of investors create a financial transmission channel that results in a positive comovement of production, independently of the size of international trade linkages.

Our paper follows the methodology developed by Ng (2000), who proposed a two-step approach to investigating the volatility spillover from the U.S. and Japanese stock markets to the Asia Pacific-Basin region stock markets. Ng (2000) two-step approach starts with the calculation of the volatility in a bivariate GARCH model including the U.S. and Japanese stock markets. In the second step it includes the innovations derived in the first step to calculate the volatility spillover to the Asia Pacific-Basin region. Previous literature has also focused on volatility spillovers such as the Bekaert and Harvey (1997), which allow for an impact, or spillover, of global shocks to other countries. More recently, Engle, Gallo and Velucchi (2012) find that a network of interdependencies propagates volatility shocks across Asia, which make the system more unstable during crisis. The methodology of Ng (2000) is appealing as it captures non-linear changes in the central bank balance sheet. Our paper aims to provide some insights into the spillovers from the monetary policies of the FED and ECB to EMEs using this type of technique that takes

into account non-linearities.[3]

3 Data and Methodology

3.1 Data Description

We use monthly data from the FED and the ECB regarding the total size of the assets in their balance sheets from 2003M1 to 2014M12. The EMEs in our sample are as follows: the BRICS countries [Brazil (BRA), Russia (RUS), India (IND), China (CHI), and South Africa (ZAF)], Poland (POL), Croatia (HRV), Hungary (HUN), the Czech Republic (CZE), Colombia (COL), Chile (CHL), Peru (PER) and Mexico (MEX). Monthly data on the following variables has been collected: the EMEs bilateral exchange rate against the U.S. dollar and the euro, the main stock market index, EMBI spreads, industrial production and the consumer price index. Using a monthly data frequency is more appropriate than using lower frequency data, which can smooth out volatility effects.

For the ECB we estimate the volatility spillovers to the BRICS plus Poland, Croatia, the Czech Republic and Hungary, which are closely connected to the euro area economy. For the FED we estimate the volatility spillovers to BRICS plus Colombia, Chile, Peru and Mexico, which are more closely connected to the U.S. economy. The data have been collected using Haver analytics, which provides seasonal adjustments for most of the variables for the EMEs and the FRED Dataset for data regarding the FED and ECB balance sheets and from JP Morgan Markets data for EMBI spreads. We calculate the percentage change in the FED and ECB balance sheet using asset data provided by the respective central banks in monthly frequencies. We also calculate the percentage change in the financial and macroeconomic variables of the EMEs in monthly frequencies.

3.2 Methodology

Our methodology is similar to Ng (2000), who proposed a two-step approach to investigating the volatility spillover from the U.S. and Japanese stock markets to the Asia Pacific-Basin region stock markets. The Ng (2000) methodology is very useful in terms of capturing the non-linear changes in the FED and ECB balance sheet, which the previous literature on spillovers had difficulty modelling. While Ng (2000) uses a bivariate GARCH model to include both the U.S. and Japanese stock markets, we use only one variable for each of the FED and the ECB, namely the changes in the respective balance sheets.[4] We test for the significance of the spillover from

[3] The ARCH model developed by Engle (1982) and Bollerslev (1986) provides a good fit for financial time series. Several volatility models have been proposed, and the GARCH specification has become an important tool in measuring volatility of various financial and economic variables. We use the GARCH model to estimate the volatility of balance sheet of central banks, which has increased significantly since the crisis. The GARCH model is a good fit for both the central bank balance sheets and some of the financial and macroeconomic variables in EMEs because it captures the non-linear changes in the FED and ECB balance sheets and the non-linear pattern found in EME's variables.

[4] This has been done in order to have a consistent approach to the estimation across all EMEs. In our sample, we do not estimate volatility spillovers from the Fed and ECB balance sheets to each of the 13 EMEs in our sample. Of the 13 EMEs, only five are common to both the Fed and ECB spillover analyses. As a result, we opted for a univariate

the FED and ECB respectively and then we estimate the volatility ratio as the ratio of the estimated variances of the EMEs and the central bank balance sheets.

We use a two-step GARCH specification to assess the impact of monetary policies in developed countries, on EMEs. We start with the specification of GARCH(1,1) model for the central bank:

$$r_{cb,t} = \alpha_{cb} + \sqrt{\sigma^2_{cb,t}} z_{cb,t}, \qquad z_{cb,t} \sim \mathcal{N}(0,1) \tag{1}$$

where $r_{cb,t}$ is the percentage change in the central bank's balance sheet at time t. $z_{cb,t}$ is independently and identically distributed as a normal distribution with mean 0 and variance 1. The GARCH variance is defined as:

$$\sigma^2_{cb,t} = \omega_{cb} + \beta_{cb} r^2_{cb,t-1} + \gamma_{cb} \sigma^2_{cb,t-1} \tag{2}$$

where $\omega_{cb} > 0$, $\beta_{cb} \geq 0$, $\gamma_{cb} > 0$ and $\beta_{cb} + \gamma_{cb} < 1$. The innovations from our model are defined as:

$$\varepsilon_{cb,t} = r_{cb,t} - \alpha_{cb} - \sqrt{\sigma^2_{cb,t}} z_{cb,t} \tag{3}$$

