The International Spillover Effects of US Monetary Policy Uncertainty*

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Abstract

An extensive literature studies the international transmission of US monetary policy surprises (shifts in expected path of the policy rate). In this paper we show that changes in uncertainty around the expected path constitute an important additional dimension of spillover effects to global bond yields. In advanced countries, it is the term premium component of yields that responds to uncertainty. We find that this can be explained by an international portfolio balance mechanism. In contrast, for emerging countries it is the expected component of yields that reacts to uncertainty. This can be rationalized from a flight to safety channel. We find heterogeneity in the country-level response to uncertainty only in emerging countries and it is driven by the degree of financial openness. Finally, equity markets in both advanced and emerging countries also respond to US monetary policy uncertainty.

Keywords: monetary policy uncertainty, international spillover, international portfolio balance, flight to safety

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1 Introduction

Recent work has highlighted the phenomenon of the global financial cycle and the crucial driving role of US monetary policy (Miranda-Agrippino and Rey (2015), Jordà et al. (2019)). The literature has documented a variety of transmission channels through which Federal Reserve actions affect international financial markets. However, most of the focus in the literature has been on transmission through changes in the level of the Federal Reserve's policy rate (i.e. first moment changes).[1] In this paper we show that changes in uncertainty around the level of the policy rate (i.e. second moment changes) constitute an important *additional* dimension through which Federal Reserve decisions transmit to international financial markets.

The importance of uncertainty as an additional dimension of FOMC announcements is readily seen from the Aug 2011 FOMC meeting. At this meeting the FOMC introduced explicit calendar-based forward guidance for the first time by saying that rates will be low until "...mid-2013". Commonly used measures of the first-moment monetary policy shocks (e.g. changes in futures rates up to 1 year ahead) did not move much in response to the announcement but the market-perceived uncertainty fell substantially. In this paper we conduct a systematic evaluation of how such FOMC-induced changes in uncertainty transmit to international financial markets.

To perform this analysis, we use an event-study framework around FOMC meetings with bond yield data for a panel of 31 advanced and emerging countries.[2] Our measure of monetary policy uncertainty is the recent one developed by Bauer et al. (2019). This measure relies on high frequency options data to calculate the market's perceived uncertainty; the conditional, risk-neutral 1 year ahead standard deviation of changes in the Federal Reserve's policy rate. We find that an increase in this market-based uncertainty raises bond yields in both advanced and emerging countries. This effect is over and above the effect of surprise changes in the expected policy rate, which is the most widely used measure of monetary shocks. In other words, uncertainty matters even after controlling for first moment shocks. While the average effect is moderate, we document that the international spillover through monetary policy uncertainty is larger when the Federal Reserve made deliberate changes to its forward guidance language in the FOMC statement. This suggests that by changing its communication about the uncertainty of its future actions, the Federal Reserve has an additional policy tool through

[1] Albagli et al. (2019), Gilchrist et al. (2019) and Curcuru et al. (2018) are some recent examples from this literature. There are also numerous papers that study the transmission of unconventional monetary policy actions and we discuss how our work relates to that literature below.

[2] While the primary focus is the response of global bond yields, we also show that global equity markets react considerably to monetary policy uncertainty.

which it can affect international financial conditions.[3]

What is the channel through which changes in US monetary policy uncertainty affect international bond yields? We find that there is a key difference in the mechanism through which monetary policy uncertainty is transmitted to yields in advanced versus emerging countries. In advanced countries, the response works through an international portfolio balance channel whereas for emerging countries it is related to a flight to safety channel. We perform a variety of analyses to better understand the differential transmission mechanisms.

First, we note that a standard asset pricing framework implies that the excess return of a long-term bond is a function of its conditional volatility (among other things). A change in the market's perceived uncertainty about future short rates is a clear signal about long-term bonds' conditional volatility. Thus an increase in uncertainty would imply that investors should demand a greater premium for holding long-term bonds. We document that changes in monetary policy uncertainty do indeed affect US bond yields through risk/term premia. This result is consistent with the recent work of Bundick et al. (2017) and Bauer et al. (2019).

Next, we decompose changes in international bond yields into an expected (or risk-neutral) component and a term premium component. This is done using the methodology of Joslin et al. (2011) and applying the bias correction of Bauer et al. (2012). Interestingly, we find that US monetary policy uncertainty affects bond yields in advanced countries only through the response of the term premium whereas the emerging country response is entirely due to changes in the expected component.

Taking up the advanced country response first, we show that the effect of monetary policy uncertainty on term premia in these countries works through changes in the term premium on the US 10 year Treasury bond.[4] Thus, the transmission channel runs from monetary policy uncertainty to US term premia and eventually to advanced country term premia. This mechanism is consistent with recent theoretical work on the so-called international portfolio balance channel, for example see Alpanda and Kabaca (2019). In this framework investors view bonds in different countries as imperfect substitutes for each other and this creates a link for changes in bond term premia in one country to affect those in another.[5] A key

[3] From a structural perspective, monetary policy uncertainty shocks can arise from variance of the residual of a policy rule or from uncertainty about the reaction function part of the policy rule. See Appendix Section A.1 for a detailed discussion.

[4] Specifically, in a regression of advanced country term premia on uncertainty, the coefficient on uncertainty is positive and significant. But when we control for the US 10 year term premium in this regression, the coefficient on uncertainty essentially goes to zero.

