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by Ricardo J. Caballero and Gunes Kamber

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On the Global Impact of Risk-off Shocks and Policy-put Frameworks

Ricardo J. Caballero and Gunes Kamber*

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Abstract

Global risk-off shocks can be highly destabilizing for financial markets and, absent an adequate policy response, may trigger severe recessions. Policy responses were more complex for developed economies with very low interest rates after the Global Financial Crisis (GFC). We document, however, that the unconventional policies adopted by the main central banks were effective in containing asset price declines. These policies impacted long rates and inspired confidence in a policy-put framework that reduced the persistence of risk-off shocks. We also show that domestic macroeconomic and financial conditions play a key role in benefiting from the spillovers of these policies during risk-off episodes. Countries like Japan, which already had very low long rates, benefited less. However, Japan still benefitted from the reduced persistence of risk-off shocks. In contrast, since one of the main channels through which emerging markets are historically affected by global risk-off shocks is through a sharp rise in long rates, the unconventional monetary policy phase has been relatively benign to emerging markets *during* these episodes, especially for those economies with solid macroeconomic fundamentals and deep domestic financial markets. We also show that unconventional monetary policy in the US had strong effects on long interest rates in most economies in the Asia-Pacific region (which helps during risk-off events but may be destabilizing otherwise–we do *not* take a stand on this tradeoff).

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*Ricardo Caballero, MIT and NBER. Gunes Kamber, Bank for International Settlements and the Reserve Bank of New Zealand. Contact information: caball@mit.edu and gunes.kamber@bis.org. This article is a contribution to "Asia-Pacific fixed income markets: evolving structure, participation and pricing," a BIS Asian Office research programme. We thank Eric Swanson for sharing his data with us. We also thank Chris Ackerman, Efrem Castelnuovo, Stijn Claessens, Piti Disyatat, Ippei Fujiwara, Peter Hoerdahl and Benjamin Wong for their comments. Jose-Maria Vidal Pastor and Giulio Cornelli provided excellent research assistance. The views expressed in this paper are those of the authors and do not necessarily represent the views of the Bank for International Settlements. First draft: February 2018

1. Introduction

Global risk-off shocks can be highly destabilizing for financial markets and, absent an adequate policy response, may trigger severe recessions. Policy responses were more complex for developed economies with very low interest rates after the GFC. We document, however, that the unconventional policies adopted by the main central banks were effective in containing asset price declines. These policies worked by quickly reducing long rates *and* by signaling a reliable policy-put framework that reduced the persistence of risk-off shocks.

The conceptual framework behind our analysis is motivated by the risk-centric perspective in Caballero and Simsek (2018). In this framework, we add a market for "risk", similar to the traditional market for goods or output. Demand recessions work as follows. First, a risk-off shock hits and causes a gap in the demand for "risk". Investors are unwilling to purchase risky assets at their current prices. When monetary policy is unconstrained, a central bank can lower the risk-free rate to increase the excess return on these risky assets. The risky assets become more attractive, investors purchase them, and equilibrium is restored. However, this mechanism cannot work when interest rate policy is constrained by an effective lower bound (or by some other consideration, such as a currency peg). When the central bank cannot lower interest rates, the risky asset's price must fall to restore equilibrium in the risk market. But falling asset prices have negative impacts on the goods/output market and create a downward spiral. There are two mechanisms that can counteract this vicious cycle. First, the central bank can directly absorb some of the risk that private agents are unwilling to bear. Second, the central bank can prop up the price of risky assets by inducing hope of an economic recovery. If a recovery is more likely, then the asset's expected value, and hence price, is higher. A credible policy-put framework operates through these two channels.

With this perspective in mind, we empirically explore the response of financial markets around the world to risk-off shocks and the policy responses that followed them. We acknowledge that much of our evidence is circumstantial but, collectively, our findings are consistent with a view in which risk-off shocks have a significant impact on financial markets, access to conventional and unconventional monetary policy is an important palliative, and these policies spill into the rest of the world, especially to countries that are poised to benefit from developed market (DM) policies. Note that our goal is to document a set of organized facts, not to assess the broad welfare implications associated with different policies. In fact, we are acutely aware that these policy spillovers are a blessing for recipient countries during risk-off episodes but a source of concern during reach-for-yield environments. Our main claims are:

1. Risk-off shocks are highly correlated across major economies. (Figure 1). The correlation coefficients are 0.91 between the US and the Euro Area and 0.83 between the US and Japan over 1999-2017.

2. Risk-off shocks trigger stock market declines that are partially insulated by monetary policy responses. (Figure 2). A VIX spike of 15 vols, which is the average of the three largest weekly increases in VIX in our sample, triggers a stock market decline of around 14 percent. This is in line with other empirical macro papers, such as Caldara et al. (2016).

3. Both conventional and unconventional monetary policy effectively limit the selloff (Figure 2). (This is why we (and many others) refer to them as policy-puts).

   Quantitatively, in the conventional policy period, the Fed responded to a risk-off shock that raised VIX by 15 volatility points by lowering the federal funds target rate by slightly more than 100 basis points (Figure A.2). This magnitude is in line with the policy responses to risk-off shocks documented in other empirical macro papers such as Basu and Bundick (2017). We show that this policy response generates a persistent decline in the 1-year Treasury yield, which drops by slightly less than 100 basis points (Figure 2). It also significantly lowers long rates, with a peak impact on the 10-year Treasury yield of around 40 basis points 16 weeks after the shock.

   In the unconventional monetary policy period, a risk-off shock of the same size leaves the 1-year rate almost unchanged. Despite unresponsive short rates, the 10-year Treasury yield not only declines by a similar amount to the conventional monetary policy period but the decline is more frontloaded, with its peak impact at the time of the risk-off shock.

4. The policy-puts framework during the post-crisis period seems to have operated not only by frontloading long rate declines but also by reducing the perceived persistence of risk-off shocks. The combination of these effects has supported asset values, which was one of the key goals of the policy framework designed by the Fed and other major central banks to address the aftermath of the financial crisis (Figure 2).

   The reduction in the persistence of risk-off shocks is large. The impulse responses of VIX across the two subsamples imply that the half life of the risk-off shock was halved in the post-GFC period, dropping from 10 weeks to 5 weeks.

5. Domestic conditions matter for the impact of both domestic and foreign risk-off shocks and policy-puts. Policy-puts helped in Europe, but particularly so after the "whatever it takes speech," which allowed periphery economies (Italy in our sample) to benefit from the policy-puts (Figures 5 and 6). For Japan, which already had low long rates, policy-puts helped less and imposed indirect costs via the Yen's appreciation. Still, the reduced persistence of risk-off episodes also benefited Japan. (Figure 7)

6. Risk-off shocks have similar qualitative implications for equity markets in emerging markets (EMs) and DMs, but EMs experience capital outflows that push up their long rates and depreciate their exchange rates. (Figure 8)

7. Overall, monetary policy in DMs has a significant impact on how severely EMs are affected by global risk-off episodes. (Figure 10)

8. Somewhat paradoxically, unconventional monetary policies in DMs appear to benefit EMs more than conventional monetary policy during risk-off episodes (Figure 9). We conjecture this is because unconventional policies act directly on long rates and reduce the persistence of risk-off shocks, which are the main drivers of EMs' sudden stops of (net) capital inflows.

9. There are substantial differences across EMs. In particular, richer and more financially integrated economies, economies that have low current account deficits and high foreign reserves, or economies that can produce local safe assets, behave more like DMs and experience significantly smaller rises in long rates in response to risk-off shocks. (Figure 11)

10. Focusing on the Asia-Pacific region, we find that conventional and unconventional monetary policy in the US have a significant impact on local long rates. Moreover, the pass-through of the forward guidance component of monetary policy surprises to the region's long rates has increased post-GFC. Related, monetary policy surprises associated with large scale asset purchase programs significantly lowered the regions' long rates. The latter effect was larger for the advanced economies in the region.

The remainder of the paper is organized as follows: Section 2 sketches the conceptual framework behind our empirical analysis. Section 3 studies the impact of risk-off shocks for developed market economies during different monetary policy regimes. Section 4 extends the analysis to emerging market economies. Section 5 focuses on the transmission of US policy-puts to the

Asia-Pacific region. Section 6 contains final remarks, and is followed by an appendix with a detailed description of our data, empirical methods, and robustness analyses.

2. Sketching a Conceptual Framework

In this section we sketch the essence of the risk-centric view of macroeconomic fluctuations in Caballero and Simsek (2018) and discuss the mechanisms through which a credible policy-put framework stabilizes asset markets and the economy.

2.1. The Risk-centric Mechanism and Conventional Monetary Policy

Let us capture the essence of the risk-centric macroeconomic perspective with two simple equations:

$$\begin{aligned} y &= \min\{AD(q), \overline{y}\} \\ \sigma &= \frac{Er(q, y(q), Hope(q^+/q)) - r^f}{\gamma\sigma} \end{aligned}$$

The first equation says that, if demand is insufficient (relative to potential output $\overline{y}$), then output, y, is determined by aggregate demand, AD, which is an increasing function of current asset prices, q. The second equation says that the perceived supply of volatility (risk) generated by the productive capacity, σ, must be matched by the demand for volatility, which is an increasing function of the market's perceived Sharpe ratio (we interpret the market as a broad measure of wealth). The numerator of the Sharpe ratio is the market's expected excess return and it contains many of the conceptual framework's key ingredients. First, it depends on asset prices through two opposing forces: on one hand, for any given expected earnings, a drop in q increases the expected return on risky assets. On the other, the drop in q drags down aggregate demand and earnings. Caballero and Simsek (2018) show that, in their model, the aggregate demand effect always dominates and the economy implodes unless there is sufficient hope about a prompt recovery, $Hope$, with significant capital gains q^+/q (where q^+ represents the asset price upon exit from the risk-off episode). The denominator of the Sharpe ratio is the risk-adjusted perceived volatility, $\gamma\sigma$, where γ can be interpreted as a coefficient of relative risk aversion.

It is easy to see from the first equation that there is a level of asset prices $\overline{q}$, such that for any $q < \overline{q}$ there is insufficient aggregate demand (hence there is an output gap). If monetary policy is unconstrained, r^f can adjust to ensure that there is sufficient demand for risk at the asset price level $\overline{q}$. That is,

$$\begin{aligned} q &= \overline{q} \\ r^f &= Er(\overline{q}, y(\overline{q}), Hope(1)) - \gamma\sigma^2 > 0 \end{aligned}$$

In this context the immediate impact of a spike in perceived volatility (a risk-off episode), $\gamma\sigma$, is to lower asset prices, but this can be offset if the monetary authority drops r^f and restores equilibrium in risk markets at $q = \overline{q}$, preventing an output gap.

If monetary policy is constrained, which we capture with a Zero Lower Bound (ZLB), conventional monetary policy can no longer offset a spike in perceived volatility, and the economy drops into a recession as asset prices must fall to restore equilibrium in risk markets:

$$r^f = 0 \quad \Longrightarrow \quad q < \overline{q} \quad \Longrightarrow \quad y(q) < AD(\overline{q})$$

The severity of the recession and the drop in asset prices critically depend on the degree of agents' optimism. If $Hope$ is low, then asset prices and aggregate demand drag each other down in the process of restoring equilibrium in asset markets.

This observation offers a natural interpretation for unconventional (put) policies: they try to substitute for the private sector's missing $Hope$. Because the central bank cannot increase asset prices by decreasing the risk free rate, they must increase the perceived value of the risky assets themselves. It is straightforward to see, from the risk equilibrium condition at the ZLB:

$$Er(q, y(q), Hope(q^+/q)) = \gamma\sigma^2$$

that a policy-induced increase in $Hope(q^+/q)$ raises asset prices and reverses the downward spiral.

2.2. Unconventional Monetary Policy and Policy-puts

Conventional monetary policy acts like a policy-put with respect to risk-off shocks. In the risk centric perspective, unconventional monetary policy seeks a similar goal once conventional policy is no longer available.

There are essentially two channels. In the first channel, a government/central bank with a credible balance sheet absorbs part of the risk the private sector does not want at $r^f = 0$:

$$\upsilon\sigma = \frac{Er(q, y(q), Hope(q^+/q) - 0}{\gamma\sigma} \qquad \upsilon < 1.$$

For example, Quantitative Easing (QE) policies that swap credit products for US treasury bonds effectively amount to reducing υ. By purchasing risky assets from the private sector, the government has decreased the private sector's exposure to risk.

In the second channel, the central bank increases the expected capital gain in case of a recovery. One can think of Forward Guidance (FG) as increasing q^+ by keeping rates below the natural rate for an extented period during the recovery. Moreover, a policy-put framework that is explicit and credible is likely to directly help by reducing the perceived volatility and the perceived persistence of risk-off shocks (captured by an upward shift in the function $Hope(\cdot)$).

3. Risk-off Shocks in DMs

In this section we explore how risk-off shocks affect US financial markets and the effectiveness of the policy-put framework. Then, we explore the impact of these risk-off shocks and policy puts on major economies.

3.1. Risk-off Shocks in the US

We present empirical evidence on the impact of volatility shocks on financial markets under different policy regimes (pre- and post-ZLB) in the US. We also highlight the role played by the policy-put frameworks that have been in place since the global financial crisis in offsetting the transmission of volatility shocks to financial markets (and implicitly to the economy).

Our empirical analysis is based on structural VARs. We identify risk-off shocks in line with the growing empirical literature on the macroeconomic effects of uncertainty shocks. Several studies have shown that uncertainty shocks have large and persistent effects on economic activity and that they have been responsible for a substantial share of historical fluctuations in output and prices.[1] Accordingly, our baseline VARs contain data on an index of perceived volatility, interest rates, equity prices, and exchange rates.

We identify risk-off shocks using a recursive identification scheme and order our measure of volatility first in the system. This ordering implies that volatility does not respond to other

[1] See for instance Bloom (2009), Bekaert et al. (2013), Caggiano et al. (2014), Leduc and Liu (2016), Caldara et al. (2016) and Basu and Bundick (2017) for the empirical evidence in the US and Carriere-Swallow and Cespedes (2013), Mumtaz and Theodoridis (2015) for the empirical evidence on the international transmission.

shocks in the impact period but that all the other variables in the system can react contemporaneously to a volatility shock.[2] The evolution of volatility in the following periods, however, can be shaped by all the other shocks through their impact on the lags of all the other variables. In appendix A.1, we provide results from an alternative identification scheme in which we identify risk-off shocks using an external instrument that reflects large spikes in volatility. We see this as a good robustness check since the identification of the risk-off shocks doesn't require a recursive ordering of the variables or zero restrictions. We show that, using this alternative approach, we obtain qualitatively similar results to our baseline findings and only a marginally smaller impact of risk-off shocks on financial variables.[3]

We use weekly data on a number of macro/financial indicators. We take VIX, the implied volatility of the S&P500 index options, as our index of volatility. It is worth noting that even though VIX is a measure of stock market implied volatility in the US, it is highly correlated with implied volatility indexes in other major economies. Figure 1 shows the historical evolution of implied volatilities in the US, the Euro Area and Japan since 1999. Figure 1 suggests a sizable global component of volatility as there is a high degree of comovement in implied volatility measures across countries. The correlation coefficient is 0.91 between the implied volatility indexes in the US and the Euro Area and 0.83 between those in the US and Japan. The comovement seems to be particularly strong around major global events, such as 9/11, the collapse of Lehman Brothers and the height of the European sovereign debt crisis. Therefore, we interpret shocks to the VIX index as risk-off shocks, either from the US or from any region large enough to generate a movement in global volatility.