We use the GARCH (1,1) model as in Bollerslev (1987), since during the period of 2003-2014, monetary policy was characterized by periods of calm followed by periods of volatility.[5]

In order to model the volatility spillovers from the FED and ECB balance sheet expansions, in the second step we use the innovations from our first GARCH (1,1) regression and add them as an explanatory variable in the second GARCH(1,1) regression for the emerging market variables. The specification is as:[6]

$$r_{em,t} = \alpha_{em} + \phi \varepsilon_{cb,t} + \sqrt{\sigma^2_{em,t}} z_{em,t}, \qquad z_{em,t} \sim \mathcal{N}(0,1) \tag{4}$$

where $r_{em,t}$ is the percentage change in the emerging market variable at time t. $z_{em,t}$ is independently and identically distributed as a normal distribution with mean 0 and variance 1. The GARCH variance is defined as:

$$\sigma^2_{em,t} = \omega_{em} + \beta_{em} r^2_{em,t-1} + \gamma_{em} \sigma^2_{em,t-1} \tag{5}$$

where $\omega_{em} > 0$, $\beta_{em} \geq 0$, $\gamma_{em} > 0$ and $\beta_{em} + \gamma_{em} < 1$.

The above specification means that we include the innovations from our first step, the central bank GARCH(1,1), to capture its explanatory power with regards to the volatility in the variables of developing countries. The above specification is the general specification but we test each time for the significance of the coefficient of the innovations from the step 1 regression. We

approach (the bivariate approach is more appropriate in the case of Ng (2000), where volatility spillovers are estimated from the US and Japanese stock markets to a common set of EME stock markets).

[5] We use GARCH(1,1) for both the FED and ECB.

[6] Following Ng (2000).

use the Wald test to test if the coefficient of the innovations of the change in the central bank balance sheet is different from zero. Where we find that these coefficients are not different from zero, then we conclude that there are no volatility spillovers.[7]

Then we find the ratio of the volatility of the variables in the developing countries that is explained by the volatility in the developed countries central banks' balance sheet. We calculate this ratio, which holds by construction, as:

$$VR_{cb,t} = \frac{\phi^2 \sigma^2_{cb,t}}{\sigma^2_{em,t} + \phi^2 \sigma^2_{cb,t}} \tag{6}$$

$VR_{cb,t}$ is the volatility ratio, a measure of the proportion of conditional variance of the developing countries variables that is accounted for by the change in the central banks' balance sheets. This measure will be our volatility spillover measurement from developed countries central banks' balance sheet volatility to variables in EMEs. We present this volatility spillover graphically to show our results in an intuitive way.

4 Results

4.1 Volatility spillovers to EMEs: Overall effects

We find several differences between the volatility spillovers originating from the FED compared to the ECB, to EMEs. Spillovers from the FED can explain some of the volatility in almost all EMEs' bilateral exchange rates with the U.S. dollar, their stock market returns and bond spreads. By contrast, we find very limited evidence of volatility spillovers to the real economy. In particular, while the actions of the FED and ECB transmit to the industrial production in EMEs in a few cases, the magnitude of the effect is not substantial. As regards to inflation volatility in EMEs, we find no evidence that changes in the FED and ECB balance sheets affect this. Table 1 shows that there are more volatility spillovers from the FED's policies to EMEs compared to spillovers from the ECB (Table 2) in terms of the number of EME variables affected. The dominant role of the U.S. dollar in international financial markets and trade means that U.S. monetary policy affects a larger number of EMEs and more of their financial and macroeconomic variables. The magnitude of the effect is broadly similar for the FED and ECB in the case of bond and stock market spillovers, while spillovers to EME currency markets from the FED are greater than those from the ECB by a factor of about ten.

Table 2 summarises the estimated volatility spillover coefficients from the monetary policies of the ECB. We find that positive volatility spillovers originating from the ECB have the greatest effect in terms of magnitude on EME bond markets, and to a lesser extent, EME currencies. As in the case of FED spillovers, negative volatility spillover effects emerge as regards EME stock markets.

[7] We use various specifications using the Wald to determine if there are volatility spillovers.