[5] The theoretical papers in this field do not explicitly focus on monetary policy uncertainty as the originating source for the transmission. However, the transmission mechanism is relevant as long as there is an effect through term premia. For example, Alpanda and Kabaca (2019) focus on the role of quantitative easing in driving term premia, while we are interpreting this effect coming from changes in monetary policy uncertainty.

implication from this framework is that the size of this spillover should directly depend on the degree of substitutability between the countries' bonds. We provide a test of this hypothesis by constructing an empirical measure of the degree of substitutability between the bonds of a foreign country with the US. This measure is similar to the recent work of de los Rios and Shamloo (2017) and related to the older idea of Frankel (1982). As expected, we find that bonds of advanced countries are viewed as more substitutable with the US. Importantly, and consistent with the theoretical framework, we find that the term premium response to uncertainty in a given country is larger if its bonds are more substitutable with the US.

These results also shed light on the driving force behind some recent empirical work in the literature on the international spillover of US financial markets. Two recent papers (Mehrotra et al. (2019) and Curcuru et al. (2018)) find that changes in US term premia have a stronger effect on yields in advanced countries relative to emerging countries, consistent with our results. Our work highlights that an important source of this transmission through term premia is driven by FOMC-induced changes in uncertainty.

US monetary policy uncertainty transmission to emerging countries works through a different channel than the one we highlighted for advanced countries. Changes in monetary policy uncertainty show up not in the term premium component of emerging country bonds, but rather the expected component. In other words, after an increase in uncertainty, markets expect that interest rates in emerging countries will rise. Using a local projections framework we confirm that the market reaction is correct; short rates in emerging countries do indeed rise and are higher a year after the shock. This response in emerging countries is tied to a flight to safety channel whereby an increase in uncertainty makes investors pull capital out of countries that are perceived to be risky. Using the Treasury's TIC monthly capital flows, we show that net holdings of emerging country (but not of advanced country) bonds decrease in response to monetary policy uncertainty shocks. Overall these results are consistent with the recent idea that capital flows in emerging countries are quite risk-sensitive (Kalemli-Ozcan (2019)).

The recent work of Rey (2013) suggests that the classic Mundell-Fleming "trilemma" may have morphed into a "dilemma", whereby flexible exchange rates do not insulate countries from financial spillovers unless there are additional restrictions on capital mobility. Kalemli-Ozcan (2019) argues that for emerging countries this is not quite the case, at least in response to first moment US monetary shocks. We find that the emerging country response to US monetary uncertainty is not related to the exchange rate regime, but rather to that country's financial openness. Specifically, the higher is the Chinn and Ito (2006) index of capital account openness, the larger is that country's response to uncertainty. We also investigate more broadly if there is heterogeneity across countries in their responsiveness to monetary policy uncertainty following the methodology of Iacoviello and Navarro (2019). For advanced countries, we do not find evidence of this. The usual country characteristics that are used in the literature to explain cross-country differences do not matter for reaction to monetary policy uncertainty.[6] For emerging countries we see somewhat more heterogeneity across countries but do not find much other than financial openness that can explain the responsiveness of yields.[7]

There are differences in the advanced and emerging country yield response over time. The advanced country response is relatively stable over our full sample from January 1995 to June 2019. But for emerging country bonds the responsiveness to monetary policy uncertainty is only prevalent in the period since the financial crisis. This suggests that in more recent years not only has the interconnectedness of global financial markets increased but shocks originating in one country are now being transmitted through new channels. These results highlight the need for exploring and incorporating these uncertainty-based transmission mechanisms in theoretical open economy macroeconomic models.

We also investigate the impact of US monetary policy uncertainty on international stock prices. An increase in US monetary policy uncertainty leads to a reduction in stock prices in both advanced and emerging countries, but only in the period since the financial crisis.[8] For both advanced and emerging countries, stock markets respond more to uncertainty in the post-crisis sample.

For long term yields and equity prices in both advanced and emerging countries, the size of the response to monetary policy uncertainty is larger than the response to the conventional first moment policy surprises.[9] Moreover, accounting for changes in the second moment is important even if one is only interested in the first moment effect of international spillovers. Leaving out changes in monetary policy uncertainty in the event-study regression biases the estimated effect of monetary policy surprises. This is because there is a positive correlation between changes in the first and second moment. Our estimates suggest that omitting uncertainty can lead to overstating the effects of monetary policy surprises by up to 50%.[10] Moreover, we

[6]Our baseline variables include financial depth, exchange rate regime, trade openness, capital account openness and the short-term interest rate differential with the US. We also attempted specifications using trade with the US and dollar debt exposure.

[7]Consistent with our results, Bowman et al. (2015) find that financial vulnerability (including capital account openness) is one of the main determinants of yield responses.

[8]This result confirms a general pattern that is consistent with the investigation of Indian stock markets carried out in Lakdawala (2018), where they attribute the increased responsiveness to the growing role of foreign institutional investors in domestic equity markets.

[9]For shorter maturity yields, relative to the first moment policy surprise, the uncertainty effect is somewhat smaller in advanced countries and roughly the same size in emerging countries.

[10]Our uncertainty measure is a risk-neutral measure and thus (as we explain below) the 50% estimate may be better viewed as an upper bound.

document substantial increases in R^2 when adding uncertainty to the event-study regressions. Thus we argue that leaving out monetary policy uncertainty gives an incomplete picture of the transmission of Federal Reserve actions to international financial markets.

Our paper builds on the work of Bauer et al. (2019) that develops the measure of monetary policy uncertainty used in our paper. The main focus in Bauer et al. (2019) is on exploring how uncertainty is related to forward guidance language used by the FOMC and its transmission to domestic financial markets in the US. In this paper we focus on the international transmission of changes in uncertainty to bond and stock markets in a large set of advanced and emerging countries.