As our sample covers periods during which short rates were constrained by the zero lower bound, we include both short (1-year) and long (10-year) rates on government bonds. Their inclusion helps us characterize and compare monetary policy responses and their effectiveness in constrained and unconstrained periods. Our final variable in the VAR is the log of the S&P 500 stock market index.

We are interested in documenting the impact of risk-off shocks for two subperiods, one on each side of the global financial crisis. We take the period from early 1999 to September 2008 as representative of conventional monetary policy for the US. The starting date is constrained

[2] In the literature on the effects of uncertainty shocks, ordering the measure of volatility first in recursively identified VARs is common. See for example Leduc and Liu (2016), Basu and Bundick (2017), Carriere-Swallow and Cespedes (2013), Moore (2017), Rice et al. (2018), Larcher et al. (2018)

[3] In appendix A.3, we present the impulse responses under alternative orderings of the variables, namely ordering the VIX after stock prices and ordering it last. Our main conclusions do not change under these alternative identification assumptions.

by data-availability for emerging markets (see below). In order to limit the effect of rapidly falling interest rates and high volatility during the height of the crisis, we exclude observations from the last quarter of 2008. More precisely, we exclude data on the weeks after Lehman's collapse. The second subsample covers the post-GFC period when the Federal Reserve deployed a number of unconventional policies. Again, in order to limit the effects of the heights of the financial turmoil, we start our second subsample in April 2009. Finally, we estimate the VAR including six lags as suggested by Akaike information criterion.

Figure 2 presents the impulse responses to a risk-off shock in the US using VIX as the volatility indicator. In Figure 2, red lines and red shaded areas correspond to the impulse responses and one standard deviation confidence bands from the VAR estimated during the pre-crisis period. Blue lines and blue shaded areas are impulse responses from the VAR estimated for the second subsample. In order to give our results a quantitative dimension, we calibrate the initial response of the VIX to be equal to the average of the three largest weekly increases in VIX in our sample. These three events are associated with major risk-off episodes over the last decade. The first episode is immediately following the collapse of Lehman Brothers. The second one is in August 2011, amidst concerns of the European sovereign debt crisis spreading to Spain and Italy. And the final event is during the sell-off following China's Black Monday in August 2015. The average increase in VIX at these three events corresponds to about 15 volatility points. Importantly, since we are concerned with the *relative* response of financial variables to similar risk-off shocks in both periods, but the process for risk-off shocks itself is different in the two periods, we need to rescale the shocks in the post-ZLB period (see below for specifics): all our statements are based on this rescaled metric.

The transmission of risk-off shocks echoes some of the findings from the uncertainty literature. Following an unexpected increase in volatility, equity prices in the US drop sharply and significantly, and interest rates fall to a lower level, where they remain over the medium term. In the conventional policy period, the Federal Reserve eases monetary policy in response to heightened volatility and falling stock prices consistent with findings in Cieslak and Vissing-Jorgensen (2018). This reaction manifests itself in the significant and persistent drop in the 1-year Treasury yield immediately following the risk-off shock. The effect on the 1-year Treasury yield displays a hump-shaped response, with a peak decline of around 100 basis points at four to five months, and the 1-year yield stays below the pre-shock level even after a year. The easier monetary policy also has an impact on long rates. The 10-year Treasury yield follows a somewhat similar pattern but the impact is smaller. The peak impact on the 10-year Treasury yield is around 40 basis points. Increased volatility has a significant and persistent impact on stock prices. Despite looser monetary policy, the equity market experiences a sharp decline, losing around 14 percent of its value.

We next present the effects of risk-off shocks in the aftermath of the global financial crisis, a period when short term interest rates were constrained by the ZLB and the Federal Reserve relied on a number of unconventional policies such as forward guidance on interest rates and large scale asset purchases. The first observation is that the VIX index's response to an unanticipated risk-off shock is much less persistent in this period. Following an unanticipated shock in the conventional policy period, the VIX index stays significantly above the pre-shock level for more than 9 months, while in the post-GFC period, the effect on the VIX index dies out after about 4 months. This change is also evident when measured in terms of the half-life of a risk-off shock on the VIX index. The impulse responses of VIX across the two subsamples imply that the half life of the risk-off shock drops from 10 weeks to 5 weeks.

The reduction in volatility's persistence is most likely related to the policy-put framework implemented after the GFC. In order to compare the effects across the two subperiods, we scale the impulse responses in the unconventional policy period to take into account the change in the persistence of volatility. To this end, we scale the impulse responses so that in both subperiods the cumulative change in the VIX index is the same during the first 12 weeks. This implies that the impact response of the VIX index in the second subperiod is about 20 percent.[4]

Looking at the response of interest rates, the change in the dynamics of interest rates on the short end of the yield curve is not surprising. While the Federal Reserve's response to heightened volatility triggers a persistent decline in the 1-year rate in the conventional policy period, in the post-GFC period the response of the 1-year rate is small and mostly insignificant, as the federal funds rate was constrained by the ZLB. The interesting observation is that the 10-year Treasury yield in the ZLB period is more responsive to risk-off shocks, in the sense that its response happens more quickly. Following the risk-off shock, the 10-year yield immediately drops about 40 basis points and stays significantly below the pre-shock level for more than half a year. Although its decline is less persistent, this uick recovery is consistent with the risk-off shock itself being less persistent. This finding supports the view that, even though the Federal

[4]If we consider the unscaled impulse responses, the impact response of the VIX index to a risk-off shock is about 24% higher in the post-ZLB sample compared to pre-ZLB sample. The cumulative increase in the VIX index in the first 12 weeks is, however, about 11% higher in the pre-ZLB period, which is itself an indirect testament to the effectiveness of policy-puts, as risk-off shocks are more contained in the post-ZLB period.

Reserve was unable to manipulate short term interest rates, it was still able to directly generate significant movements in longer term interest rates via its unconventional monetary policy tools and adjust its monetary policy stance in response to shocks. Moreover, it appears that the policy-put framework was credible enough to trigger an immediate and reinforcing response from the private sector in anticipation of the risk-off contingent policy.

The Federal Reserve's ability to respond to a risk-off shock by loosening monetary policy is also evident in the response of equity markets in the ZLB period. If the monetary policy reaction is completely muted in all dimensions, one would expect that an equivalently large increase in volatility would trigger a bigger fall in asset prices. We find, however, that the equity market response to a risk-off shock is not different under ZLB from its response under the conventional monetary policy period.

Overall, the results are consistent with the direct evidence reviewed by Swanson (2018), in which he concludes that there is near consensus that the zero lower bound on nominal interest rates was not a serious constraint on the Federal Reserve (Fed). The Fed was able to effectively use forward guidance and large scale asset purchases to influence medium- and long term interest rates, stock prices and exchange rates. We return to this literature and extend it in section 5.

Returning to the risk-centric framework, we have argued that the stabilizing effect of these policies operated not only by substituting for conventional monetary policy but also by reducing the persistence of risk-off shocks. Before concluding this section, we examine the evolution of two measures of volatility persistence to provide additional evidence supporting this claim. First, we follow ECB (2016) and measure the half-life of a shock to VIX, calculated from a GARCH(1,1) model estimated over a rolling window of four years. Figure 3 depicts half-life estimates alongside major unconventional monetary policy announcements. Although our half-life measure fluctuated considerably over the sample, it has been trending down to below 5 weeks from a peak of around 15 weeks near the end of 2009. Moreover, major unconventional policy announcements, especially after LSAP II, appear to be followed by persistent declines in half-lives.

Second, we investigate the relationship between changes in the VIX spot index and the VIX futures term structure. We measure the slope of the VIX curve using the difference between the VIX futures 1 month and 6 months to expiration. We then calculate the correlation between changes in the VIX spot index and changes in the slope. The idea is that if changes in the VIX spot index are expected to be short lived, the short end of the VIX curve will jump more than the long end of the curve, implying a negative correlation between the changes in the spot index and the slope. Figure 4 shows the evolution of this correlation since 2008, a sample dictated by the availability of VIX futures data. The correlation coefficient is calculated using a six month rolling window. Figure 4 shows that the correlation between these two variables has also been trending down since the crisis. Together with the findings from the impulse response analysis, figures 3 and 4 reinforce the point that a significant share of the success of the unconventional policy framework appears to have operated through the increased perception among investors that containing risk-off shocks had become a central objective of major central banks. That is, central banks were successful in providing a credible policy-put framework.

3.2. Risk-off Shocks in the Global DM Context

As Figure 1 illustrated, significant risk-off events, regardless of their origin, quickly spread to other regions of the world economy. It stands to reason that policy-puts also spread across regions. We do not attempt to disentangle the sources but instead focus on understanding the net (of policy) effect of risk-off shocks in the different subperiods of U.S. monetary policy, and how these effects interacted with local conditions.

In this section we consider the global implications of risk-off shocks by expanding our analysis to other major economies. We estimate larger VAR models including data on the Euro Area and Japan. Specifically, we estimate two VAR models, one with US and Euro Area data only, and a second model with US and Japanese data.[5] Our expanded VARs include data on Euro and Yen exchange rates, 1- and 10-year Treasury yields and stock prices. We recursively identify risk-off shocks by ordering the VIX index first in the VAR. The data is at weekly frequency and the sub-samples are identical to the ones presented before. Although the Bank of Japan and the ECB faced different constraints and the timing of the policy responses differed, comparing the global effects of risk-off shocks in these economies before and after the global financial crisis provides additional insights on the effectiveness of alternative monetary policy measures.

Figure 5 displays the impulse responses to a risk-off shock obtained from the US-Euro Area VAR. The quantitative responses of the US variables are slightly different, possibly because we now consider cross-border interactions. Qualitatively, however, they convey the same message as Figure 2, so we do not discuss them again.

The rest of the panels in Figure 5 show the response of Euro Area variables. For the Euro

[5] The results are robust to estimating one large VAR that includes data on the US, the Euro Area and Japan altogether.

Area and for all economies throughout the paper, we define our exchange rate index as the number of units of foreign currency per US dollar. Therefore an increase in our exchange rate indices represents the depreciation of the foreign currency against the US dollar. The second column of Figure 5 shows the impulse responses of 10-year yields and the Euro/Dollar exchange rate. The essence of our findings for the Euro Area is similar to the findings for the US. The ECB was able to generate movements in long rates larger than in the pre-crisis era. Moreover, the euro depreciated against the dollar during the risk-off periods in the post-crisis period (partly due to concentration of European risk-off shocks during this period). The fall in long rates and exchange rate depreciation both boost equity markets, and the sell-off in equity markets is no larger than during the pre-ZLB (third column, top panel). The last panel of Figure 5 shows the response of 10-year Italian Treasury yields. It is interesting to note that, in the pre-crisis era, Italian long rates moved in tandem with the average Euro Area long rates. In the post-crisis period though, Italian rates seem to decouple and increase persistently. Pre-crisis, Eurozone governments' bonds were treated as homogenous safe assets but that changed post-crisis, with concerns about the ability of several periphery countries in the Eurozone to service their debts. This led to investors treating Eurozone government's bonds as heterogenous, with different risk profiles.

The next figure shows, however, that the periphery economies also benefited after the ECB's policy-put framework became credible. For this purpose, we focus on the policy setting in the Euro Area during the period after the global financial crisis. We partition the post-crisis period into two subperiods. Our cut-off point is Mario Draghi's "Whatever it takes" speech. In July 2012, with investors betting on the break-up of the euro zone, Draghi delivered a speech in London where he said "Within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough". Even though an actual unlimited bond buying program (Outright Monetary Transactions) was not announced for more than a month and was never actually used, the speech is widely seen as key in calming financial market turmoil, or even in saving the European monetary union. European stock markets rallied after the speech, and perhaps more importantly, spreads on sovereign bonds and credits narrowed, taking the pressure off countries that investors thought were worse credit risks.

In Figure 6, we focus on the impulse responses of Italian long rates from a VAR that only includes Euro Area variables. The VAR is estimated for two subsamples: The first subsample goes from 2009 to the week before the Draghi speech; the second one covers the post-speech period. Figure 6 depicts the responses of Italian 10-year yields to an unexpected risk-off shock identified using the implied volatility of the Euro Stoxx 50. The increased effectiveness of policy puts is evident in the changing dynamics of Italian long rates, as their response to risk-off shocks essentially switches sign in the period following Draghi's speech. Prior to Draghi's commitment, a risk-off shock would generate a significant increase in Italian long rates, 40 basis points at its peak. Once the put-policy in the Euro Area became more credible, the effect is completely reversed, and long rates in Italy fall together with other European long rates. Overall, our findings provide evidence that the unconventional monetary policies deployed by the ECB in the post-2012 periods have helped mitigate the adverse effects of risk-off shocks for the periphery economies.

Finally, we investigate the effects of risk-off shocks in Japan. Figure 7 presents the impulse responses obtained from the US-Japan VAR. An important caveat, which we address indirectly in our conclusion about Japan's response to global risk-off shocks, is that the pre-crisis period does not fully correspond to a conventional policy period in Japan. The BOJ first implemented its zero interest rate policy in 1999 followed by its first QE programme, which ended in 2006. BOJ then ran a conventional monetary policy until the start of the Comprehensive Monetary Easing policy in 2010. However, the targeted overnight call rate remained below 0.5% during the entire period. In the post crisis era, the quantitative and qualitative easing policies were introduced in 2013, but our sample ends in 2015 so the effect of these policies is probably not fully reflected in our results.

With this in mind, our results show that the BOJ had limited influence on short rates in response to risk-off shocks even before 2008. The response of the 1-year JGB yield is essentially zero throughout both samples. On longer dated yields, we find that the 10-year yield tended to drop in the pre-crisis sample but not in the second subsample. Consistent with these observations, the impulse responses for the exchange rate reflect the relative inability of the BOJ to effectively respond to risk-off shocks. First, whereas a global risk-off shock left the Yen/Dollar exchange rate essentially unchanged in the pre-crisis period, the Yen appreciated significantly against the US dollar after the GFC. Second, and possibly as a result of the currency appreciation and unresponsive long rates, the stock market experienced a larger initial decline. Note, however, that in line with the positive effect of global policy-puts on the persistence of risk-off episodes, the fall in Japan's equity market is much less persistent in the second period. In sum, these results suggest that the BOJ, which already had low long rates, was more constrained than the Federal Reserve in its ability to offset the effects of risk-off shocks on financial markets in the aftermath of the global financial crisis. In this context, global policy-puts had a mixed effect on Japan, as it benefitted from the decline in the persistence of risk-off episodes but it was hurt by the sharper appreciation of the Yen.

4. The effects of risk-off shocks on EMs

In Section 3, we showed that both conventional and unconventional monetary policies can limit the effects of risk-off shocks in major economies. In this section, we extend our analysis to emerging markets and test three predictions of the conceptual framework outlined in Section 2. First, even though emerging markets might not be directly constrained by the ZLB, global risk-off shocks significantly affect EMs since their ability to respond is limited due to exchange rate and capital flow concerns. Second, policy-puts in major economies can provide support to global financial markets and alleviate the effects of global risk-off shocks on EMs. Third, the ability of EMs to benefit from these policy-puts, and the direct impact of global risk-off shocks on them, depends on their economic fundamentals.

To test these predictions, we estimate the effects of global risk-off shocks on financial markets and capital flows for 19 emerging market economies.[6] We distinguish the effects of global risk-off shocks between the conventional and unconventional policy periods. Further, we estimate the effects of risk-off shocks conditional on the monetary policy stance in major economies. Finally, we interact risk-off shocks with measures of economic fundamentals in EMs.