Table 1: Volatility spillovers from the FED

	ER	Stock	EMBIG	IP	CPI
Brazil	0.122***	-0.285***	0.461***	-0.02***	0
	(0.0292)	(0.0741)	(0.017701)	(0.0092)	(0.0021)
Russia	-0.069***	-0.212	0.95***	0.079***	0
	(0.0301)	(0.1516)	(0.0262)	(0.0209)	(0.0055)
India	0.089***	-0.214***		0.016	0.003
	(0.0324)	(0.0886)		(0.0256)	(0.0211)
China	-0.003	-0.331	1.141***	-0.002	0.001
	(0.0075)	(0.2277)	(0.009278)	(0.0072)	(0.0059)
South Africa	0.234***	-0.229***	1.325***	0.119***	0.003
	(0.0361)	(0.0855)	(0.0160)	(0.0355)	(0.0049)
Colombia	0.318	-0.265***	0.819***	-0.026	0.001
	(0.0850)	(0.0774)	(0.0181)	(0.0436)	(0.0040)
Chile	0.234***	-0.108***	0.796***	0.025	0.001
	(0.0381)	(0.0425)	(0.0107)	(0.0593)	(0.0041)
Peru	0.026	-0.428***	1.184***	-0.035	0.001
	(0.0366)	(0.0950)	(0.0265)	(0.0486)	(0.0043)
Mexico	0.285***	-0.175***	0.39***	0.001	-0.001
	(0.0133)	(0.0477)	(0.014310)	(0.0095)	(0.0021)

Note: these spillover coefficents refer to the ϕ terms, as per equation (4).
***, **, * denote 1, 5, 10 percent signifance levels respectively.

Table 2: Volatility spillovers from the ECB

	ER	Stock	EMBIG	IP	CPI
Brazil	0.0743	-0.3095***	0.2302	-0.0335***	-0.0012
	(0.0919)	(0.0925)	(0.0365)	(0.0135)	(0.0021)
Russia	0.0527***	-0.0663	0.9231***	0.0094	-0.0009
	(0.0240)	(0.1695)	(0.057021)	(0.0119)	(0.0038)
India	-0.0517	-0.1794*		-0.0231	-0.0056
	(0.0412)	(0.1062)		(0.0506)	(0.0162)
China	-0.0903***	-0.6634***	1.1207***	-0.0006	0.0066
	(0.0289)	(0.1773)	(0.015393)	(0.0084)	(0.0048)
South Africa	0.0261	-0.1824***	1.0183***	-0.0151	-0.0064
	(0.0544)	(0.0791)	(0.0344)	(0.0578)	(0.0041)
Poland	0.0843***	-0.3269***	1.7507***	0.0096	0.0005
	(0.0398)	(0.0825)	(0.0164)	(0.0668)	(0.0024)
Hungary	0.0175	-0.3804***	2.2659***	0.0122	-0.0039
	(0.0222)	(0.0845)	(0.018487)	(0.0373)	(0.0057)
Croatia	-0.005	-0.0976	-0.004	0.027	0.0026
	(0.0080)	(0.0886)	(0.148522)	(0.1293)	(0.0052)
Czech Rep.	0.0352	-0.1698*		-0.0561***	0.0012
	(0.0258)	(0.0998)		(0.0158)	(0.0026)

Note: these spillover coefficents refer to the ϕ terms, as per equation (4).
***, **, * denote 1, 5, 10 percent signifance levels respectively.

The sign of the estimated volatility spillover coefficient points to whether volatility spillovers

Figure 3: EME Currency Market Volatility - FED Variance Proportion

Note: Figure 3 plots the proportion of the conditional variance of EME exchange rates that is accounted for by the volatility of the FED balance sheet, as per equation (6).

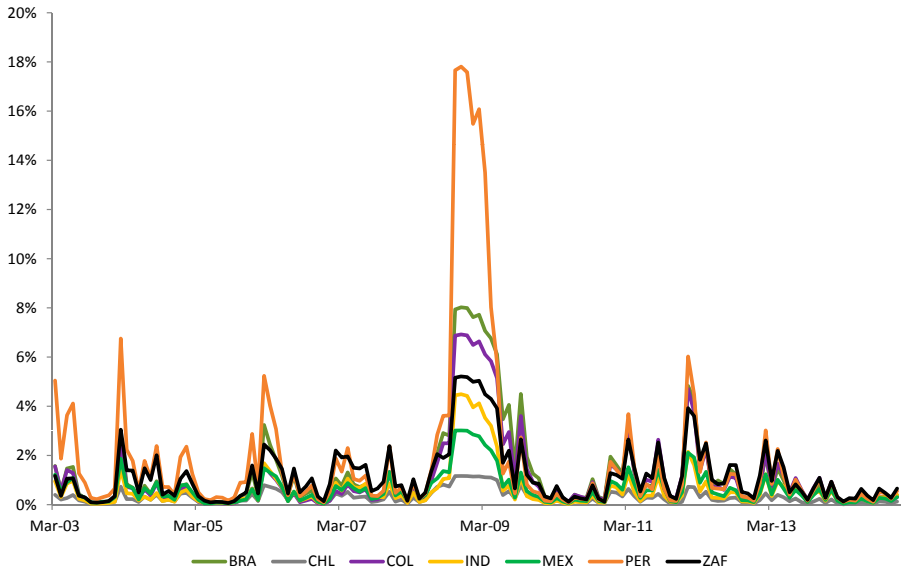
originating from the FED and ECB dampened or amplified volatility in EMEs. On the one hand, we find that spillovers originating from the FED and ECB appear to have a dampening effect on the volatility of EMEs stock markets (Table 1 and 2), as shown by the negative estimated coefficients. On the other hand, we find that spillovers originating from the FED and ECB appear to amplify volatility of EMEs EMBIG spread (Table 1 and 2), as shown by positive estimated coefficients. In particular, the results for volatility spillovers to EME bond markets are notable in the sense that the size of the coefficient implies a proportional or greater than proportional spillover in the majority of cases.