There is also a substantial literature that focuses on the international effects of unconventional Federal Reserve actions, e.g. see Anaya et al. (2017), Bhattarai et al. (2015), Bowman et al. (2015), Neely (2015), Fratzscher et al. (2018), and Kolasa and Wesołowski (2020). We show that the transmission of uncertainty is not altered on FOMC meeting dates with notable quantitative easing announcements. There is a view that attributes quantitative easing announcements as working through a signal about the future expected path of the policy rate, the so-called signalling channel (Bauer and Rudebusch (2014) and Bauer and Neely (2014)). Our results suggest that signals about the uncertainty around future rates are an additional and largely unexplored dimension of unconventional monetary policy transmission.

In addition to the literature that studies the effects of US monetary policy on asset prices (e.g. Albagli et al. (2019), Gilchrist et al. (2019), Curcuru et al. (2018), Ehrmann et al. (2011) and Hausman and Wongswan (2011)), there is also a large literature exploring the effects on capital flows (e.g. Kalemli-Ozcan (2019), Dahlhaus and Vasishtha (2014), Chari et al. (2020)). But this literature estimates the effect of changes in the *level* of the Federal Reserve's policy rate. We extend this literature to consider the international spillovers of changes in US monetary policy *uncertainty*.

While there is also a growing literature studying the international spillover effects of overall US uncertainty (see for example Bhattarai et al. (2019) and Carrière-Swallow and Céspedes (2013)), few papers have explored the international transmission of monetary policy specific uncertainty. On the empirical front, Lakdawala (2018) shows that the effect of US monetary policy uncertainty on the Indian stock market has grown since the financial crisis. Gupta et al. (2020) study uncertainty spillovers between a sample of nine advanced countries using the measure of Istrefi and Mouabbi (2018), which primarily captures disagreement among professional forecasters. A related theoretical work is Ghironi and Ozhan (2019), which investigates the impact of shocks to the variance of the domestic country's policy rate. Our emerging country results are broadly consistent with their framework.

2 US Monetary Policy Shocks

An increasingly common approach in the literature to measure US monetary policy shocks is to use changes in futures rates around FOMC announcements.[11] This measure is a first moment shock that captures surprise changes to the expected path of the FOMC's policy rate. The main contribution of this paper is to show that a second moment shock (i.e surprise changes to the uncertainty around the expected path of the FOMC's policy rate) also has substantial spillover to international financial markets. In Appendix Section A.1 we frame monetary policy uncertainty through the lens of a simple structural monetary policy rule. There we show that monetary policy uncertainty can come from variance of the residual in the monetary policy rule and also uncertainty about the reaction function part of the policy rule. Next, we detail the construction of this shock from option prices and provide a discussion of how prominent changes in our measure are related to specific changes in the forward guidance language used by the FOMC. While the focus will be on the transmission of this uncertainty measure, we also include the traditional first moment shock because, as we discuss below, the two measures are correlated.[12]

2.1 Monetary Policy Uncertainty

To construct the monetary policy uncertainty (mpu) measure, we use the methodology of Bauer et al. (2019). The object of interest is the standard deviation of the federal funds rate τ-periods ahead conditional on the current information at time t, i.e. $\sqrt{Var(FFR_{t+\tau}|\mathcal{I}_t)}$. The methodology provides a model-free estimate of the risk-neutral conditional standard deviation, given prices of futures and options at time t. Our baseline measure will set τ to 12 months to measure the uncertainty about the 1 year ahead rate. The change in this measure is calculated in a two-day window around the FOMC announcement. We scale our measure to have unit standard deviation.

We refer the reader to Appendix Section A.2 for the details of the construction of the uncertainty measure. Here we provide a brief discussion of the relevant empirical properties and also what drives the big changes in our measure. Figure 1 plots our baseline measure: the change in the standard deviation of the 1 year ahead expected rate in a two day window around the FOMC announcement. We label this measure mpu in the regression analysis that follows.

[11] For example see the early work of Kuttner (2001). For more recent work see Nakamura and Steinsson (2018).

[12] We view our approach of separately studying the second moment shock transmission as complimentary to the large literature that studies the overall effect of both conventional and unconventional monetary policy actions.

On average, our measure declines on FOMC days: the average is -0.49 standard deviations (2 basis points) and is statistically significant with a p-value less than 0.01. In other words, the FOMC announcement leads to a resolution of uncertainty on average. But there is also a fair amount of variation across individual FOMC dates, with some large declines and even some large increases.

Importantly, there is typically a direct relation between a specific change in the forward guidance language used by the Federal Reserve and changes in our measure. To aid in interpretation, the figure labels the three biggest falls and three biggest increases and provides a snippet from the FOMC statement or related market coverage that helps understand these episodes. For example, the biggest fall in our sample is in December 2008, where the FOMC cut rates to reach the zero lower bound. But in addition to this rate cut, there was explicit forward guidance language ("... warrant exceptionally low levels of the federal funds rate for some time") that signaled to the market that low rates were here to stay. The second biggest fall is in August 2011. Prior to this meeting, the FOMC statement contained a phrase that rates would be kept low *"...for an extended period"*. At the August meeting, the FOMC explicitly changed the language to signal that rates would be kept low *"at least through mid-2013"*, the start of so-called "calendar-based forward guidance". Markets clearly interpreted this as a sign that rates would indeed stay low and revised downwards their uncertainty about future rates. Another date labeled on the figure is January 29, 2004. At this meeting there was a change in the language to "*can be patient in removing its policy accommodation*" from the previous statement which said "*accommodation can be maintained for a considerable period*". The market interpreted this as increasing uncertainty about when rates would eventually increase.