We conduct our analysis using weekly data, in line with the analysis on DMs. As in the previous section, we study the dynamics of the following variables: yields on government bonds issued in local currency, bilateral US dollar exchange rates and equity market indices. In order to better understand the transmission of risk-off shocks, we also include data on weekly capital flows. Our capital flows data report net portfolio flows in equities and bonds for each country. Our sample starts in 2004.

Our first objective is to document the transmission of risk-off shocks to these EMs. Our empirical strategy is different from Section 3, which relied on Structural VARs to identify the transmission channels of risk-off shocks. However, extending the analysis using a VAR framework to analyze 19 additional countries and five variables per country would be impractical.

[6] The countries we include are: Brazil, Chile, China, Colombia, Czech Republic, Hong Kong, Hungary, India, Indonesia, Israel, Korea, Malaysia, Mexico, the Philippines, Poland, Russia, Singapore, South Africa, and Thailand.

Instead, our empirical strategy here is based on the local projection methodology proposed in Jorda (2005). Within that approach, we specify the global risk-off shocks building on section 3. Specifically, we use the risk-off shock identified in the structural VAR for the US economy as the global shock for these emerging markets. Therefore, we implicitly assume that each emerging market economy is too small to affect the dynamics of shocks hitting the US economy and that the shocks we identified are exogenous to these economies.

Our baseline specification for estimating the effects of global risk-off shocks on emerging markets is:

$$\Delta y_{i,t+h} = \alpha_i^h + \delta_t^h + \beta^h \varepsilon_t^v + \Sigma_{k=0}^K \omega_k^h x_{i,t-k} + \varepsilon_{i,t+h} \qquad (1)$$

where $\Delta y_{i,t+h}$ is the h period ahead change in country i's long rates, exchange rate or equity market index. The variable ε_t^v denotes the risk-off shocks identified from the structural VAR presented in section 3. Control variables include 8 lags of the dependent variable y and 8 lags of the following variables: US shadow short rate, S&P 500 index, the DXY US dollar index and oil prices. We include time and country fixed effects. The coefficients β^h measure the effect of a global risk-off shock on our response variable of interest at horizon h. We estimate this equation for horizons going up to 20 weeks.

Figure 8 presents the estimated effects of risk-off shocks on emerging market economies for equity markets, 10-year local government bond yields issued in local currency, exchange rates and capital flows. As in section 3, the exchange rates are defined as the number of units of the local currency per US dollar and an increase represents a depreciation of the EMs' currencies. In order to ease the comparison, we calibrate the responses in EMs to represent responses of these variables to a shock that corresponds to a 15 vol increase in the VIX. The dynamic responses in Figure 8 are in line with the conventional wisdom that financial markets in emerging markets are adversely affected during high risk-off environments. The first panel depicts the response of equity markets. A global risk-off shock triggers a large fall in equity markets, comparable in size to what we found in developed markets. The trough in stock prices (more than a 7% decline) occurs after about one month. The negative effect on stock prices is persistent, as after about five months stock prices are still significantly below their pre-shock level.

The second panel in Figure 8 shows the response of 10-year government bond yields. Contrary to what we found in major economies, where long rates tend to fall following a risk-off shock thanks to an easier monetary policy stance, increased global risk puts upward pressure on emerging market interest rates. 10-year sovereign bond yields in emerging markets increase persistently, with a peak increase of around 15 basis points. Global risk-off shocks also trigger persistent depreciations of emerging market currencies against the US dollar of around 2 percent.

Finally, we find that, in line with the response of equity markets, interest rates and exchange rates, global risk-off shocks induce sharp net capital outflows. EMs experience both net equity and bond outflows. The drop in net equity flows appears, however, to be larger than the drop in bond flows (a result that is mostly driven by Asia-Pacific). At its trough, weekly net equity outflows drop by close to 150 million USD, while net bond flows fall by around 40 million USD. Overall, our baseline impulse response analysis suggests there is a strong portfolio rebalancing effect following a global risk-off shock. Emerging markets experience sharp capital outflows, putting pressure on the long end of their yield curve, and risk-off shocks are associated with persistent falls in stock prices and exchange rate depreciations.

To investigate the empirical relevance of the second prediction of our conceptual framework, we run two additional regressions. First, in parallel with section 3, we estimate equation (1) for two subperiods: pre-ZLB and post-ZLB. Second, we estimate a variant of equation (1) by adding an interaction term between risk-off shocks and the shadow short rate. Our objective with this specification is to determine whether the monetary policy stance in the US has an effect on the strength of the impact of volatility shocks on emerging markets. Using shadow short rates provides a continuous measure of short rates across the whole sample.[7] We estimate:

$$\Delta y_{i,t+h} = \alpha_i^h + \delta_t^h + \beta^h \varepsilon_t^v + \beta^{h,ssr} \varepsilon_t^v SSR_t + \Sigma_{k=0}^K \omega_k^h x_{i,t-k} + \varepsilon_{i,t+h} \tag{2}$$

where SSR_t is the shadow short rate and $\beta^{h,ssr}$ gives the additional impact of the volatility shock conditional on the level of the shadow short rate. We estimate equation (2) for the whole sample.

Figure 9 compares the impulse responses of equity markets, long rates and exchange rates between the conventional and unconventional monetary policy periods. Starting with the response of equity markets, our results show that the fall in stock prices was larger during the conventional policy period. Somewhat paradoxically, unconventional monetary policies in major economies appear to benefit EMs' equity markets more than conventional policies during risk-off episodes. This larger benefit appears to result from the larger effect of unconventional policies on emerging markets' long rates. For instance, as in our baseline impulse responses, the long

[7] We use the Krippner (2013) measure of shadow short rate.

rates rise by more than 10 basis points in response to the risk-off shock in the conventional policy period, despite falling long rates in major economies. In the unconventional policy period, however, after an initial jump EMs' long rates fall as much as 20 basis points. This suggests that major economies' unconventional policies have acted directly on EMs' long rates. The change in the response of EMs to risk-off shocks is also evident in the dynamics of exchange rates, even though the differences are somewhat less pronounced. Nonetheless, our point estimate of the peak impact of the risk-off shock on the exchange rate is reduced from 4.2% under conventional policies to 3.5% under unconventional policies.

Figure 10 presents the effect of risk-off shocks and the role of the interaction term with the shadow short rate. The first row in Figure 10 reports the direct impact of the risk-off shock obtained from the specification in equation (2). The direct impact of the risk-off shock is very similar to the impacts obtained from the baseline specification. The second row reports estimates of the interaction term for each variable. The interaction terms are statistically significant for all variables for multiple horizons, suggesting that the stance of monetary policy in the US has a direct impact on how risk-off shocks transmit to EMs. For all three variables, the interaction term has the same sign as the baseline effect. This suggests that the effect of risk-off shocks on these three variables increases with the level of shadow short rates. Put differently, when short rates are low or monetary policy is loose, a risk-off shock triggers a smaller decline in EMs' equity markets, their 10-year yields increase less and their exchange rate depreciation is less pronounced.

Taken together, our results from interacting the effects of risk-off shocks with the monetary policy stance in core economies agree with the second prediction from our conceptual framework. That is, policy-puts in major economies support global financial markets and alleviate the effects of global risk-off shocks on EMs.

Next, we present empirical evidence on the third and last prediction of our conceptual framework. So far, we have assumed that the effects of risk-off shocks are homogeneous across economies. The economies in our sample, however, are heterogeneous with respect to their economic fundamentals, and it is likely that these economy-specific characteristics shape the sensitivities of their financial markets to global risk-off shocks. In what follows, we investigate which characteristics of these emerging market economies are important in helping insulate against the effects of risk-off shocks. We consider a wide range of indicators that could contribute to cross-country differences in response to global risk-off shocks. First, we consider a set of variables that are commonly used indicators of external vulnerabilities in emerging markets: current account deficit, foreign reserves to GDP and short term debt to foreign reserves. Second, we include indicators relating to government debt: Moody's local currency sovereign rating and total government debt to GDP. Third, we examine whether an economy's financial integration with the rest of the world (measured as financial openness to GDP) and GDP per capita can explain cross-country differences. Fourth and final, we construct an index that proxies for an individual economy's ability to produce safe government debt denominated in local currency. We construct this indicator by dividing the ratio of government debt issued in local currency to GDP by each economy's sovereign Credit Default Swaps (CDS).

We augment equation (1) to take into account the interaction between the indicator variables and risk-off shocks. We estimate:

$$\Delta y_{i,t+h} = \alpha_i^h + \delta_t^h + \beta^h \varepsilon_t^v + \beta^{h,I} \varepsilon_t^v I_{i,t} + \Sigma_{k=0}^K \omega_k^h x_{i,t-k} + \varepsilon_{i,t+h} \tag{3}$$

where the coefficient $\beta^{h,I}$ measures the additional effect of the risk-off shock interacted with the indicator variable. Figures 11-16 present point estimates and the corresponding confidence intervals of the interaction coefficients for each variable we consider.

Focusing on the effects of fundamentals on the transmission of risk-off shocks on bond yields, we find that most of the interaction terms are significant and have the expected sign. For instance, in terms of indicators related to external vulnerabilities, countries with low current account deficits (or surpluses), countries with low short-term debt to foreign reserves and countries with high foreign reserves to GDP ratios appear to experience less upward pressure on their bond yields. The same seems to be true for countries with higher levels of GDP per capita and countries that are more integrated to the international financial markets, as both interaction terms are estimated to be negative. Regarding indicators related to public debt, our results suggest that, while a country's sovereign debt rating appears to be important in attenuating the effects of risk-off shocks, the level of total public debt doesn't seem to have a statistically significant effect. Finally, the interaction term with the index of ability to create safe assets also has a negative coefficient. This suggests that, in countries that can produce local currency-denominated sovereign debt at low spreads, the long end of their yield curve is less sensitive to global risk-off shocks.

Most of our findings on the sensitivity of bond yields to fundamentals apply to the dynamics of exchange rates during risk-off episodes. That is, there is less pressure on the currencies of economies with strong fundamentals during these periods. Further, unlike our results on bond yields, we find that the ratio of short-term debt to foreign reserves can significantly contribute to and exacerbate the response of the exchange rate. On equity market responses and equity flows dynamics, we find a rather limited role for fundamentals in differentiating across emerging markets. None of the interaction variables we consider are estimated to be significantly different from zero for equity market response. The level of GDP per capita and the rating on sovereign debt limit equity outflows but we find that, somewhat counter-intuitively, high levels of short term foreign debt are associated with lower equity outflows. Figure 17 depicts the share of foreign investors' holdings in debt and equity markets as a percentage of GDP in the first quarter of 2018. Indeed, foreign investors' equity holdings are larger than their debt holdings in Asian economies. In Latin America and other central and eastern European economies, however, foreign investors constitute an important part of the investor base in debt markets.

5. The effects of US Policy-puts on Asia-Pacific Economies

In this section, we directly test our (empirically motivated) conjecture from section 4 that policy-puts in core economies impacted EMs' long rates. We focus on Asia-Pacific economies and estimate the impact of US monetary policy shocks on each economy's long rates (and financial markets). In particular, we define US monetary policy shocks using high frequency movements in a number of asset prices around FOMC announcements. The advantage of using high-frequency monetary policy shocks is that we can establish a causal relationship (or identify spillovers) from US monetary policy to AP economies. We also distinguish between conventional policy announcements and unconventional policy announcements such as forward guidance and LSAPs. This enables us to isolate US monetary policies that targeted US long rates and test whether these policies had a significant and sizeable impact on AP economies' long rates. We do not take a stand on whether this large impact has been good on net for the region: it is a positive shield during severe global risk-off episodes but it is a source of concern during reach-for-yield environments.

There is an emerging consensus that the Federal Reserve was not very constrained by the zero lower bound on nominal interest rates, as it was able to effectively use forward guidance and large scale asset purchases to influence medium- and long term interest rates, stock prices and exchange rates. Our findings in Section 3 are consistent with this conclusion (see Swanson

(2018) for a review). Several papers also find that US unconventional policies have had large international effects (e.g., Wright, 2012; Neely, 2015; Bowman et al., 2015; Fratzscher et al., 2017; Rogers et al., 2018). Our contribution to the existing literature is twofold. First, we systematically document the effects of US monetary policy using high frequency data on 11 Asia-Pacific economies. The economies included in our sample are Australia, China, Hong Kong, Indonesia, India, Korea, Malaysia, New Zealand, the Philippines, Singapore and Thailand. Second, instead of characterizing US monetary policy surprises by the response of yields at a particular maturity, we follow Gurkaynak et al (2005) and Swanson (2017) to take into account additional dimensions of US monetary policy: forward guidance and LSAPs.

Our measure of monetary policy shock is taken from Swanson (2017) who uses asset price changes in a tight window (30 minutes) around FOMC announcements. Using high-frequency movements in asset prices ensures that the surprise component of monetary policy announcements is well captured. Swanson (2017) decomposes the monetary policy surprise associated with each FOMC announcement into three components based on the movements in several asset prices: federal funds futures, Eurodollar futures, a number of Treasury bond yields up to 30-year maturity, the stock market and the dollar exchange rate against the euro and the yen. The three components of monetary policy announcements correspond to a target factor (related to the changes in the federal funds rate), a forward guidance (or path) factor and an LSAP factor. In order to separately identify the three components Swanson first assumes that the LSAP factor is as small as possible during the pre-ZLB period. Then, each factor is identified by imposing that the forward guidance and LSAP components are orthogonal to changes in the federal funds rate.

We estimate the effects of each component on Asia-Pacific financial markets using regressions at daily frequency. We regress daily changes in asset markets on intraday monetary policy surprises because Asian-Pacific markets are closed at the time of most FOMC announcements. Therefore, for each country in our sample, we construct a dataset that collects the changes in interest rates, exchange rates and stock prices between the day before and the day after each FOMC announcement. To be consistent with the definition of subsamples in the previous sections, we use data on FOMC announcements in the pre-ZLB period up to the collapse of Lehman Brothers. That is, the last monetary policy announcement in our pre-ZLB subsample is on 5 August 2008. Similarly, the ZLB subsample starts in April 2009 and the FOMC announcement on 29 April 2009 is the first observation in this subsample. By construction we exclude the QE1 announcement on 18 March 2009.[8] We estimate the following equation separately for the two subsamples defined above:

$$\Delta y_{i,t} = \alpha_i + \beta_i F_t + \varepsilon_t \tag{4}$$

where $\Delta y_{i,t}$ is the daily change in the 10-year yield, the US dollar exchange rate or stock prices in country i. F_t corresponds to target and forward guidance factors in the conventional monetary policy period or forward guidance and LSAP factors in the ZLB period. For each economy in our sample, the starting date for the estimation varies according to data availability. In most cases, data on equity markets and exchange rates are available for a longer period than other variables. The data on interest rates are more limited. For each economy, we estimate equation (4) using the same sample period when all three variables are available. As a result, the sample periods are not identical in the pre-ZLB period, and one must be cautious comparing coefficients across economies. We have data on all three variables for all economies in the post-ZLB period,.

Table 1 presents the responses of bond yields in economies in the Asia-Pacific region and in the US. We first discuss the effects of these shocks on the 10-year Treasury yield in the US. Swanson (2017) already reports estimates of the effect of each component on the 10-year Treasury yield at intraday frequency. In Table 1, we report the effect of these shocks at a daily frequency for the US to make our analysis self-contained.[9] Moreover, the estimates for the US long rates are useful for getting a sense of the relative magnitude of the spillovers on other countries.