4.2 Time-varying variance proportions accounted for by the FED

Focusing on the time-varying proportion of variance accounted for by changes in the FED balance sheet to EME exchange rates, Figure 3 shows that the share is at its peak around the Lehman Brothers crisis in 2008, when the FED intervened and substantially increased the size of its balance sheet. As expected, we do not find any volatility spillovers from the FED to the Chinese renminbi and U.S. dollar exchange rate since the nominal exchange rate between the U.S. and China remained largely stable during the crisis. It appears that there is some correlation between the degree of openness of a country's capital account and the amount of volatility spillovers originating from the FED.

On EME stock market volatility, changes in the FED balance sheet account for about a small proportion of this, as shown in Figure 4. The share was at its highest at the end of 2008 and

Figure 4: EME Stock Market Volatility - FED Variance Proportion

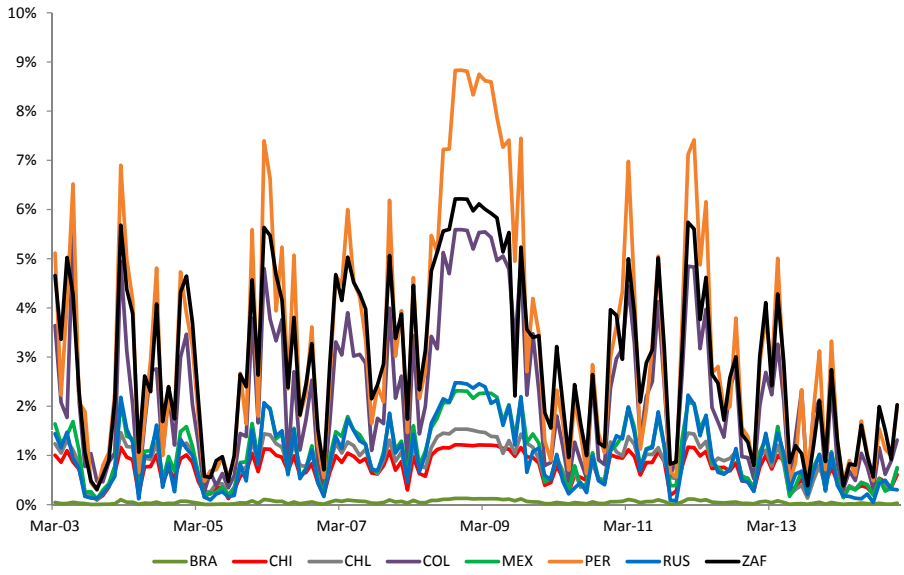


Note: Figure 4 plots the proportion of the conditional variance of EME stock market returns that is accounted for by the volatility of the FED balance sheet, as per equation (6).

the beginning of 2009, but has since diminished significantly. More broadly, it is notable that volatility spillovers from the FED have decreased despite the FED's continued accumulation of assets until end-2014. Further rounds of quantitative easing from the FED generated smaller volatility spillovers than during the most intense period of the crisis and this coincided with the increasing communication or guidance of the FED's subsequent asset purchases. The unexpected or 'shock' nature of the FED's asset purchases during the most severe period of the crisis, have probably increased the magnitude of volatility spillovers to EMEs. This was also apparent when the FED announced its 'tapering' of asset purchases; the initial reaction in EMEs variables was sharp but the slow pace and extended communication from the FED helped to reduce volatility spillovers to EMEs.

Volatility spillovers originating from the FED to EME bond markets are broad-based across countries, as shown in Figure 5. EME borrowing costs are particularly vulnerable to the actions of the FED. Given the dominant role of the U.S. dollar in financial markets and that a large proportion of EMEs borrowing is done in U.S. dollars, we find significant volatility spillovers originating from the FED to EMEs borrowing costs. As expected we observe a spike in the share of EME bond market volatility attributable to the FED during the peak of the crisis, which then gradually tapered off in recent years. Borrowing costs for all EMEs in our sample have been affected by the volatility spillovers from FED and it is reasonable to expect that a sharp decrease in the FED's assets would also lead to an increase in volatility spillovers to EMEs borrowing costs.