In Section 4.2 below we discuss that changes in uncertainty are positively correlated with first-moment surprises. But the biggest changes in uncertainty do not always coincide with surprises about the policy path, and vice versa. For example, among the four announcements with the largest changes in uncertainty, two of them (in October 2008 and December 2008) also led to substantial first-moment surprises, whereas the other two (in August 2011 and November 1998) caused only modest ones. Moreover, we find that our measure of uncertainty (but not the first-moment shock) is positively correlated with changes in the dispersion of survey forecasts. In Appendix Table A.1, we show this using data from the Survey of Professional Forecasters (SPF) and the Summary of Economic Projections (SEP).

Overall, our narrative evidence suggests that Fed communication has important effects on perceived monetary policy uncertainty and that these changes in uncertainty are often a separate dimension of the Fed's policy actions. We will systematically evaluate how these changes in market-perceived uncertainty about the future rate caused by FOMC announcements is transmitted to international financial markets and document that they indeed constitute an important additional dimension of FOMC actions.

2.2 Monetary Policy Surprise

As mentioned above, we also consider the well-known measure of a first moment monetary policy shock. This is because surprises to the expected path of policy rates (i.e. mps) are positively correlated with changes in uncertainty about future rates (mpu), as can be seen in Appendix Figure A.1. Thus to isolate the effect of monetary transmission through changes in the second moment we need to control for changes in the first moment. We do that in our analysis by using the following first moment measure, labeled *mps* or MP Surprise. This shock is calculated as the change in the futures price in a window around the FOMC meeting. Let e_t represent the monetary shock and ε represent the length of the window, then $e_t^{(h)} = p_t^{(h)} - p_{t-\varepsilon}^{(h)}$ where $p_t^{(h)}$ is the price of a futures contract at time t that matures in $t + h$. As with *mpu* our baseline measure uses a two-day window. We use four Eurodollar futures contracts, expiring 1 quarter ahead (ED1) to 4 quarters ahead (ED4).[13] Taken together, the four contracts contain rich information about the short and medium term path of expected interest rates. To summarize this information in a parsimonious way we perform a principal component analysis. The first principal component of the 4 futures price changes explains more than 90% of the total variation across all the contracts. We therefore use this first principal component as one of our measures of monetary policy shocks. This is essentially identical to the measure used in Nakamura and Steinsson (2018). Since the scale of this principal component is arbitrary, we normalize our measure to have a one standard deviation effect on the 1 year ahead rate.

One issue worth noting for both measures of monetary policy shocks is that the underlying interest rate for Eurodollar futures is the three month LIBOR rate. LIBOR typically trades at a spread over the federal funds rate; thus, our monetary shock measures capture not only changes in the first and second moments of the future policy rate but also changes owing to the time-varying spread. The difference between LIBOR and the fed funds rate is best measured by the LIBOR-OIS spread. Other than the period around the financial crisis of 2007-2009, this spread has been low, and crucially, stable. Moreover, as we discuss in the section on robustness checks below (Section 4.6) the results are unchanged when we control for this spread in the regression analysis.

[13] In Section 4.6 we show that our results are robust to using longer-horizon measures of *mps*.

3 Data

Next, we describe the data used to measure the international spillover of US monetary policy. Our primary outcome measures are international asset prices: 2 year and 10 year government bond yields, equity prices and exchange rates vis-à-vis the US. We collected this data from Bloomberg for 28 advanced countries and 16 emerging market countries between January 1995 and June 2019, where available. The data availability varies by country.[14] Appendix Table A.2 details the data coverage for our international asset price data and the classification of countries. We will focus on two day changes around FOMC announcements. We use two day changes to allow for all international asset markets to respond to US monetary policy shocks.[15] The two day change is calculated as the difference between the closing price one day after and one day before an FOMC announcement. Some markets are open when FOMC announcements are made while others are not. We account for these country-specific timing differences when calculating the two day changes. Below, we also show that our results are robust to using a narrower one day window.

For constructing both of our US monetary policy shocks, we use daily Eurodollar futures data and daily Eurodollar options data which are from the Chicago Mercantile Exchange. For US data, the treasury yields are zero-coupon yields from Bloomberg and the S&P 500 return is from Yahoo Finance.

3.1 Summary Statistics

Table 1 reports summary statistics for the key variables of interest. Panel (a) contains our measures of monetary policy surprise and monetary policy uncertainty. The full sample includes 204 FOMC announcements from January 1995 to June 2019.[16] To aid in interpreting the regressions coefficients, we normalize the two monetary policy shocks in the following way. The monetary policy uncertainty measure is standardized to have unit standard deviation. Since the monetary policy surprise measure is calculated using a principal component analysis, its scale is arbitrary; thus, we normalize it to have an effect on the 1 year ahead futures

[14] We have data on exchange rate and stock prices for 28 advanced countries and 16 emerging countries. For government yields we have data for 22 advanced countries and 8 emerging countries.

[15] This is consistent with the recent literature that uses two-day changes (Albagli et al. (2019) and Hanson and Stein (2015)) and is based on the idea that since FOMC meetings happen at 2:15 pm, using daily changes does not give markets enough time to react before close.

[16] We exclude the 9/17/2001 announcement following the 9/11 terrorist attacks and the 5/2/2018 announcement due to a lack of asset data availability. The 10/8/2008 announcement is excluded because many other central banks took joint action on that date, making it impossible to isolate the effect of US monetary policy. The 5/22/2013 "taper tantrum" episode is excluded as well, as it was driven by a speech by the Chairman rather than an FOMC announcement.

rate equal to one standard deviation. Panel (b) presents summary statistics for exchange rate return, stock return, and changes in 2 and 10 year government bond yields for the advanced and emerging countries in our sample, calculated in a two day window around FOMC announcements.