Each component of monetary policy surprises is normalized to unit standard deviation over the sample. For example, a one standard deviation surprise in the target or the federal funds rate (FFR) component corresponds to an 8.8 basis point change in the FFR. For the forward guidance (FG) component, a one standard deviation surprise corresponds to a 6 basis point increase in 1-year ahead Eurodollar futures. In order to ease interpretation, for both FFR and FG surprises, we calibrate the responses of bond yields to correspond to an unexpected 100 basis point fall in each component.

Starting with the pre-ZLB period, our coefficient estimates suggests that a surprise 100 basis point cut in the FFR would push the 10-year yield down significantly, by 18 basis points. We also find that the impact of a forward guidance shock on the US 10-year Treasury yield is significant

[8] In appendix A.4, we provide coefficient estimates obtained including these dates. Our main results are unchanged under this alternative split of pre-ZLB and post-ZLB samples.

[9] Our coefficient estimates on daily changes are broadly similar to his results.

in both pre- and post-ZLB periods. The coefficient estimates suggest that the effect is slightly smaller in the post-ZLB period, 49 vs 37 basis points. Finally, a one standard deviation LSAP surprise is equivalent to a 225 billion dollar LSAP surprise, and it triggers a 6.7 basis point decline in the 10-year US Treasury yield. Our estimates of the effects of different components of monetary policy shocks are broadly in line with the existing empirical work.

Table 1. The effects of US monetary surprises in Asia-Pacific

	Pre-ZLB		Post-ZLB	
	Change in		Change in	
	FFR	**FG**	**FG**	**LSAP**
Response of 10-year yields				
Australia	-8.1	-31.9***	-31.9**	-7.4***
China	12.8	32.1***	-6.6	-0.1
Hong Kong	-30.4***	-39.0***	-43.0***	-6.5***
Indonesia	-4.1	-15.1	-97.1***	-0.4
India	-17.5***	-16.9*	-19.3*	-3.4***
Korea	-26.3***	-4.2	-31.8**	-3.1***
Malaysia	5.4	-7.2	-21.6**	-0.8
New Zealand	1.9	-12.1	-21.0	-5.4***
Philippines	2.1	-21.5	-32.4	-4.8**
Singapore	-3.6	-27.9***	-45.0***	-6.1***
Thailand	-17.6***	0.5	-40.0*	-3.6**
US	-18.2**	-49.3***	-37.1**	-6.7***

Notes: The Table reports the effects of each component of FOMC announcements on Asia-Pacific economies' 10-year yields; coefficient β_i in equation 4. In the pre-ZLB estimates, the two components of monetary policy announcements are changes in the federal funds rate (FFR) and forward guidance (FG). In the post-ZLB estimates, the two components of monetary policy announcements are changes in forward guidance and LSAPs. * ,** and *** denote statistical significance at 10%, 5% and 1%, respectively

We now turn to the effects of US monetary policy shocks on long rates in Asia-Pacific. We start with spillovers in the pre-ZLB period. The first two columns of Table 1 present the responses of foreign bond yields under the conventional policy regime. We find statistically significant spillovers to long rates in 7 out of 11 economies in our sample, for at least one of the two components of US monetary policy surprises. Individually, the FFR component has a significant effect on long rates in 4 economies, and the forward guidance component has a significant effect in 5 economies. Hong Kong is the only economy where both FFR and forward guidance have a statistically significant impact on long rates. Further, the magnitude of the spillovers from US monetary policies is also largest in Hong Kong. This is not surprising as Hong Kong interest rates tend to follow movements in US interest rates given Hong Kong's linked exchange rate system.

For other economies, the strength of spillovers from shocks to the FFR and forward guidance components are somewhat different. In addition to Hong Kong, the effect of FFR surprises on 10-year government bond yields is statistically significant in three economies (India, Korea and Thailand). In these economies, the effect of the FFR surprise on long rates is about as strong as the effect in US 10-year Treasury yield and ranges from 17 to 26 basis points.

The effect of forward guidance is also statistically significant in a subset of economies in the pre-ZLB period. We should note, however, that we estimate a positive effect of a surprise drop in the FG component for China. For other economies, long rates fall less than in the US following a forward guidance surprise. A 100 basis points forward guidance surprise that lowers US long rates by 49 basis points reduces these economies' long rates by 17 to 39 basis points.

We next present the spillovers of US monetary policy shocks under unconventional policies. The last two columns of Table 1 presents the estimated effects of the forward guidance and LSAP components. A first observation is that, with the exception of China, the long rates of all countries in the Asia-Pacific region are statistically significantly affected by either the forward guidance or LSAP components. This is remarkably different from pre-ZLB spillovers and probably reflects the increasing influence of US unconventional monetary policies on the region's long rates. Turning to the effects of shocks to individual components, forward guidance shocks have significant effects on the long rates of 8 economies. The magnitude of spillovers from forward guidance shocks, however, varies substantially across countries. In economies where forward guidance shocks have a significant effect, long rates increase more than in the US in half of the economies (Hong Kong, Indonesia, Singapore and Thailand), while in the other half (Australia, India, Korea and Malaysia) the effect is less than for the US.

Relative to their effect on US long rates, the effect of forward guidance surprises on long rates in the Asia-Pacific region has strengthened between pre-ZLB and post-ZLB periods. As an additional way to evaluate the spillovers of US monetary policy, we compare the implied level of pass-through of forward guidance to long rates, both domestically and internationally. As in Gilchrist et al. (2016), we define the implied pass-through of forward guidance as the ratio of the response of the Asia-Pacific economies' long rates to the response of US long rates to a forward guidance shock. Using this metric in the conventional policy period, we find that the implied pass-through of forward guidance to the Asia-Pacific region's 10-year yields ranges between 35 and 80 percent. For the unconventional policy period, the implied pass-through is higher on average and ranges from 60 to 260 percent.[10] Moreover the implied pass-through increases for every economy. This suggests that forward guidance in the US has larger international spillovers in the unconventional policy period.

The last column of Table 1, where we present the sensitivity of long rates to LSAP shocks, provides estimates of the impact of monetary policies in the US that directly targeted domestic long rates. We find that these shocks have had significant international spillovers in all countries except China, Indonesia and Malaysia. There is, nonetheless, a certain degree of heterogeneity across economies. For example, long rates in the more advanced group of countries seem to be more sensitive to LSAP shocks. The largest effect of the LSAP shock is on Australian long rates, which increased more than US long rates (7.4 basis point). The coefficient estimates for other rather advanced economies (Hong Kong, New Zealand and Singapore) range from 5.4 to 6.5 basis points and these coefficients are distinctly larger than those for less advanced economies. For the remaining economies in our sample, the coefficient estimates range from 3.48 (India) to 4.99 (the Philippines) basis points. The positive relationship between economic fundamentals and the reaction to US LSAP shocks supports our claim that fundamentally strong economies experienced larger spillovers from policy-put frameworks in major economies.

6. Final Remarks

We have shown that the policy-put framework implemented by the core economies following the global financial crisis was highly effective in substituting for the exhausted conventional monetary policy instruments. Absent these policies, financial markets would have been substantially more vulnerable to the periodic risk-off episodes experienced by the world economy.

These policies had substantial spillovers to the rest of the world. While most of the policy discussion has focused on the problems caused by the reach-for-yield capital flows towards emerging market economies, we document that there is a positive side of these policy-put frameworks since they increase the resilience of the rest of the world with respect to global risk-off shocks. For EMs in particular, this increased resilience took the form of more stable long rates and smaller credit spreads in the face of risk-off shocks. Core policy-put frameworks seem to

[10] Excluding Indonesia, the highest passtrough is 120 percent (Singapore).

have prevented the traditional unhinging of the long end of EMs' yield curves during risk-off episodes.

By the same token, this policy-framework spillover observation raises the issue that as (and if) the core policy-put framework is gradually removed, individual economies may need to boost their self-hedging mechanisms. Self-hedging often means an increased demand for safe assets, which may reignite the downward pressure on long interest rates and global imbalances, unless regional supplies of safe assets expand as well, an issue on which the Asia-Pacific region has much to contribute. This expansion in the supply of safe assets can take place at the individual country or regional level, perhaps by creating tranches from pooled regional debts. Similarly, the region could consider creating a regional policy-put framework.

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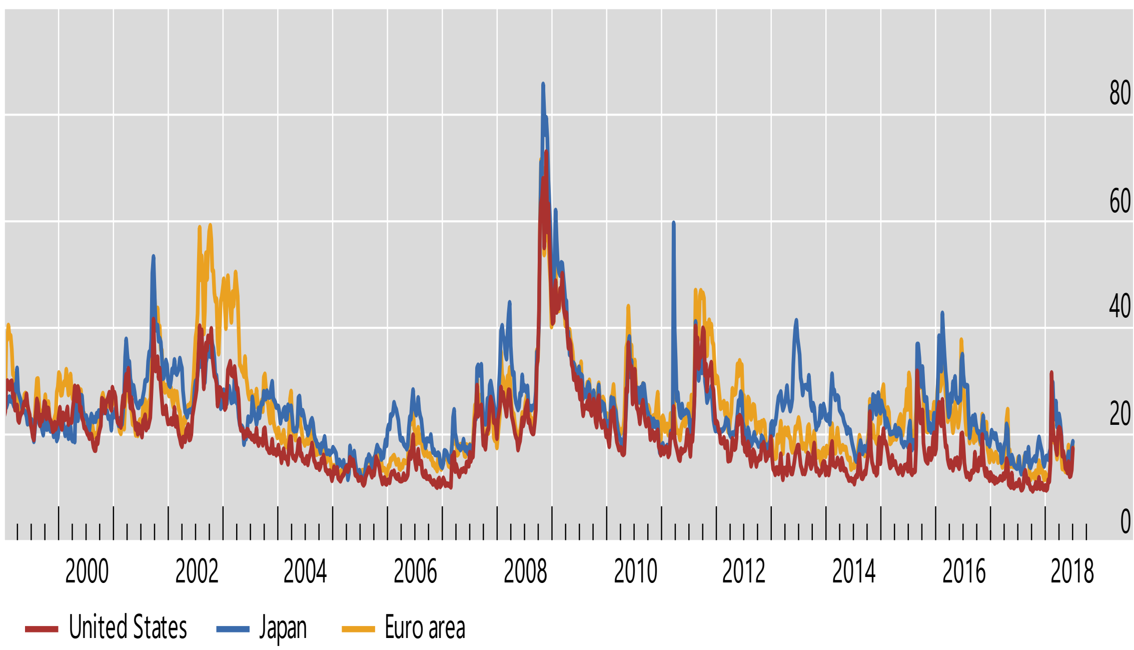
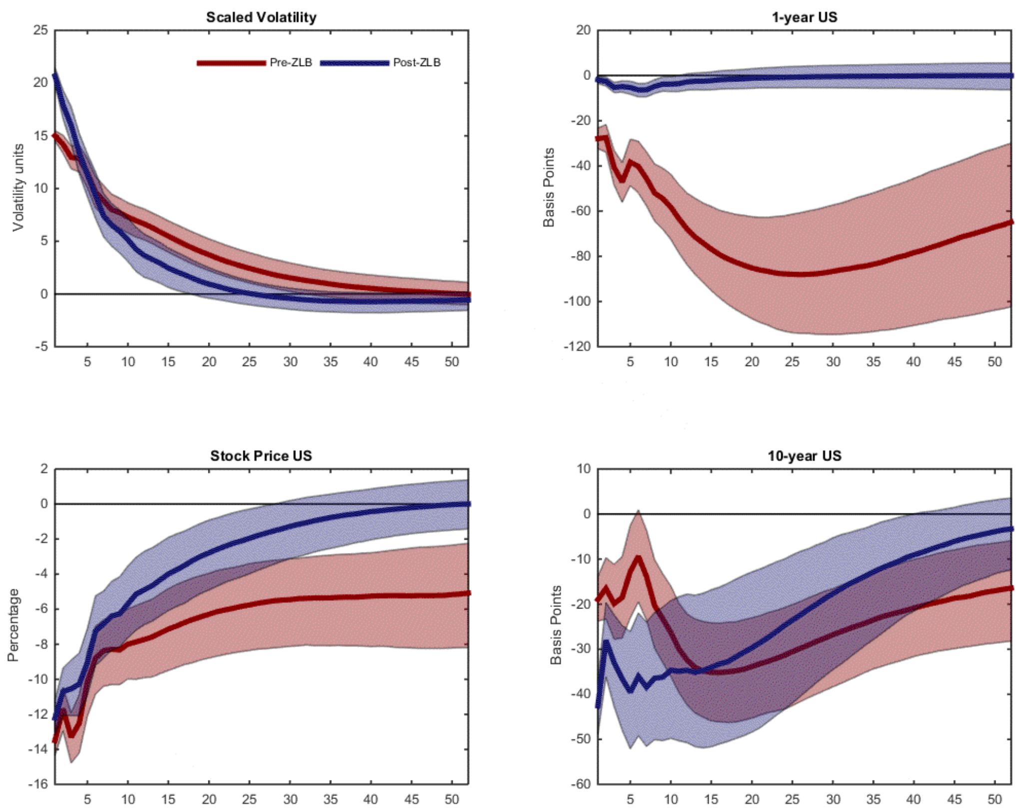
7. Figures

Figure 1: Implied Volatilities



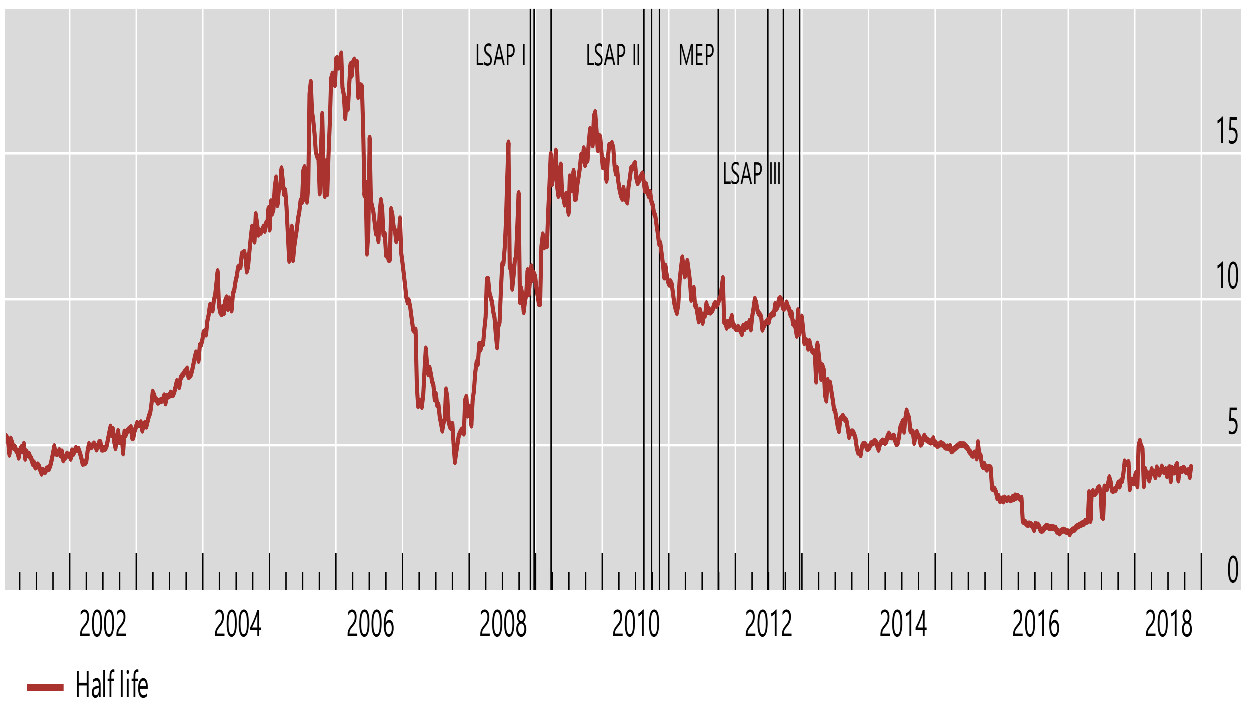
Notes: For US, CBOE VIX Index. For Japan, Nikkei Stock average Volatility Index. For Euro Area VSTOXX Volatility Index. Data up to 25 Jun 2018. Sources: Bloomberg, Datastream.