Figure 5: EME Bond Market Volatility - FED Variance Proportion

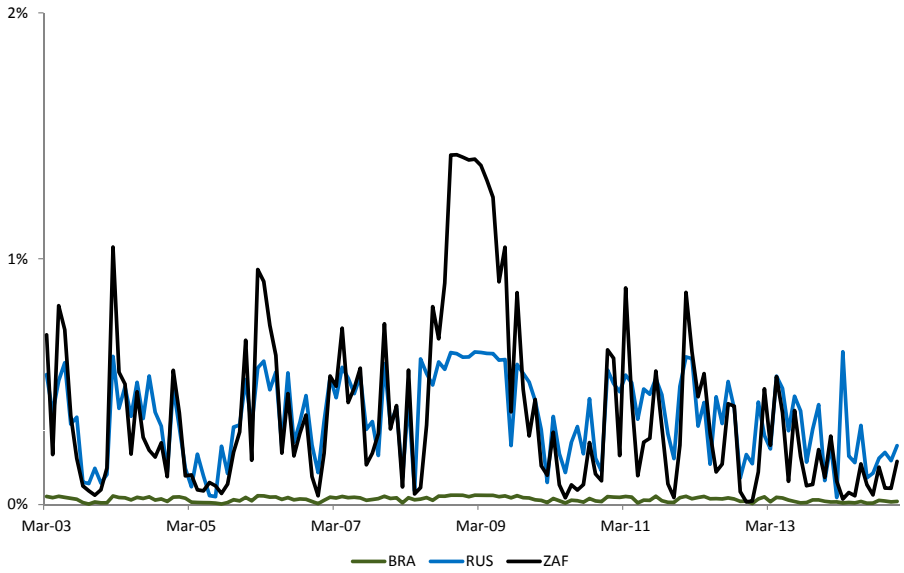


Note: Figure 5 plots the proportion of the conditional variance of EME bond market that is accounted for by the volatility of the FED balance sheet, as per equation (6).

Volatility spillovers originating from the FED can explain a very small proportion of the volatility in EMEs Industrial Production (IP), again with most spillovers apparent at the peak of the global financial crisis, as shown in Figure 6. Volatility spillovers originating from the FED on EMEs IP were much smaller than volatility spillovers to financial variables. We find volatility spillovers originating from the FED to Russia, Brazil and South Africa's IP. All three countries are major commodity exporters of goods primarily invoiced and settled in U.S. dollars, whose prices depend on the FED's monetary policy. We do not find volatility spillovers originating from the FED to China's IP, despite the country being the larger commodity importer, and this may be related to the fact that China's capital account is not as open as that of Russia, Brazil and South Africa.

During the peak of the crisis in late 2008 and the beginning of 2009, volatility spillovers originating from the FED to the EMEs were more pronounced. During that period the FED significantly increased its balance sheet to stop the panic in the U.S. financial system and support the U.S. economy by aggressively accumulating assets. The FED introduced a range of measures including the Term Auction Facility (TAF), Dollar Swap Lines, Term Securities Lending Facility (TSLF), Primary Dealer Credit Facility (PDCF), Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF or ABCP MMMF), Commercial Paper Funding Facility (CPFF) and Term Asset-Backed Securities Loan Facility (TALF). Countries with more open capital accounts seem to be the ones experiencing the highest volatility spillovers from the expansion of the FED's balance sheet. We can also observe that volatility spillovers originating from the FED were more pronounced during 2008-9 and have since generally decreased in magnitude, even

Figure 6: EME Economic Activity Volatility - FED Variance Proportion



Note: Figure 6 plots the proportion of the conditional variance of EME industrial production that is accounted for by the volatility of the FED balance sheet, as per equation (6).

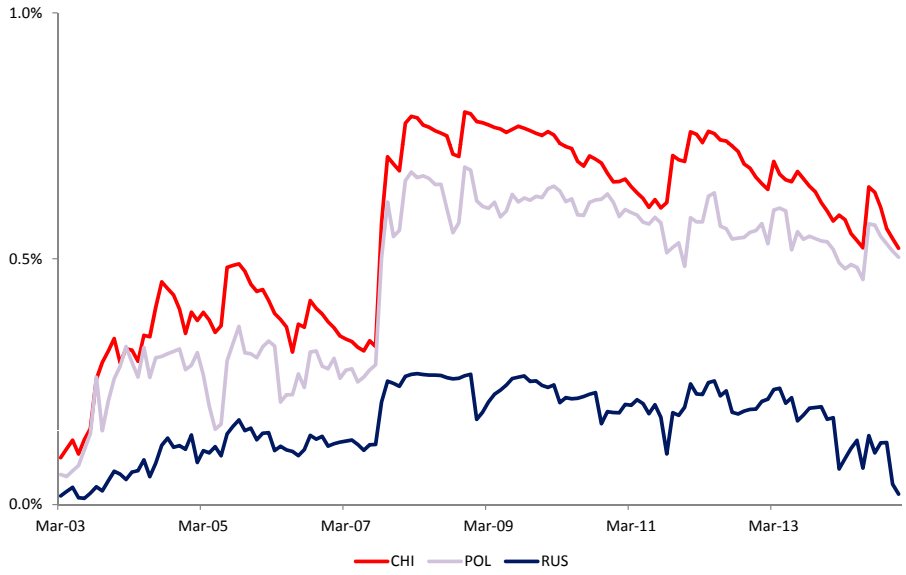
during the 'tapering' period. Perhaps the enhanced guidance and steady approach to changes in the FED balance sheet have diminished volatility spillovers from the FED.