4 Results

In this section we present the main results that show the spillover effects from changes in US monetary policy uncertainty to international asset prices. To establish a benchmark, we first document the response of US asset prices to monetary policy uncertainty changes. In Section 4.2 we present our main results for international bond yields, followed by an investigation of the mechanism behind our baseline results in Section 4.3. Next, we provide a discussion of the heterogeneity in the country-level responses in Section 4.4. This is followed by results on the response of international equity markets in Section 4.5 and we conclude with robustness checks in Section 4.6.

4.1 Response of US asset prices to US monetary policy uncertainty

We study the response of 2 and 10 year Treasury bond yields and the S&P 500 return. The two monetary policy shocks detailed in Section 2 are i) monetary policy surprise (mps_t) which measures surprise changes in the expected path of the policy rate and ii) monetary policy uncertainty (mpu_t) which measures surprise changes in the uncertainty around the expected path, both for the 1 year horizon. As mentioned above, both measures have been scaled to reflect a one standard deviation effect. For each asset, we calculate the change in a two-day window, labeled (y_t). We estimate the following regression equation:

$$y_t = \alpha_0 + \alpha_1 mps_t + \alpha_2 mpu_t + \varepsilon_t \tag{1}$$

The results are presented in Table 2 with heteroskedasticity-robust standard errors in parentheses. The top panel shows the results for the full sample that runs from January 1995 to June 2019. The middle panel shows a pre-crisis sample from January 1995 to November 2007 and the bottom panel shows the post-crisis sample from December 2007 to June 2019. The first row shows the well-known effect of monetary policy surprises on US financial markets. A contractionary surprise lowers stock prices and raises both 2 and 10 year yields.[17] Results for

[17] The response of the stock price to mps is smaller and less significant than Bernanke and Kuttner (2005). This result in the more recent sample is due to our use of daily futures data as also noted by Lakdawala and Schaffer (2019).

the two samples are quite similar with somewhat smaller effects in the post-crisis sample.

The second row shows the response to monetary policy uncertainty shocks. An increase in monetary policy uncertainty lowers stock prices and raises long-term bond yields, but not short-term yields. For the full sample, the response of the 10 year yield is significant (at the 1% level) but the stock market and 2 year yield responses are not. Qualitatively, the effects of an increase in uncertainty have similar effects to a contractionary monetary policy surprise. In terms of magnitude, the response to a one standard deviation increase in *mpu* is about half the size of *mps* for stocks and 10 year yields. For example the 10 year yield increases by 4 basis points (0.3 standard deviations) in response to a one standard deviation increase in *mpu*. Finally, the effect of *mpu* strengthens in the post-crisis sample. In the pre-crisis sample *mpu* only has a statistically significant effect on 10 year yields. But in the post-crisis sample, stock returns and 10 year yields respond significantly to *mpu*, with a rise in the size of the effect as well. These results of the additional effect of *mpu* on US financial markets are consistent with those documented in Bauer et al. (2019). We now turn our attention to the main focus of this paper: the spillover effects of *mpu* to international financial markets.

4.2 Response of international bond yields to US monetary policy uncertainty

The common event-study approach in the literature involves regressing an asset price on the monetary policy shock measure in the event window. For studying the international spillover this would translate to the following panel regression

$$y_{i,t} = \delta_0 + \delta_1 mps_t + \nu_{i,t} \tag{2}$$

where $y_{i,t}$ is the two-day change in asset price of country i on date t, with the monetary shock measured by the so-called monetary policy surprise measure (*mps*) in a window around the FOMC announcement. *mps* typically measures surprise changes in the expected path of the policy rate. The main goal of this paper is to evaluate the response to changes in monetary policy uncertainty. To do this we augment the above specification by adding *mpu*, which measures surprise changes in the uncertainty around the expected path. The regression takes the following specification[18]

$$y_{i,t} = \beta_0 + \beta_1 mps_t + \beta_2 mpu_t + \varepsilon_{i,t} \tag{3}$$

[18] As we discuss in the section on robustness checks (Section 4.6), adding country fixed effects to this baseline specification does not change our results.

where $y_{i,t}$ is the two-day change in the 2 or 10 year bond yield around the FOMC meeting on day t for country i. As discussed in Section 2, both monetary shock measures are calculated for a 1 year horizon and have been scaled to reflect a one standard deviation effect. We also standardize the international bond yields to have unit standard deviation within each country.[19] Since our variables are measured within a relatively tight window around FOMC days, we make the assumption that the FOMC announcement is the primary driver of asset prices in this window. This assumption is commonly used in the event-study literature. While our baseline window is a two-day window following Hanson and Stein (2015) and Albagli et al. (2019), we show in Section 4.6 below that our results are robust to using a one-day window.

For our main specification we separate the countries into two groups: advanced and emerging market countries.[20] Table 3 reports the regression coefficients with the advanced country results in the top panel and emerging country results in the bottom panel. Standard errors reported in parentheses are two-way clustered along the country and time dimension. In column (1) we estimate Equation 2 with only *mps* as the regressor to document that monetary policy surprises have a statistically significant and economically meaningful impact on international yields in both advanced and emerging countries. A contractionary monetary policy suprise in the US raises bond yields around the world. This result is well established in the literature for both advanced and emerging countries, e.g. see Hausman and Wongswan (2011), Gilchrist et al. (2019) and Albagli et al. (2019).

The second column in each panel adds *mpu* to the regression and shows our first set of main results. For both advanced and emerging countries, the *mpu* shock has a statistically and economically significant effect on 2 and 10 year bond yields. An increase in monetary policy uncertainty raises global bond yields even after controlling for the conventionally used first-moment shock (i.e. *mps*). This effect is bigger for 10 year yields compared to 2 year yields and is also bigger for advanced countries relative to emerging countries. A one standard deviation increase in *mpu* raises 10 year yields in advanced (emerging) countries by .264 (.171) standard deviations.[21] At the long end of the yield curve, *mpu* has a bigger effect than *mps*, while at the shorter end the *mps* effect is larger. Additionally, for advanced countries, an increase in monetary policy uncertainty raises 10 year yields by roughly twice as much as 2 year yields, but for emerging countries the response of 2 and 10 year yields is essentially the same.