Figure 2: The effects of risk-off shocks in the US



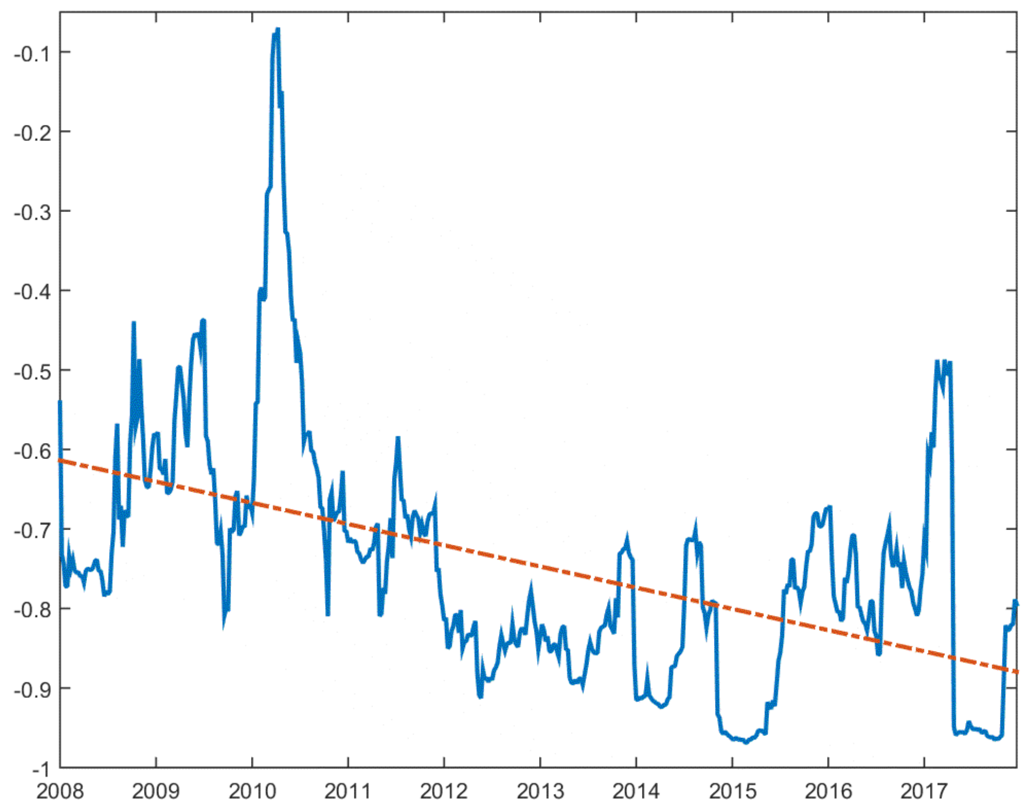
Notes: The figure shows impulse responses to a risk-off shock obtained from weekly VARs estimated for two subsamples. The variables included in the VAR are the VIX index, 1- and 10-year US Treasury yield and the log of the S & P 500 index. The first subsample, labelled pre-ZLB, covers January 1999 to September 2008. The second subsample, labelled post-ZLB, covers April 2009 to December 2015. Red (blue) solid lines and shaded areas correspond to point estimates and one standard deviation confidence intervals. The volatility shock is calibrated to generate a 15 vols increase in VIX in the first subsample. The impulse responses in the post-ZLB sample are scaled so that the 12 week cumulative increase in the response of VIX is the same in both subsamples. The units of the vertical axes are vols for VIX, basis points for interest rates and percentage points for stock prices.

Figure 3: Half-life of Shocks to Volatility



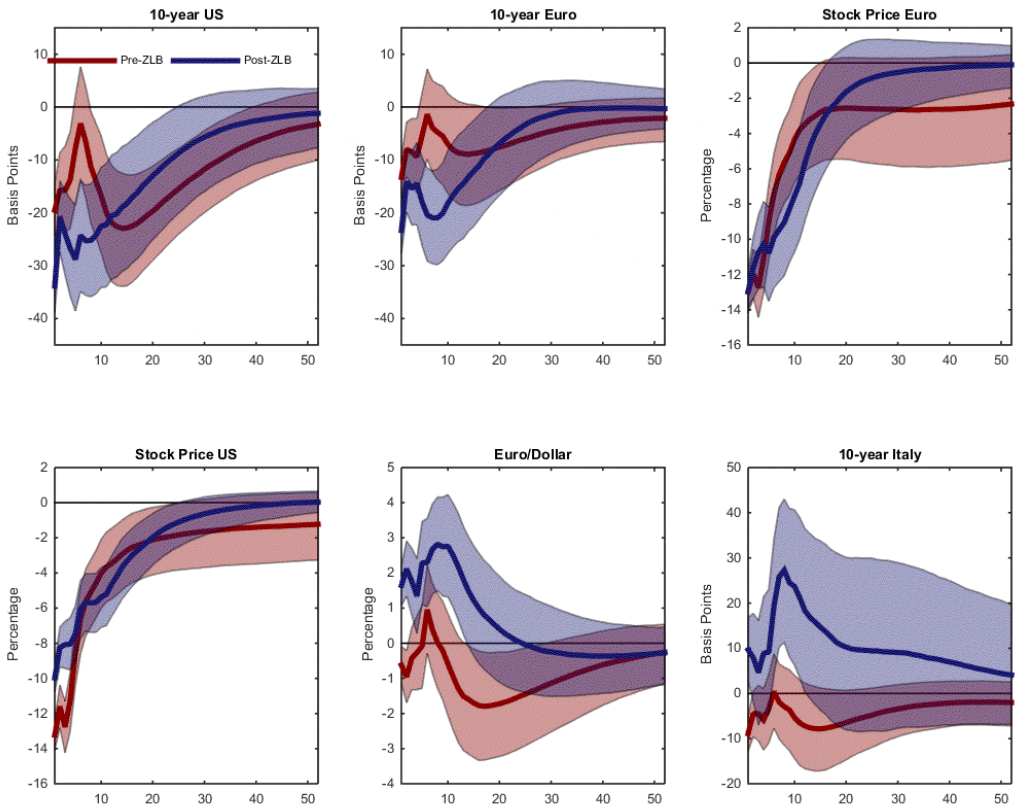
Notes: The graph shows the half-life of a shock to VIX in weeks estimated from GARCH(1,1) over four year rolling windows. The vertical lines indicate 25 Nov 2008 (Announcement of LSAP I), 16 Dec 2008 (Target federal funds is lowered to its effective lower bound), 18 Mar 2009 (Announcement to purchase Treasuries and increase the size of purchases of agency debt and agency MBS), 10 Aug 2010 (Announcement of LSAP II), 3 Nov 2010 (Announcement of additional purchase of Treasury securities), 21 Sep 2011 (Maturity Extension Program-MEP), 20 Jun 2012 (Announcement of continuation of the MEP through end of 2012), 13 Sep 2012 (Announcement of LSAP III) and 12 Dec 2012 (Announcement of an increase in LSAP-III).

Figure 4: Correlation between changes in VIX and slope of the VIX futures



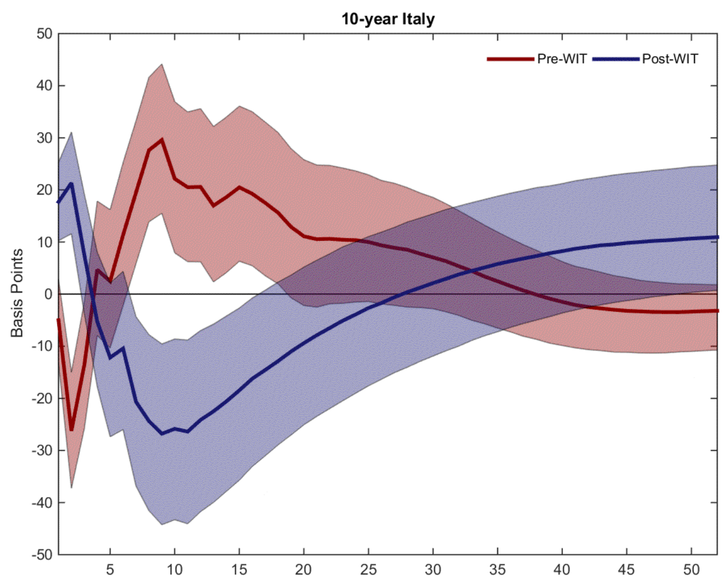
Notes: The blue line represents 6-month rolling correlation coefficient between changes in VIX and changes in the slope of the VIX curve defined as UX6-UX1. Dashed line is the fitted linear trend.

Figure 5: The effects of risk-off shocks in the Euro Area



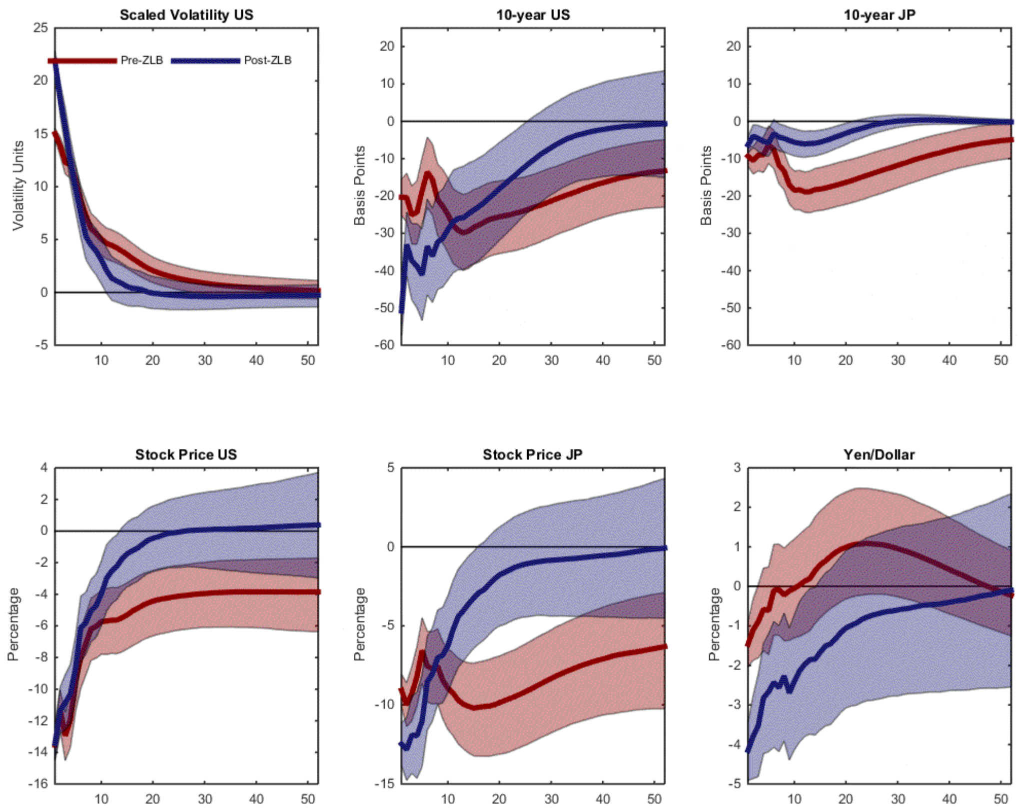
Notes: The figure shows impulse responses to a risk-off shock obtained from weekly VARs estimated for two subsamples using US and Euro Area variables. The first subsample, labelled pre-ZLB, covers January 1999 to September 2008. The second subsample, labelled post-ZLB, covers April 2009 to December 2015. Red (blue) solid lines and shaded areas correspond to point estimates and one standard deviation confidence intervals. The volatility shock is calibrated to generate a 15 vols increase in VIX in the first subsample. The impulse responses in the post-ZLB sample are scaled so that the 12 week cumulative increase in the response of VIX is the same in both subsamples. The units of the vertical axes are vols for VIX, basis points for interest rates and percentage points for stock prices.

Figure 6: The effects of risk-off shocks on Italian long rates (Before and after Draghi speech)



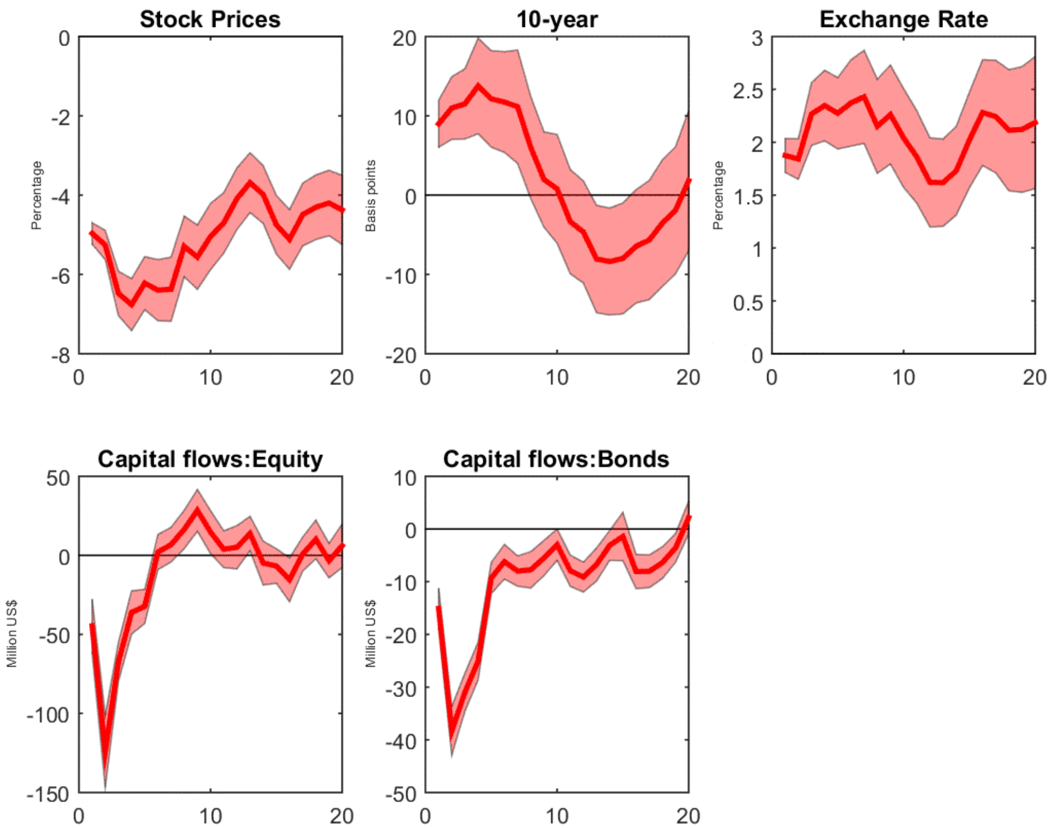
Notes: The figure shows impulse responses of Italian long rates to a risk-off shock obtained from weekly VARs estimated for two subsamples using Euro Area variables. The first subsample, labelled pre-WIT(Whatever it takes), covers April 2009 to July 2012. The second subsample, labelled post-WIT, covers August 2012 to 2017. Red (blue) solid lines and shaded areas correspond to point estimates and one standard deviation confidence intervals. The volatility shock is calibrated to generate a 15 vols increase in VSTOXX in the first subsample. The impulse responses in the post-ZLB sample are scaled so that the 12 week cumulative increase in the response of VSTOXX is the same in both subsamples. The units of the vertical axes are vols for VSTOXX, basis points for interest rates and percentage points for stock prices.