4.3 Time-varying variance proportions accounted for by the ECB

This sub-section turns to the case of the proportion of the volatility in EMEs that is accounted for by changes in the ECB balance sheet. Figure 7 shows that the volatility spillover originating from the ECB extends to some of the EMEs bilateral exchange rate with the euro. These shares are small, because the ECB did not embark on a quantitative easing programme during our sample period. Still, volatility spillovers originating from the ECB to EMEs bilateral exchange rate with the euro were more pronounced during 2008-9. More broadly, the volatility spillover from the ECB balance sheet to EMEs bilateral exchange rate with the euro are much lower than volatility spillovers originating from the FED to EMEs bilateral exchange rate with the U.S. dollar.

As regards to EME stock markets, the variance proportion accounted for by the ECB has decreased over the past few years, as shown in Figure 8. While there was an overall dampening effect of ECB balance sheet expansion on EME stock markets, we find that of the order of around 10% of the EME stock market volatility is attributable to ECB balance sheet changes. Further rounds of monetary policy adjustment from the ECB generated smaller volatility spillovers than during the most intense period of the global and European sovereign debt crisis, and this

Figure 7: EME Currency Market Volatility - ECB Variance Proportion



Note: Figure 7 plots the proportion of the conditional variance of EME exchange rates that is accounted for by the volatility of the ECB balance sheet, as per equation (6).

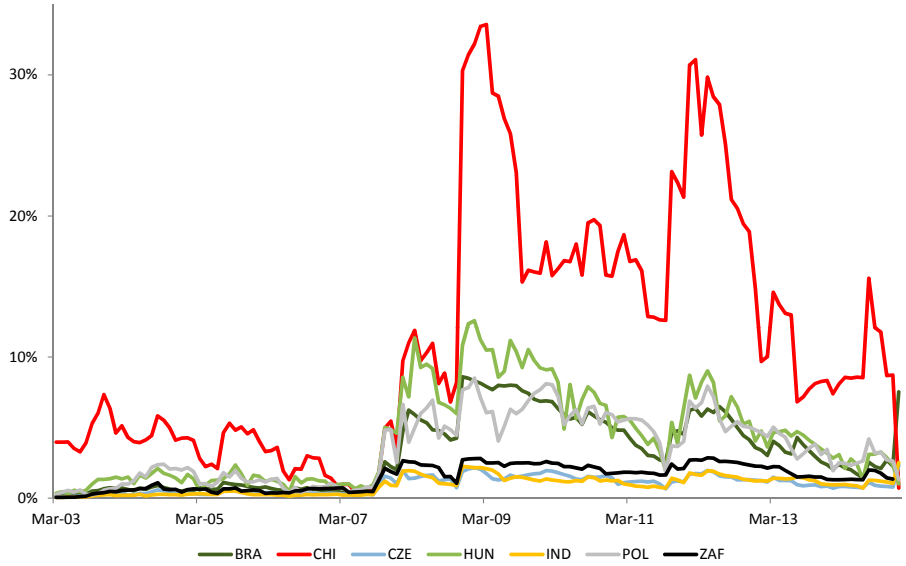
coincided with the increasing communication or guidance from the ECB.

The proportion of volatility in EME bond markets attributable to the ECB is broadly similar to that of the FED, as shown in Figure 9 but affects fewer countries. Only Hungarian EMBIG spreads were substantially affected by volatility spillovers originating from the ECB. For Hungary, volatility spillovers from the ECB remained substantial until the end of 2014.

Volatility spillovers originating from the ECB can explain only a very small part of the volatility in EMEs Industrial Production (IP), as shown in Figure 10. Volatility spillovers originating from the ECB on EMEs IP were much smaller than volatility spillovers to financial variables. We find volatility spillovers originating from the ECB to Brazil and the Czech Republic's IP. The Czech Republic is well connected with the euro area economy and therefore received some, albeit very small, volatility spillovers originating from the ECB. We do not find volatility spillovers originating from the FED to China's IP, despite the country being a large trading partner of the euro area economy.