While the average effect of *mpu* on international bond yields is moderate, we show that

[19]This is done because there is substantial heterogeneity in the standard deviation of yield changes across countries in our sample. This can be seen in Appendix Figure A.2.

[20]We have yield data for 22 advanced and 8 emerging countries. See Appendix Table A.2 for details on the sample countries.

[21]This amounts to a 2 basis point rise in advanced and 3 basis point rise in emerging countries.

this can amount to a substantially larger role for *mpu* in driving bond yields on days with big changes in *mpu*. Moreover, the effect of *mpu* dwarfs the *mps* effect on these days. As we discussed in Section 2.1, the big changes in *mpu* occur when the Federal Reserve willfully chose to make notable changes to the forward guidance language used in the FOMC statement. To study the yield response on these "prominent" dates, we isolate the ten FOMC dates with the largest increase in *mpu* and the ten FOMC dates with the largest decrease in *mpu*. We then average the total change in 10 year bond yields on these dates and compare to the average predicted component due to *mpu* and that due to *mps*, based on the coefficients estimated in Equation 3.[22] Figure 2 plots this separately for advanced and emerging countries. For advanced countries, the white bar shows that yields fall (or rise) by about one standard deviation (8 basis points) on these dates. *mpu* (gray bar) accounts for nearly half of this change on days with large increases in *mpu* and nearly all of the change on days with large decreases. In contrast, *mps* (black bar) accounts for less than one quarter. For emerging countries, the pattern is similar: *mpu* accounts for a lion's share of the change in bond yields on these 20 dates. From the 15 basis point fall in emerging yields, roughly three-quarters is due to *mpu*. Thus, Federal Reserve actions that affect the market's perceived uncertainty about future rates can have substantial effects on global yields. The implication is that the Federal Reserve has an additional tool in its arsenal to affect international financial conditions, one which has scarcely received any attention in the literature.

To contextualize the magnitude of the *mpu* spillover, we estimate the effects of "news shocks" around major US macroeconomic data releases.[23] Table 4 shows that retail sales shocks have a statistically significant effect on advanced country 2 and 10 year yields, and that CPI shocks have a significant impact on 2 year yields. Importantly, the yield response is much larger for the monetary policy shocks, as a one standard deviation change in *mpu* has an effect on international bond yields that is at least one order of magnitude higher than the effect of news shocks. Furthermore, the table also shows that none of the news shocks have a statistically significant effect on emerging country yields. These results highlight the unique impact of US monetary shocks on international yields.

We also check if the effect of *mpu* on international asset prices is driven by specific announcements about large scale asset purchases (quantitative easing or QE). Table A.3 shows

[22] In Appendix Figure A.3 we show numbers for each of the 20 FOMC meetings individually.

[23] We collect data on five news announcements in the US: employment, GDP, CPI, PPI, and retail sales. For each news release, the surprise component, or "shock", is calculated as the difference between the actual released number and the consensus forecast from Action Economics/Money Market Services. For the employment report, we use non-farm payrolls, for CPI and PPI we use headline inflation, retail sales are the total sales including automobiles and GDP is the advance GDP release. We scale the news shocks to have unit standard deviation so that the size of the coefficient can be directly compared to the *mpu* coefficient.

the baseline regression from Equation 3 where we have added a QE dummy along with its interaction with *mps* and *mpu*. The QE dates are taken from Fawley et al. (2013). The results show that yields in advanced countries do not respond differently to *mpu* on these dates and there is some weak evidence that the effects of *mpu* are stronger for 10 year yields in emerging countries. More importantly, the baseline effect of *mpu* on yields on non-QE dates stays roughly the same in terms of economic size and statistical significance. There is a debate in the literature on whether QE transmits through the signaling channel (Bauer and Rudebusch (2014)). Our results suggest that QE can also transmit through an "uncertainty signalling channel", whereby signals about uncertainty regarding future rates have an effect on financial markets. In Section 4.6 we also show that excluding the zero lower bound period does not materially affect our results.

Next, in Section 4.3 below we investigate the mechanisms driving the international yield response to monetary policy uncertainty, including differences across countries and across maturities. But first, we document that there have been some important changes over time in the transmission of *mpu* to international asset prices, especially for the emerging countries.

Appendix Table A.4 and Table A.5 report estimates for the baseline specification from Equation 3, splitting the full sample into a pre-crisis sample that runs from January 1995 to November 2007 and a post-crisis sample from December 2007 to June 2019. For our split sample results, we perform the standardization of our variables based on the split sample standard deviations. For advanced countries, the yield response is roughly similar across the samples, with a slightly larger response of the 10 year yield in the post-crisis sample. For emerging countries, however, a different picture emerges. The significant response of emerging yields to *mpu* in the full sample is driven entirely by the post-crisis sample. Specifically, the yield response is insignificant and essentially zero in the pre-crisis sample but larger in magnitude and strongly significant in the post-crisis sample. We discuss below in Section 4.4 that this can partially be explained by the average increase in capital account openness in emerging countries over the full sample.

We also investigate the dynamic response of bond yields using a local projection framework (Jordà (2005)). These results are presented in Appendix Figure A.4. While 2 and 10 year yields remain elevated in both advanced and emerging countries after the monetary policy uncertainty shock, the standard errors get large after around a month. This makes sense as there is more background noise (i.e. other events that drive yields) as the horizon gets longer. Thus, in this paper we focus on the precisely estimated higher frequency impact.