Figure 7: The effects of risk-off shocks in Japan



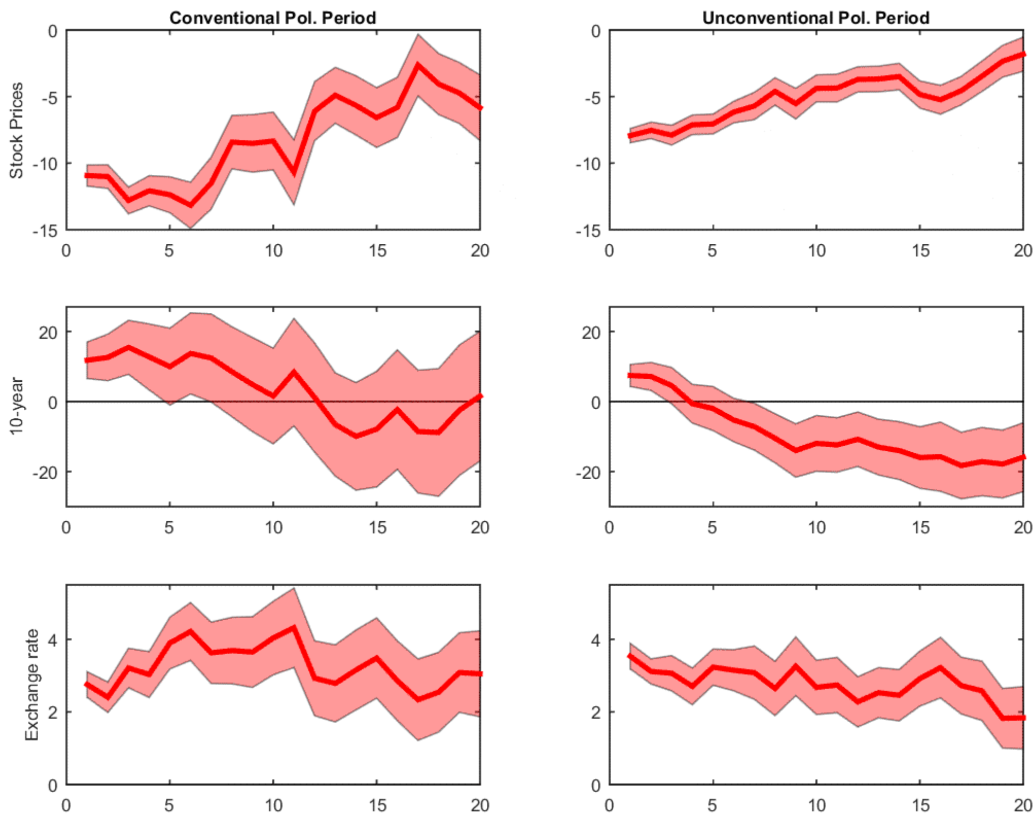
Notes: The figure shows impulse responses to a risk-off shock obtained from weekly VARs estimated for two subsamples using US and Japan variables. The first subsample, labelled pre-ZLB, covers January 1999 to September 2008. The second subsample, labelled post-ZLB, covers April 2009 to December 2015. Red (blue) solid lines and shaded areas correspond to point estimates and one standard deviation confidence intervals. The volatility shock is calibrated to generate a 15 vols increase in VIX in the first subsample. The impulse responses in the post-ZLB sample are scaled so that the 12 week cumulative increase in the response of VIX is the same in both subsamples. The units of the vertical axes are vols for VIX, basis points for interest rates and percentage points for stock prices.

Figure 8: The effects of risk-off shocks on EMs



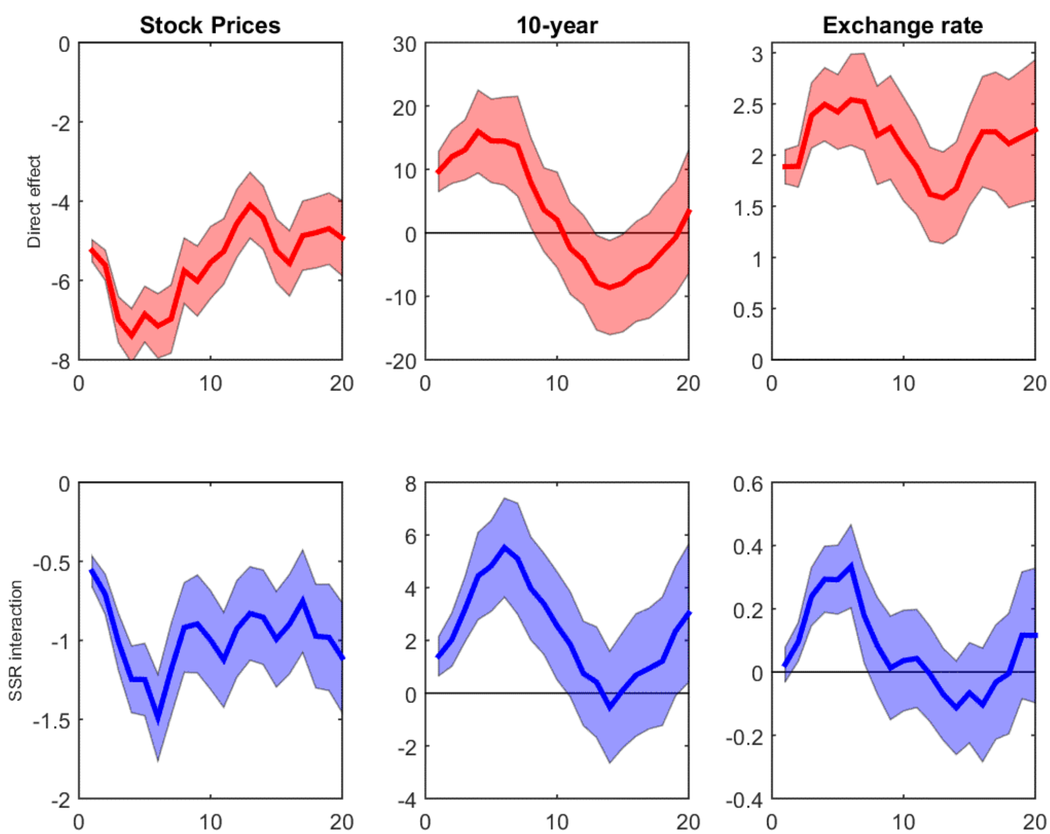
Notes: The figure shows impulse responses to a risk-off shock on EMs using panel local projection as in equation 1. The sample is 2004-2017 and the countries included are Brazil, Chile, China, Colombia, Czech Republic, Hong Kong, Hungary, India, Indonesia, Israel, Korea, Malaysia, Mexico, the Philippines, Poland, Russia, Singapore, South Africa, Thailand. Red solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals. The impulse responses are scaled to a shock that generates a 15 vols increase in VIX. The units of the vertical axes are percentage points for stock prices and exchange rates, basis points for interest rates and millions USD for capital flows.

Figure 9: The effects of risk-off shocks on EMs during conventional and unconventional policy periods



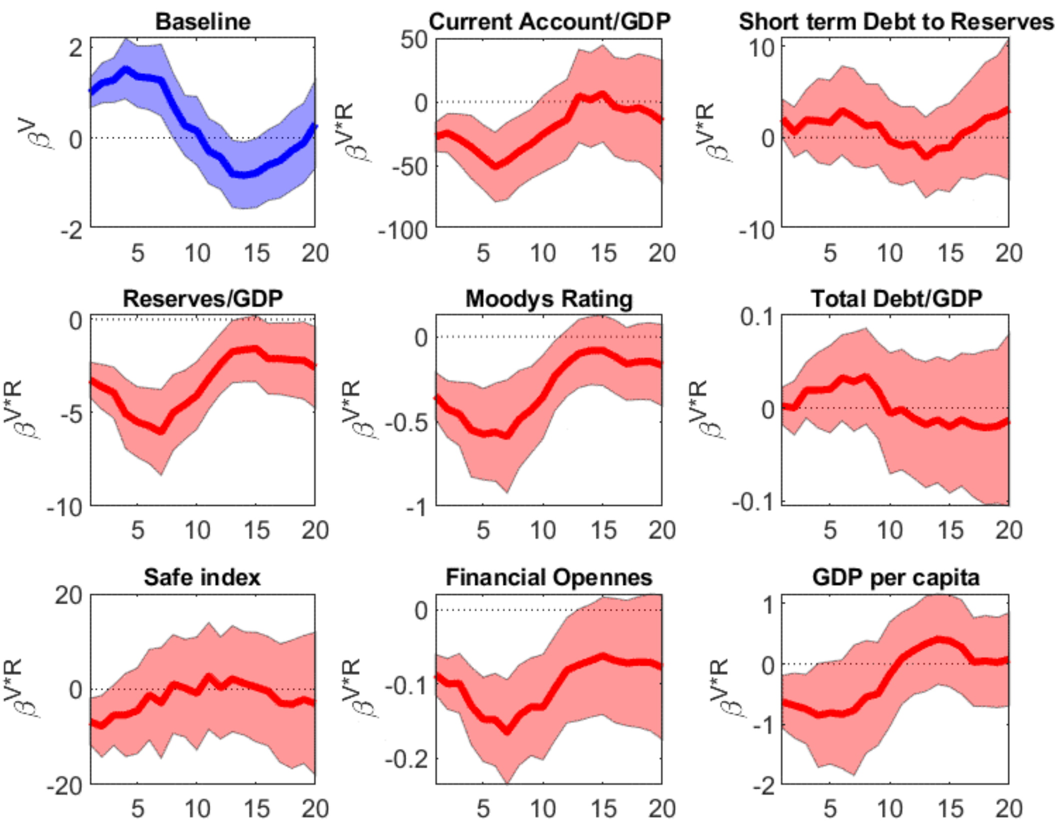
Notes: The figure shows impulse responses to a risk-off shock on EMs using panel local projection as in equation 1. The left (right) column shows impulse responses obtained from estimating equation 1 over the sample 2004-2008 (2009-2017). Red solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals. The impulse responses are scaled to a shock that generates a 15 vols increase in VIX. The units of the vertical axes are percentage points for stock prices and exchange rates, basis points for interest rates.

Figure 10: The effects of risk-off shock on EMs: controlling for shadow short rate



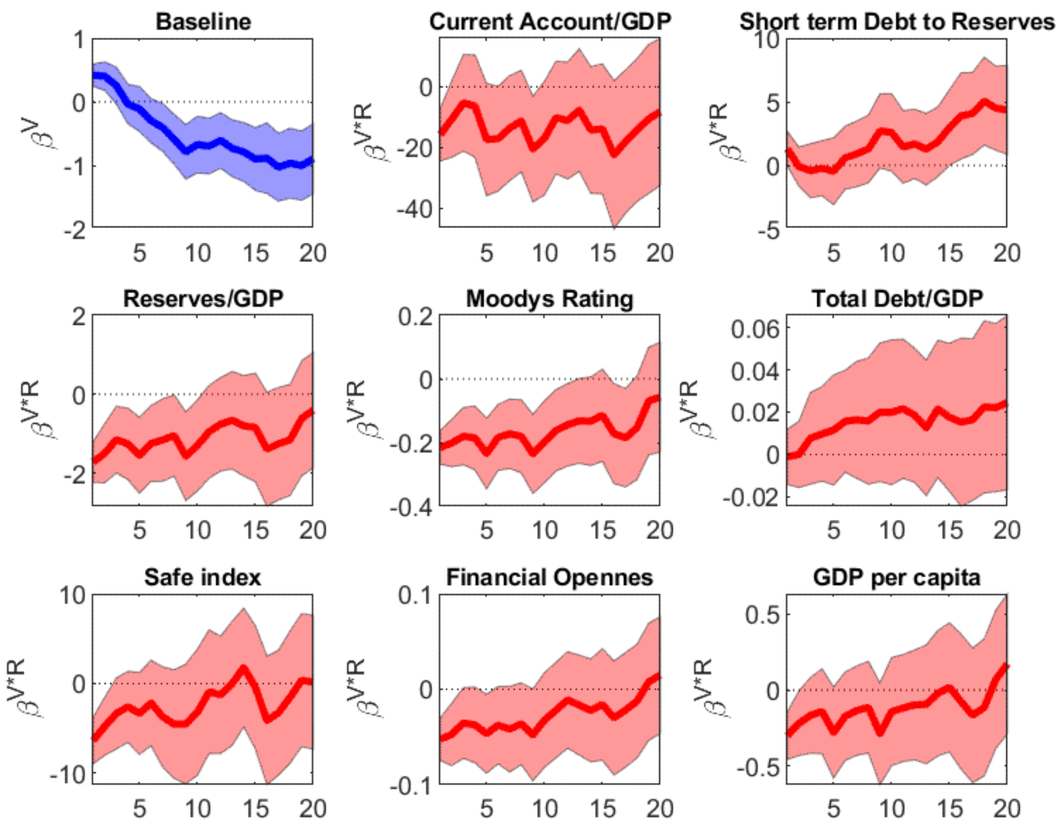
Notes: The figure shows impulse responses to a risk-off shock on EMs using panel local projection as in equation 2. The first row shows the direct impact of risk-off shocks. The second row plots the coefficient on the risk-off shock and shadow short rate interaction term. Solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals. The impulse responses are scaled to a shock that generates a 15 vols increase in VIX. The units of the vertical axes are percentage points for stock prices and exchange rates, basis points for interest rates.

Figure 11: The role of fundamentals: 10-year yields



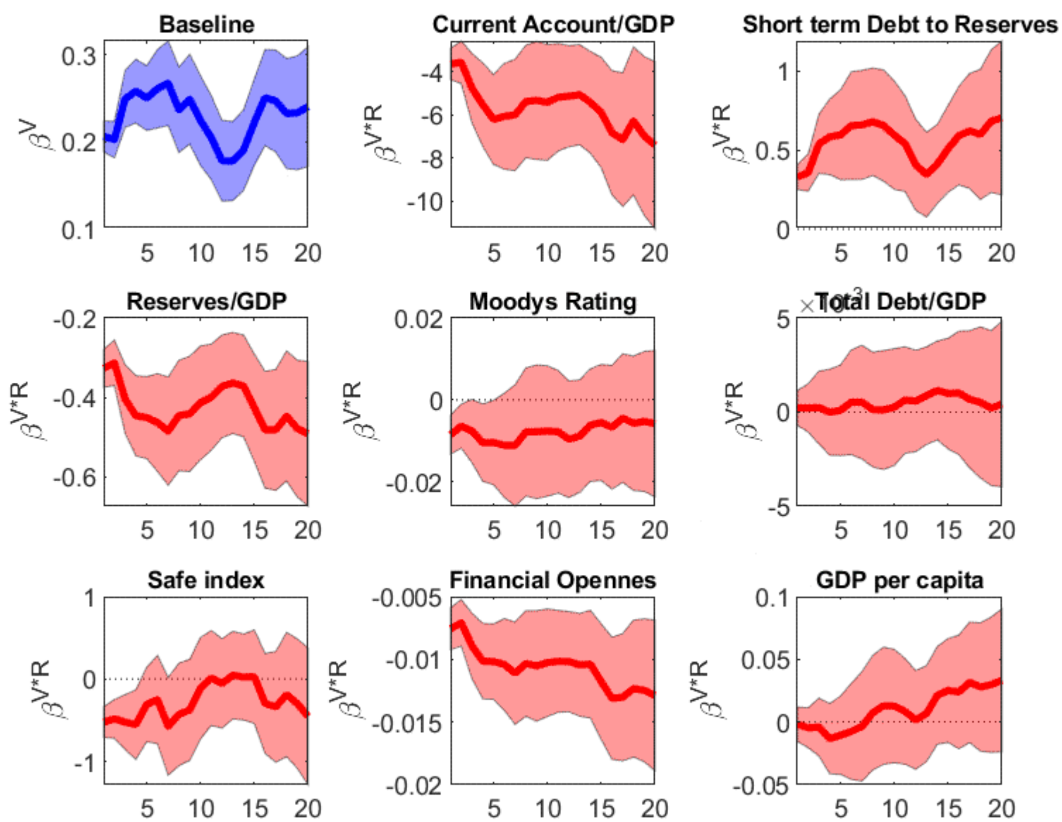
Notes: The figure shows coefficients on interaction terms and risk-off shock as in equation 2. The first panel shows the direct impact of risk-off shocks without any interaction term. The other panels show the coefficient on risk-off shock and the interaction term indicated in the title of each panel. Solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals.