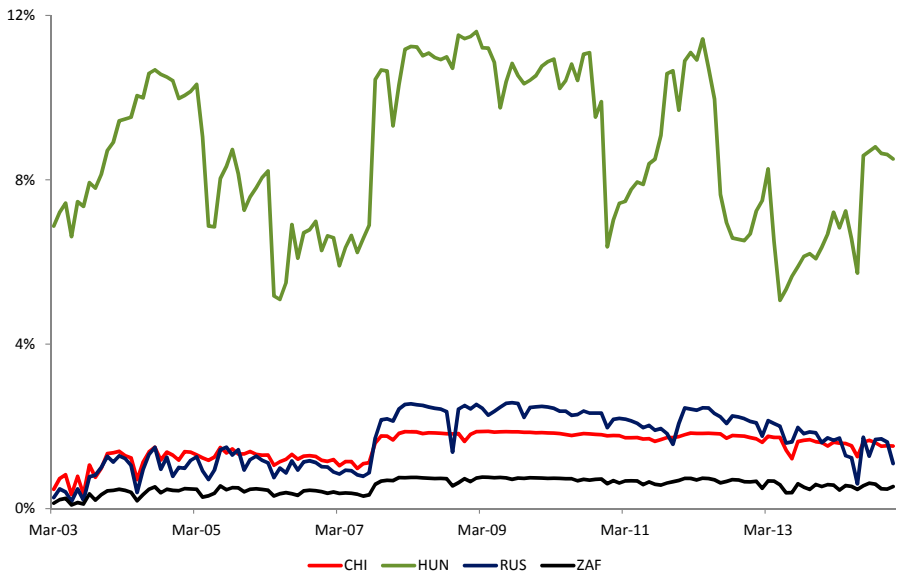
Our findings have important implications since the FED has stopped expanding its balance sheet while the ECB is embarking on a substantial increase of its own. The ECB volatility spillovers have not diminished as much as the FED volatility spillovers since 2008-9, perhaps reflecting ongoing concerns regarding the euro area and the related changes in the ECB balance sheet. Notwithstanding the end of the FED's quantitative easing programme in 2014 and the

Figure 8: EME Stock Market Volatility - ECB Variance Proportion



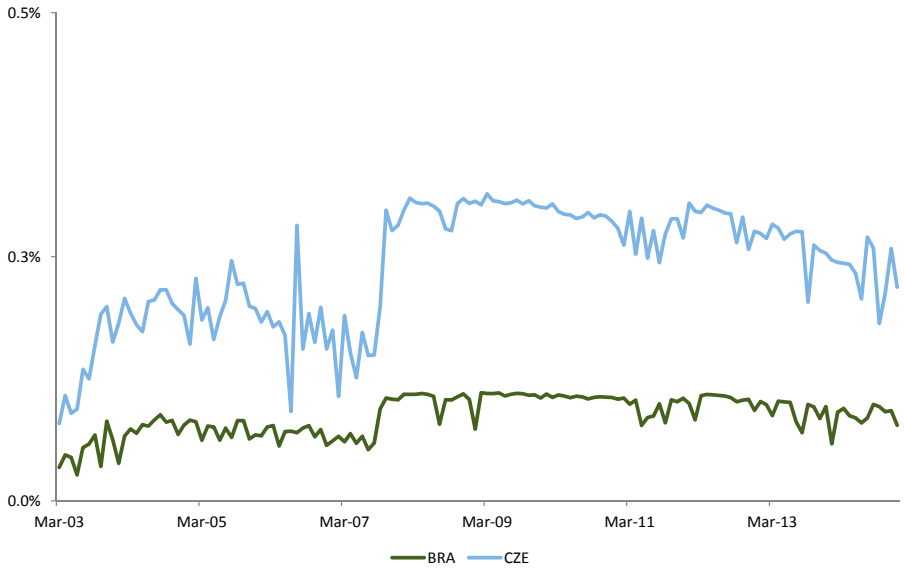
Note: Figure 8 plots the proportion of the conditional variance of EME stock market returns that is accounted for by the volatility of the ECB balance sheet, as per equation (6).

Figure 9: EME Bond Market Volatility - ECB Variance Proportion



Note: Figure 9 plots the proportion of the conditional variance of EME bond market that is accounted for by the volatility of the ECB balance sheet, as per equation (6).

Figure 10: : EME Economic Activity Volatility - ECB Variance Proportion



Note: Figure 10 plots the proportion of the conditional variance of EME industrial production that is accounted for by the volatility of the ECB balance sheet, as per equation (6).

monetary policy tightening at end-2015, overall monetary conditions in the two most important central banks in the world are likely to remain loose. The FED and ECB policies are likely to continue transmitting volatility spillovers to EMEs, albeit to a different degree.

5 Conclusion

The main contribution of this paper is to present a method for measuring volatility spillovers from the monetary policies of one country to another and to demonstrate that there have been indeed volatility spillovers from the actions of the ECB and the FED to EMEs. While only a very limited effect was found on the volatility of the real economy in EMEs, asset markets in EMEs are particularly vulnerable to volatility spillovers. More specifically, large and significant positive volatility spillovers are transmitted to EME bond markets from both the FED and the ECB. Currency markets in EMEs are particularly vulnerable to FED volatility spillovers, where the magnitude of the effect is on average around ten times greater than that originating from ECB balance sheet expansions. On EME stock markets, negative and broadly similar volatility spillover effects in terms of magnitude are apparent across both FED and ECB balance sheet expansions. We also find that the proportion of the volatility in EMEs accounted for by FED and ECB balance sheet changes shifts over time.