Table 3 also shows that accounting for *mpu* is crucial in assessing the transmission of FOMC actions to international bond yields, even if one is only interested in the conventional monetary policy surprises (*mps*). Leaving out *mpu* biases both the coefficient estimate of the yield response to *mps* and the unconditional mean, as can be seen by comparing the *mps* coefficient and the intercept in columns (1) and (2). This can be easily understood from a basic omitted variable analysis. Column (1) estimates the specification from Equation 2 with *mpu* being the omitted variable. The key point is that *mps* (i.e. surprises to the expected path of policy rates) is positively correlated with *mpu* (i.e. changes in uncertainty about future rates). We document this correlation in Appendix Figure A.1. This correlation results in an upward bias because the sign of the correlation between the dependent variable and *mpu* is the same as that between *mps* and *mpu* (both correlations are positive, as can be seen from the table). The table shows that leaving out *mpu* overstates the *mps* effect by roughly 50%.[24]

In addition to biasing the coefficient on *mps*, omitting *mpu* also affects the estimate of the intercept. Estimates of the intercept term from column (1) are negative and significant for both yields and both sets of countries. This systematic average decline is at odds with the assumptions of the event-study framework where changes in asset prices around FOMC meeting should be unpredictable. However, once we add *mpu* to the regression, the intercept term becomes effectively zero and statistically insignificant. This is driven by an average decline in *mpu* documented in Figure 1. Thus leaving out *mpu* means that the average fall in *mpu* is soaked up in the intercept, making it turn negative.[25]

Yet another way to see the importance of accounting for uncertainty changes is by comparing the R^2 in the two columns. There is a substantial increase in R^2 with the addition of *mpu*, especially at the longer end of the yield curve. For example the R^2 for emerging country 10 year yields increases from 0.036 to 0.06.

Thus our results suggest that the literature on the spillover effects has likely *overestimated* the effect coming purely through monetary policy surprises (first-moment shocks) while *underestimating* the total effects of US monetary policy actions which also work substantially through second-moment (or uncertainty) changes.

[24] Since *mpu* is a risk-neutral measure it captures both the quantity and price of uncertainty. If *mps* shocks drive risk-aversion (or risk compensation) in financial markets including option prices and *mpu*, our methodology of controlling for *mpu* would be under-estimating the true *mps* effect. On the other hand it seems reasonable to expect that uncertainty or *mpu* shocks (and not *mps* shocks) are more likely to affect risk-aversion. Since estimating the risk-aversion response is out of the scope of this paper, we caution the reader here and recommend viewing the 50% estimate as an upper bound. Regardless, this issue is not crucial for interpreting the effects of *mpu* since we always control for *mps* when reporting estimates of *mpu*.

[25] To make this clear, consider decomposing mpu_t into a constant and time-varying term, $mpu_t = \mu_{mpu} + \varepsilon_{t,mpu}$. If the true model is Equation 3 but *mpu* is omitted from the regression, then the residual will soak up $\beta_2 * \varepsilon_{t,mpu}$ and the intercept will soak up the term $\beta_2 * \mu_{mpu}$ which is negative since $\beta_2 > 0$ and $\mu_{mpu} < 0$.

4.3 Understanding the response

What explains the response of international bond yields to changes in US monetary policy uncertainty? In this section, we provide evidence that an international portfolio balance channel is primarily responsible for transmission to advanced countries whereas a flight to safety channel is likely driving the emerging country response.

We start by discussing the mechanism through which *mpu* affects bond yields domestically in the US. There is a clear risk-based explanation for the transmission mechanism. Standard asset pricing theory implies that expected excess returns depend on the negative covariance of returns with the stochastic discount factor. One factor driving this covariance is the uncertainty about future returns, as can be seen by rewriting the covariance in terms of the correlation and the standard deviations:

$$\begin{aligned} E_t R_{t+1} - R_t^f &= \frac{Cov_t(-M_{t+1}, R_{t+1})}{E_t M_{t+1}} \\ &= \frac{Corr_t(-M_{t+1}, R_{t+1})}{E_t M_{t+1}} \sigma_t(M_{t+1}) \sigma_t(R_{t+1}) \end{aligned}$$

Since changes in *mpu* are a clear signal about the conditional volatility of bond returns ($\sigma_t(R_{t+1})$), then higher short-rate uncertainty should raise term/risk premia.In earlier work, Bauer et al. (2019) and Bundick et al. (2017) show that changes in *mpu* do indeed transmit to US bond yields through changes in term premia. In Appendix Table A.6 we document this effect using the different term premium estimates of Joslin et al. (2011), Adrian et al. (2013) and Kim and Wright (2005). For all three measures, the table shows that an increase in uncertainty raises term premia on US bond yields.[26]

Next, we study whether *mpu* affects the term premia even in global yields. We apply the methodology of Joslin et al. (2011) to carry out the decomposition into an expected component and term premium component.[27] Table 5 shows the results where we use the same specification from Equation 1 now separately using the expected component and term premium component as the dependent variables.[28]

For advanced country yields, the response to *mpu* is entirely due to the response of the term premium with no response of the expected component. However, for emerging country

[26]While our results about the role of uncertainty for term premia are evident, we cannot rule out that the uncertainty about the stochastic discount factor or the correlation between future returns and the stochastic discount factor could also be important.

[27]Since we have only zero-coupon yield data from Bloomberg, it is not straightforward for us to implement the alternative procedures in the literature, for example the measure of Adrian et al. (2013).