Figure 12: The role of fundamentals: 10-year yields and unconventional polciies



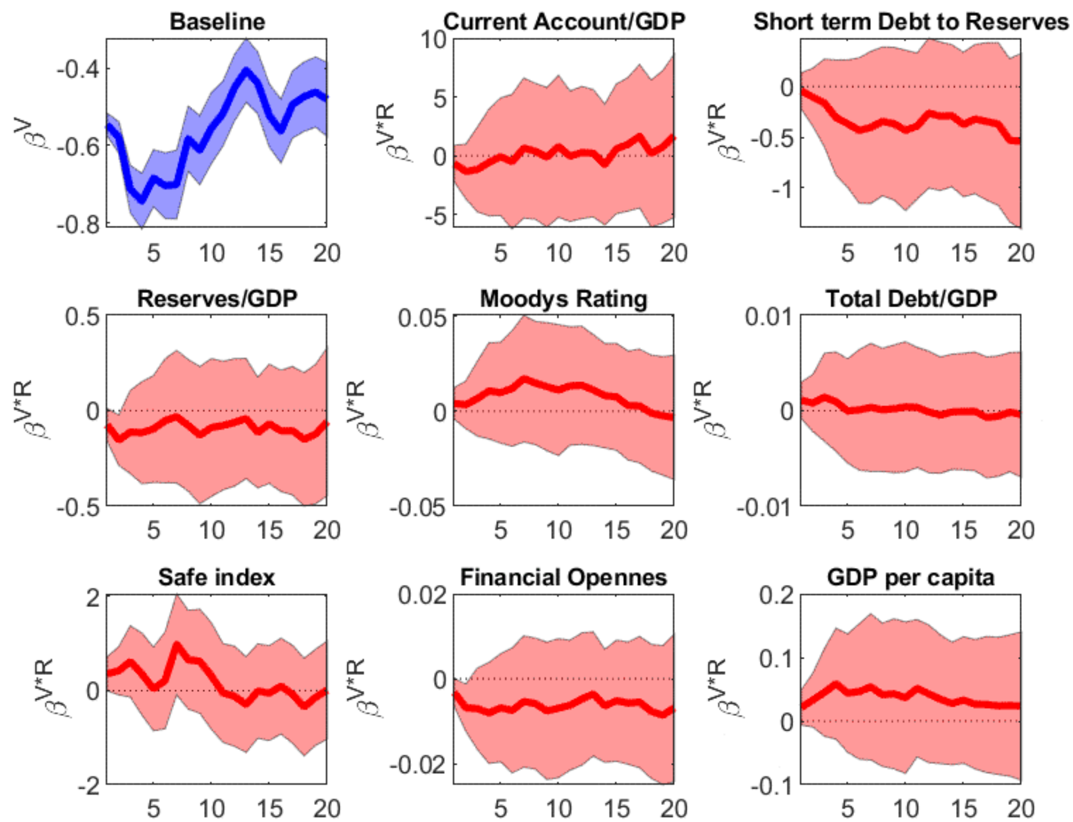
Notes: The figure shows coefficients on interaction terms and risk-off shock as in equation 2 estimated using data after April 2009. The first panel shows the direct impact of risk-off shocks without any interaction term. The other panels show the coefficient on risk-off shock and the interaction term indicated in the title of each panel. Solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals.

Figure 13: The role of fundamentals: Exchange rates



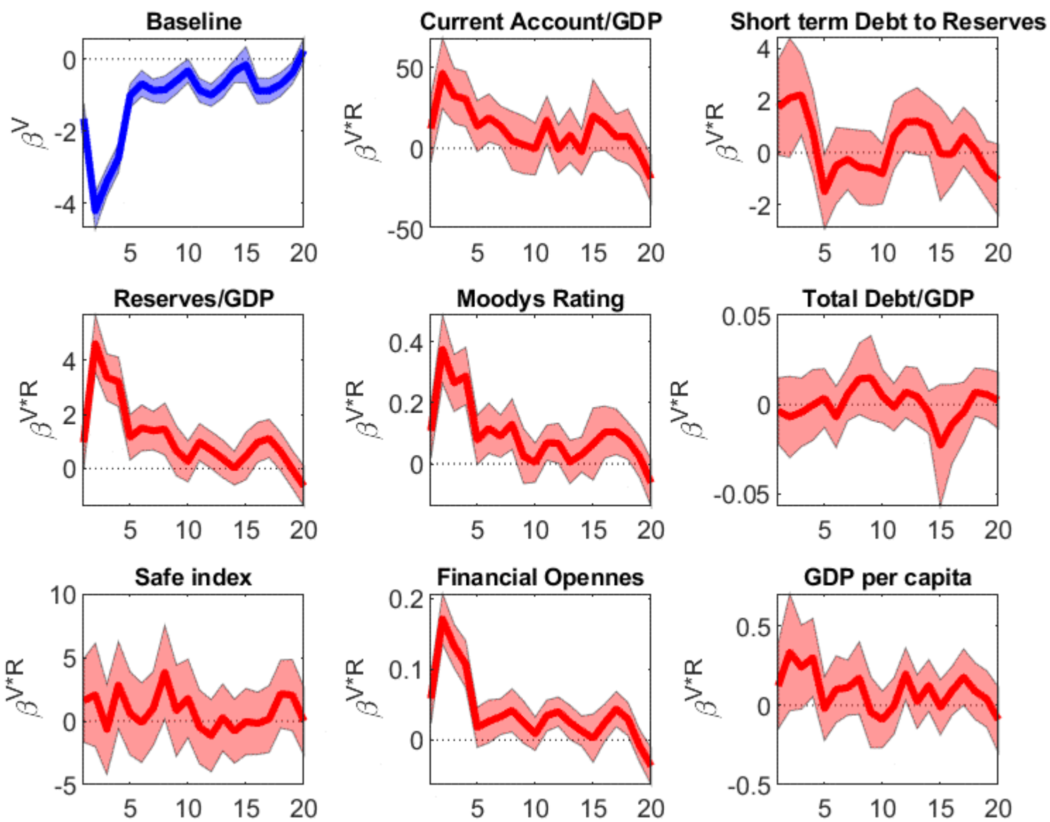
Notes: The figure shows coefficients on interaction terms and risk-off shock as in equation 2. The first panel shows the direct impact of risk-off shocks without any interaction term. The other panels show the coefficient on risk-off shock and the interaction term indicated in the title of each panel. Solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals.

Figure 14: The role of fundamentals: Equity markets



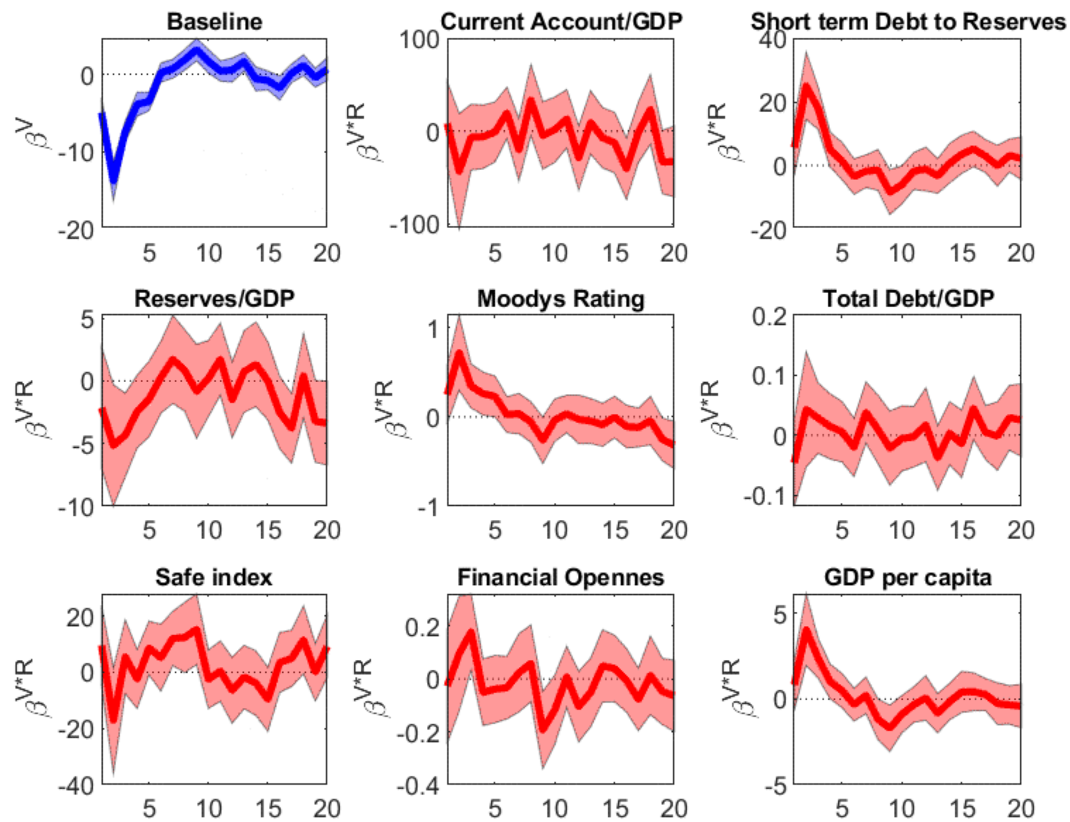
Notes: The figure shows coefficients on interaction terms and risk-off shock as in equation 2. The first panel shows the direct impact of risk-off shocks without any interaction term. The other panels show the coefficient on risk-off shock and the interaction term indicated in the title of each panel. Solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals.

Figure 15: The role of fundamentals: Bond flows



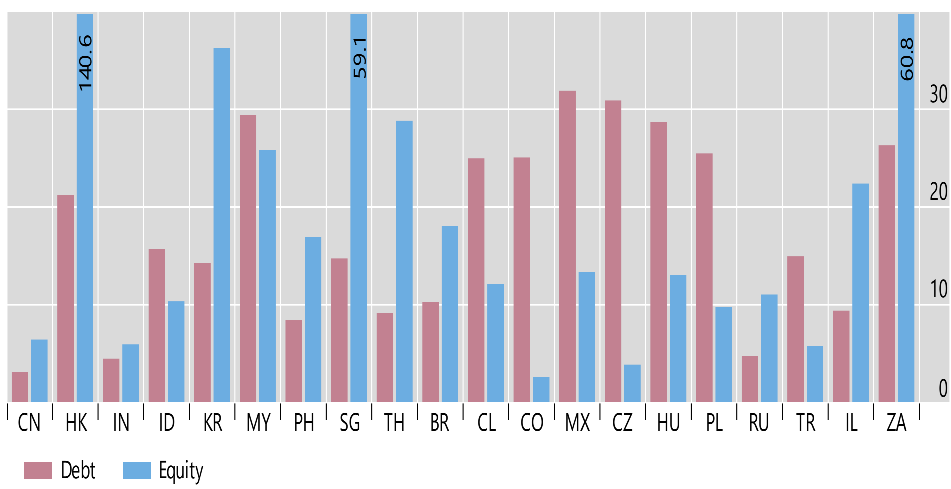
Notes: The figure shows coefficients on interaction terms and risk-off shock as in equation 2. The first panel shows the direct impact of risk-off shocks without any interaction term. The other panels show the coefficient on risk-off shock and the interaction term indicated in the title of each panel. Solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals.

Figure 16: The role of fundamentals: Equity flows



Notes: The figure shows coefficients on interaction terms and risk-off shock as in equation 2. The first panel shows the direct impact of risk-off shocks without any interaction term. The other panels show the coefficient on risk-off shock and the interaction term indicated in the title of each panel. Solid lines and shaded areas correspond to point estimates and 90 percent confidence intervals.

Figure 17: Foreign Investors' Share of Debt and Equity



Notes: The bars represent foreign investors' holdings in debt and equity markets as a share of each economy's 2017 GDP.

A. Appendix

A.1. Identification of risk-off shocks with external instruments

The identification of risk-off shocks in section 3 relies on a recursive ordering of variables that imply that volatility does not respond contemporaneously to other shocks in the VAR. In this section, we present an alternative identification approach that does not rely on the recursive ordering of the variables or on zero restrictions, namely the identification via external instruments. The idea in this approach is to use external instruments to isolate the part of reduced form shocks in the VAR owing to a particular structural shock. Our implementation closely follows Carriero et al. (2015).

Formally, we start the analysis by estimating the following reduced form VAR:

$$Y_t = c + \sum_{j=1}^{p} B_j Y_{t-j} + A_0 \varepsilon_t \tag{5}$$

where Y_t is the vector of endogenous variables. The reduced-form VAR residuals u_t are linear combinations of structural shocks, $u_t = A_0 \varepsilon_t$, and therefore the variance-covariance matrix of the reduced-form residuals $E[u_t u_t']$ is $\Omega = A_0 A_0'$.

We are only interested in the effects of risk-off shocks; our objective is to identify the column of the A_0 corresponding to the contemporaneous effect of the risk-off shock. Our approach requires our instrument to verify:

$$E(Z_t, \varepsilon_t^v) = \alpha \neq 0 \tag{6}$$

$$E(Z_t, \varepsilon_t^q) = 0 \tag{7}$$

where Z_t is our instrument. We denote ε_t^v as risk-off shocks while ε_t^q as all other structural shocks in the VAR. These two conditions state that in order for our external instrument to be valid, it should be correlated with the risk-off shocks and uncorrelated with all the other structural shocks in the VAR.

Following Carriero et al. (2015), our instrument is constructed as a dummy variable that takes the value of 1 when movements in VIX are greater than 1.65 std of the HP filtered data. When we regress the reduced-form residual from the first equation on this instrument, the regressions have large F-statistics: 33 in the first subsample and 60 in the second subsample.

Figure A.1 presents impulse responses under this identification scheme. We obtain qualitatively identical results to our baseline findings and only a marginally smaller impact of risk-off shocks on financial variables.