Despite the recent global financial crisis that slowed global growth and caused severe recessions in many developed countries, EMEs in general have been able to grow impressively compared

to developed economies. Nevertheless, EMEs growth rates have been sluggish since end-2014. As monetary policy normalises in the US, EMEs may come under increasing pressure to remain resilient in the face of further bouts of volatility spillovers as a result of this. Moreover, caution is necessary because of the asymmetric monetary policy stances with the ECB loosening monetary policy and the FED tightening it. This is likely to have an asymmetric effect on the volatility of macroeconomic and financial variables in the EMEs. Volatility spillovers originating from the FED and ECB can potentially induce capital flight from EMEs affecting financial variables. A lack of confidence in EMEs in general which could lead to more pronounced problems in the real economy, such as decreases in consumption and investment.

The policy implications of our paper are two-fold: First, EMEs need to pay particular attention to changes in the balance sheets of the FED and ECB given the extent to which there is an effect on domestic financial and real economy volatility. This is particularly the case with respect to EME bond markets, which have been subject to the most notable volatility spillovers in terms of magnitude. The most affected countries in general have been those with a more open capital account and greater financial linkages with the U.S. and euro area economies. Given the susceptibility of EME bond markets to volatility spillovers, this would point in the direction of further efforts towards the development of local currency bond markets. Other measures to limit volatility spillover by EMEs may include, but are not limited to, altering monetary and fiscal policies where policy space is available, as well as exchange rate and foreign exchange reserves management. Moreover, where possible, macroprudential policies can be used to this end, as well as targeted capital controls, to help insulate economies from volatility spillovers from abroad. Second, our results have implications for the impact of the exit from unconventional monetary policies, and how this is likely to affect the volatility of EMEs if it is not done gradually. Most EMEs remained resilient during the crisis and have been able to absorb the volatility originating from developed countries central banks. Given concerns regarding the economic outlook in EMEs, however, volatility spillovers from the end of accommodative monetary policies in the U.S. and of looser monetary policy in the euro area are likely to be large.

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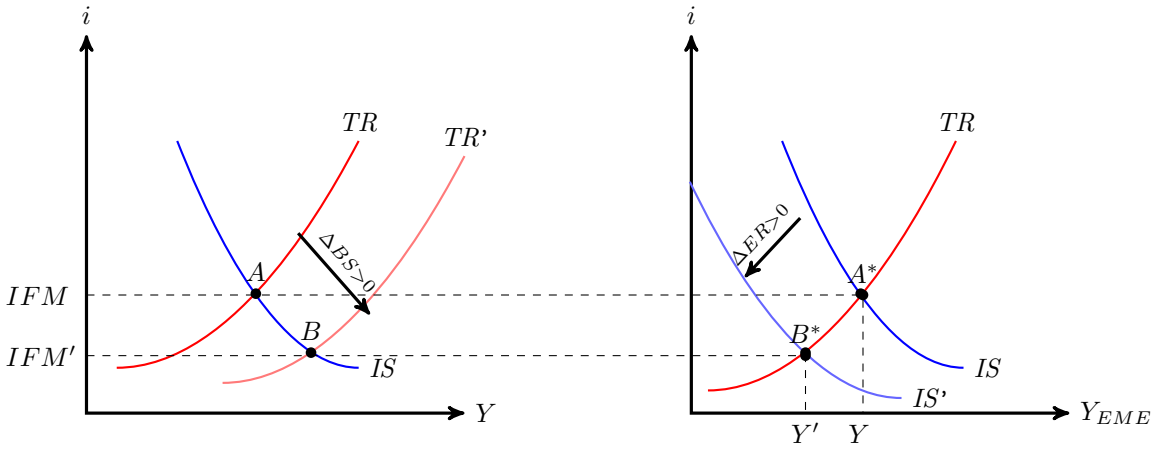
Appendix A World interest rate level spillovers to EMEs using an IS/TR framework

The basic IS/TR model of Burda and Wyplosz (2012) for the case of an open economy is depicted in Figure 11. The world interest rate facing a country is defined as *i* plus expected depreciation of that currency. This is depicted as the International Financial Market (IFM) line. Normally countries cannot affect the world interest rate but that does not apply to the cases of the FED and the ECB. The response of the FED and the ECB, which achieve a reduction in interest rates by expanding their balance sheets, is shown by the movement of the TR line to the right at TR'. During the crisis, the FED and the ECB lowered their interest rates and embarked on unconventional monetary policies, which in turn lowered the world interest. However, the ECB and the FED can only lower the world interest rate below their own domestic interest rates and as a result their currencies weakened as well. As a result of this, capital flight from the euro area and the U.S. ensued, and capital was directed towards EMEs that had a higher interest rate. In response to this, EMEs central banks' could have lowered their domestic interest rates, however due to various reasons they were not able to reduce their interest rates as much as the FED and the ECB. Therefore, to accommodate this influx of capital, their economies have to adjust. IS shifts to IS', unless governments embarked on ambitious fiscal stimulus programmes.

Using the Burda and Wyplosz (2012) methodology, Figure 11 demonstrates that unconventional monetary policies emanating from developed countries central banks, which have an effect on the world interest rate, can affect both the financial and real economy in EMEs. Moreover, the effects of these unconventional monetary policies are asymmetric.

Figure 11: World interest rate level spillovers to EMEs



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