A.2. Structural VAR with shadow short rate

In our baseline VAR for the US, we use the 1-year Treasury yield as a measure of movements in the short end of the yield curve. In this subsection, we provide a robustness exercise for our baseline results, by employing shadow short rates instead of 1-year Treasury yields in the VAR. Our measure of the shadow short rate is taken from Krippner (2013). Figure A.2 presents the impulse responses obtained from this alternative VAR. Our results are robust, as the responses of all the variables are essentially identical to the responses obtained from the baseline specification. On short rates, the response in the conventional-policy period is large (more than 100 basis points) and persistent. In the unconventional-policy period, the short rate immediately falls but its response is short-lived. This is possibly because the shadow short rate is derived using information contained in the entire yield curve, and its short-lived response reflects a combination of a muted response in the short-end of the yield curve and relatively large changes in the long rates.

A.3. Alternative orderings of the variables in the structural VAR

Figure A.3 and A.4 present the impulse responses to a risk-off shock identified by ordering VIX second, after stock prices, and by ordering VIX last.

A.4. Alternative dating of subsamples and the effects of monetary policy surprises

In this subsection, we present the effects of the three components of US monetary policy surprises for an alternative dating of pre-ZLB and post-ZLB subsamples. In the main text (Table 1), pre-ZLB includes FOMC announcements until the collapse of Lehman and post-ZLB subsample starts in April 2009. In Table 2, the pre-ZLB sample includes announcements until the Fed effectively hit the zero lower bound (16 December 2008) and post-ZLB subsample starts with the first announcement once the interest rates were at the ZLB (28 January 2009).

Table 2. The effects of US monetary surprises in Asia-Pacific

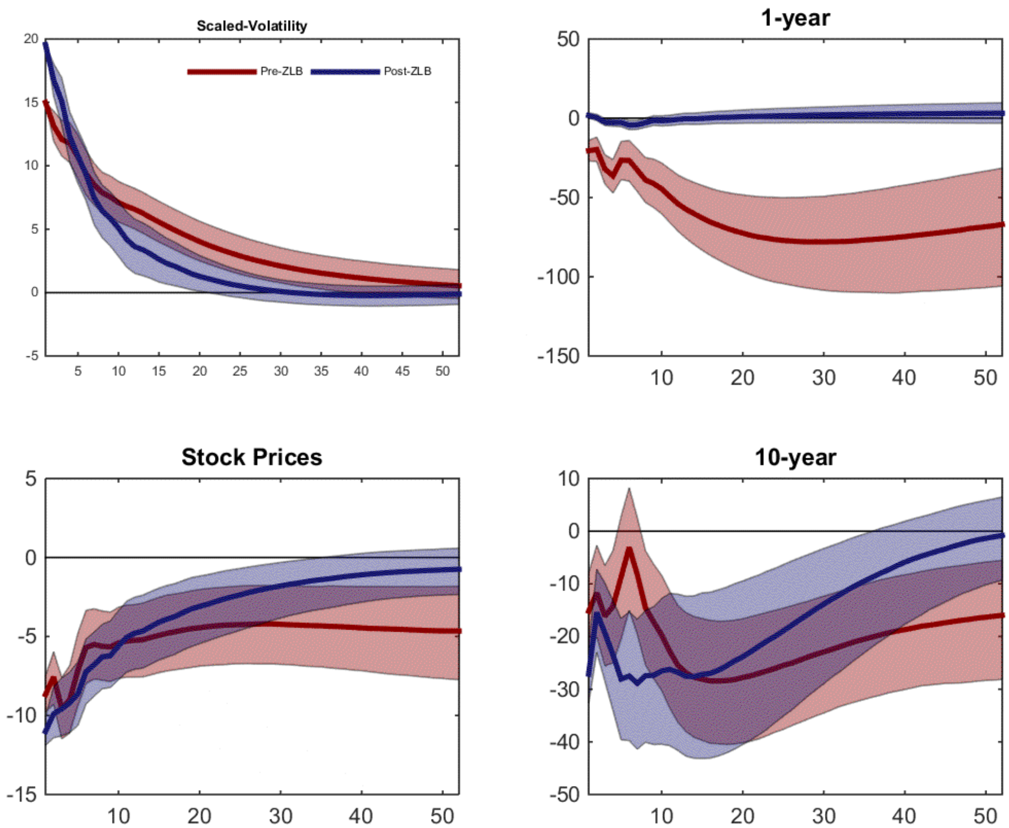
	Pre-ZLB		Post-ZLB	
	Change in		Change in	
	FFR	**FG**	**FG**	**LSAP**
Response of 10-year yields				
Australia	-9.9	-33.9***	-35.3**	-5.4***
China	13.3	28.9**	-7.3	0.3
Hong Kong	-31.9***	-42.2***	-44.7**	-4.6***
Indonesia	-69.8	-163.5*	-94.9***	-1.9
India	-23.4***	-20.6**	-24.9*	0.1
Korea	-27.3***	3.9	-32.4**	-2.5***
Malaysia	-4.6	-11.8	-18.7*	-1.9***
New Zealand	1.8	-9.2	-24.6	-3.5***
Philippines	-3	-26.6	-38.5	-1.9
Singapore	-4.2	-27.6***	-50.7***	-2.8***
Thailand	-19.5***	-4.3	-43.9*	-1.2
US	-20.4**	-54.4***	-34.6**	-7.5***

Notes: The Table reports the effects of each component of FOMC announcements on Asia-Pacific economies' 10-year yields; coefficient β_i in equation 4. In the pre-ZLB estimates, the two components of monetary policy announcements are changes in the federal funds rate (FFR) and forward guidance (FG). In the post-ZLB estimates, the two components of monetary policy announcements are changes in forward guidance and LSAPs. * ,** and *** denote statistical significance at 10%, 5% and 1%, respectively.

A.5. Data Sources

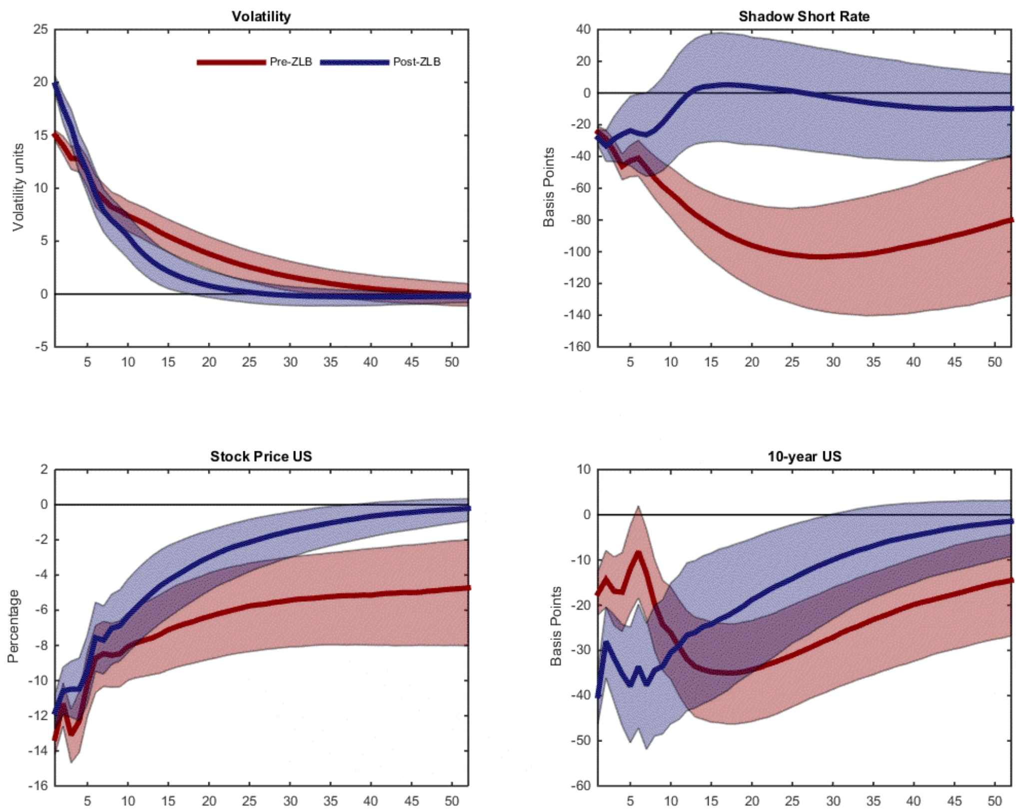
Name	Description	Source
GDP per capita	GDP per capita at current prices; in USD	IMF WEO
Current account	Net current account; in USD	IMF BOP
Current account to GDP	Ratio of net current account to nominal GDP	IMF
Foreign reserves	Foreign reserves	IMF IFS
Foreign reserves to GDP	Ratio of foreign reserves to nominal GDP	IMF
ST debt to foreign reserves	Ratio of short-term debt to foreign reserves.	BIS consolidated banking stats; IMF IFS
Financial openness	Ratio of the sum of total foreign asset and liabilities to nominal GDP	IMF
Gvt. 1Y	One-year government benchmark bid yield	Datastream
Gvt. 10Y	Ten-year government benchmark bid yield	Datastream
Equity index	Datastream equity index-price index	Datastream
Exchange rate	Exchange rate; domestic currency per USD	National sources
CF equity	Net equity flows	EPFR
CF bond	Net bond flows	EPFR
Moody's rating	Moody's long-term local currency sovereign rating	Moody's
CDS	Sovereign CDS spread	IHS Markit
Local currency debt	Ratio of the general government local currency gross debt to nominal GDP	IMF WEO

Figure A.1: Identification via External Instruments



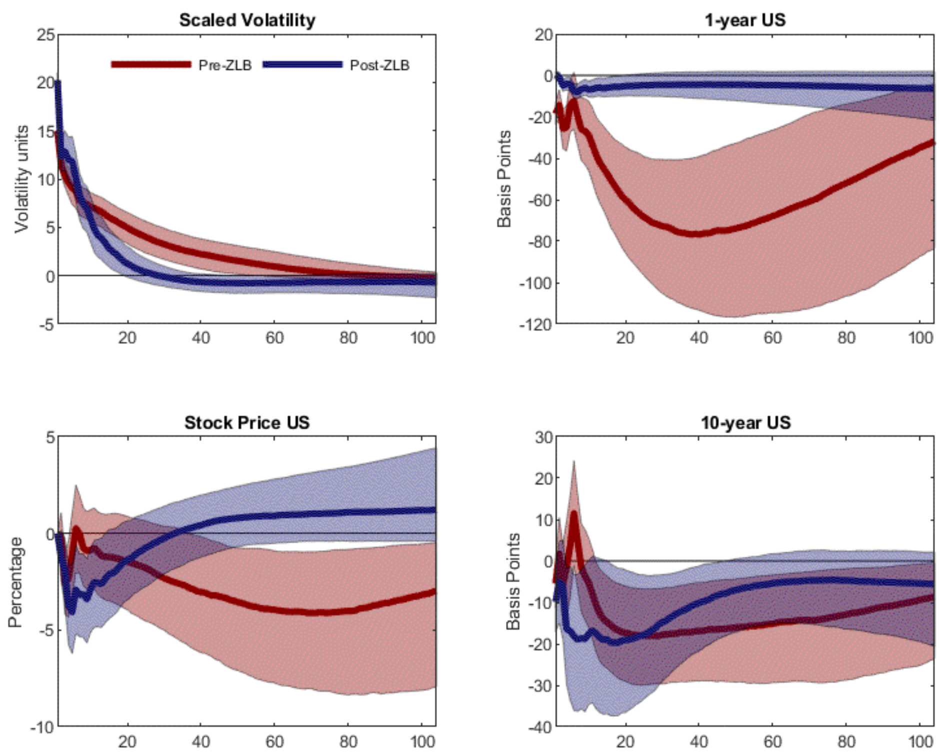
Notes: The figure shows impulse responses to a risk-off shock obtained from a structural VAR in which risk-off shocks are identified using external instruments. See text for details. The variables included in the VAR are the VIX index, the shadow short rate, 10-year US Treasury yield and the log of the S & P 500 index. The first subsample, labelled pre-ZLB, covers January 1999 to September 2008. The second subsample, labelled post-ZLB, covers April 2009 to December 2015. Red (blue) solid lines and shaded areas correspond to point estimates and one standard deviation confidence intervals. The impulse responses in the pre-ZLB sample are scaled so that the shock generates a 15 vols increase in VIX in the first subsample. The impulse responses in the post-ZLB sample are scaled so that the 12 week cumulative increase in the response of VIX is the same in both subsamples. The units of the vertical axes are vols for VIX, basis points for interest rates and percentage points for stock prices.

Figure A.2: The effets of risk-off shocks in US (Shadow Short Rate)



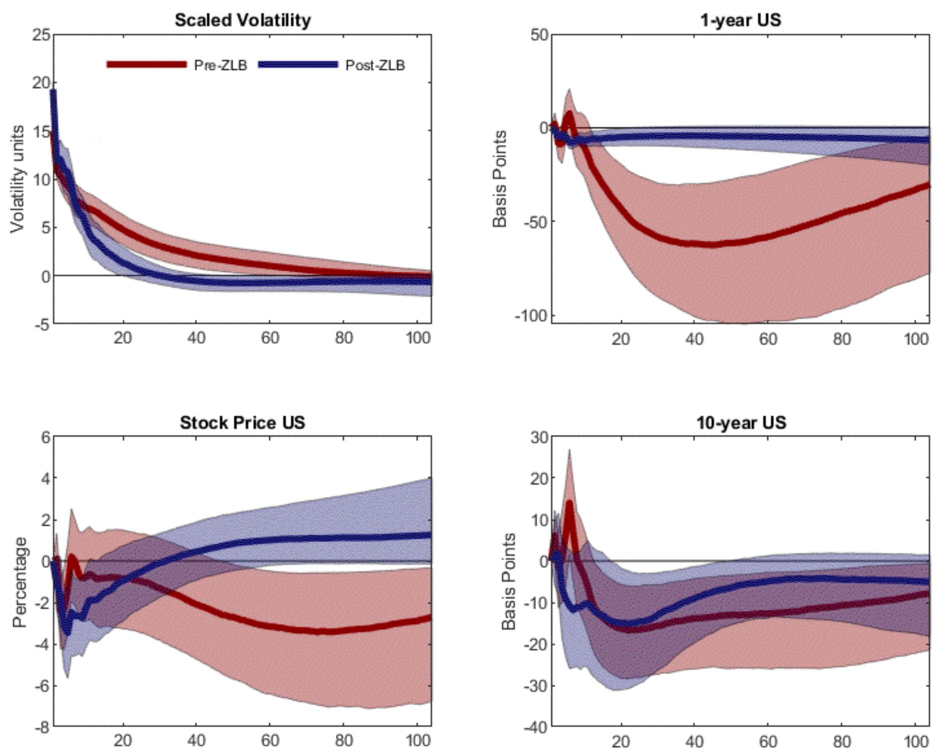
Notes: The figure shows impulse responses to a risk-off shock obtained from weekly VARs estimated for two subsamples. The variables included in the VAR are the VIX index, the shadow short rate, 10-year US Treasury yield and the log of the S & P 500 index. The first subsample, labelled pre-ZLB, covers January 1999 to September 2008. The second subsample, labelled post-ZLB, covers April 2009 to December 2015. Red (blue) solid lines and shaded areas correspond to point estimates and one standard deviation confidence intervals. The impulse responses in the pre-ZLB sample are scaled so that the shock generates a 15 vols increase in VIX in the first subsample. The impulse responses in the post-ZLB sample are scaled so that the 12 week cumulative increase in the response of VIX is the same in both subsamples. The units of the vertical axes are vols for VIX, basis points for interest rates and percentage points for stock prices.

Figure A.3: The effets of risk-off shocks in US- VIX ordered second



Notes: See notes to Figure 2.

Figure A.4: The effets of risk-off shocks in US- VIX ordered last



Notes: See notes to Figure 2.

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