[28]Note that while *mps* and a constant are included in the regression, the coefficients are left out for space considerations.

yields, this pattern is reversed. The response to *mpu* is not driven through the term premium but rather through changes in the expected component. In other words, in response to changes in monetary policy uncertainty, the market does not expect that central banks of advanced countries will respond by changing their own policy rates; however, they do expect that central banks of emerging countries will. Moreover, markets react in a way that suggest their perception of the term premium for holding advanced country bonds has changed but not for emerging country bonds.

Since we are studying the response of bonds denominated in local currencies, we might expect movement in the exchange rate to be playing a role. Table 6 shows the response of the exchange rate to *mps* and *mpu* for our full sample. The exchange rates are in units of foreign currency per US dollar and thus an increase represents a depreciation of the foreign currency relative to the US dollar. As documented in the literature a contractionary *mps* leads to an appreciation of the U.S dollar relative to both advanced and emerging countries (e.g. see Hausman and Wongswan (2011)). However, we again note that including *mpu* in the regression lowers the estimated effect of *mps*. More importantly, we notice that an increase in *mpu* depreciates currencies of emerging countries but not those of advanced countries. The advanced country response is consistent with the results of Gilchrist et al. (2019) who find a substantial effect of US monetary policy on dollar-denominated sovereign bonds. They label this channel the "financial spillover" channel. In the next section, we provide a more detailed discussion and evidence for understanding the specifics of the *mpu* spillover to advanced countries. For emerging countries, we document below that this result is consistent with the recent framework of Rey (2013), where even exchange rates being "flexible" does not insulate the country from the financial spillover. However, we show countries with more capital account restrictions respond less. This discussion is presented in Section 4.3.2.

4.3.1 Response in advanced countries

Why does the bond term premium of advanced countries (but not emerging ones) respond to *mpu*? We provide evidence for an international portfolio balance channel whereby *mpu* transmits through changes in the term premium on US bonds to term premia of foreign country bonds; but only for the bonds of countries that are considered substitutes for US bonds.

We first show that *mpu* transmission to term premia in advanced countries is driven primarily through the effect of *mpu* on *US* bond term premia. To do this we take the specification reported in Panel (a) of Table 5 (i.e. our baseline regression from Equation 3 but with the term premium as the dependent variable) and control for the change in the term premium on the

US 10 year bond. Then we compare the coefficient on *mpu* from this specification (reported in Panel (b) of Table 5) to one without the US 10 year term premium (reported in Panel (a)). If there is no change in the *mpu* coefficient from Panel (a) to (b), then we can conclude that none of the *mpu* effect is working through US term premium changes. On the other hand, if the coefficient goes to zero, then we can conclude that the *mpu* effect is working through US term premium changes. The table shows that controlling for the US term premium has a significant effect on the term premium response to *mpu*, but only for advanced countries. Specifically, the *mpu* coefficients that govern the term premium response of emerging countries are essentially unchanged: they remain close to zero and statistically insignificant. But for advanced countries, the *mpu* coefficient of the 10 year term premium response, which was substantial (0.24) and strongly significant, drops to close to zero (0.07) and is not statistically significant. The same pattern holds for the 2 year term premium response. This is suggestive evidence that changes in monetary policy uncertainty that drive term premia in US bonds also transmit to term premia in international bonds as well, although only in advanced countries.

Why do term premia in advanced countries respond to *mpu*-driven changes in the US term premium but term premia of emerging countries do not? There is not much theoretical work in the literature on the spillover effects through US monetary policy uncertainty.[29] The theoretical paper closest to our empirical work that explicitly studies this topic is the recent work of Ghironi and Ozhan (2019). However, in their paper they study only the spillover of monetary policy uncertainty to emerging countries and allow the international trade of short-term securities only. Thus there is no clear implication from their model for the differential response of long-term yields in emerging versus advanced countries. However there is a much larger literature that studies the spillover of US unconventional monetary policy, see Bhattarai and Neely (2016) for a recent survey. A common theme in this literature is that US unconventional monetary policy affects the term premium on US bond yields and also has effects on international bond yields. More specifically, the recent DSGE model of Alpanda and Kabaca (2019) that features an international portofolio balance channel is especially relevant for understanding our empirical results. They take the portfolio balance channel that features imperfect substitutability between bonds of different maturities and extend it to have imperfect substitutability between domestic and foreign bonds. A prediction from this framework is that term premium changes in the US should affect term premia in foreign countries based on how substitutable the foreign country's bonds are with the US. Specifically, a higher elasticity of substitution for a given country will mean a larger response of that country's term premium. We now provide evidence that this is indeed the channel through which *mpu* has international

[29]There is some recent work on the spillover of overall US uncertainty, see for example Bhattarai et al. (2019). But this work does not try to isolate the effect of monetary policy uncertainty.

spillover effects.

If the long-term bonds of two countries are highly substitutable, this implies the bonds share similar degrees of risk and generally belong to the same class of securities. Perceived risk and the demand for a class of securities are two main determinants of a bond's term premium; thus, the term premium of two highly substitutable bonds should positively comove.[30] Accordingly, we construct a simple measure of the substitutability of bonds by calculating the correlation between the 10 year bond term premium of each country in our sample and the US on all *non-FOMC* days between January 1995 and June 2019. Our measure is essentially identical to the method of de los Rios and Shamloo (2017) and is comparable to the empirical test of Frankel (1982). After calculating the correlation between the 10 year term premium for country i and the US, we scale our measure to lie between 0 and 1, i.e. we add 1 to each correlation and divide by 2.[31] Our specification is as follows

$$y_{i,t} = \kappa_0 + \kappa_1 mps_t + \kappa_2 mpu_t + \kappa_3 mps_t * bondsub_i + \kappa_4 mpu_t * bondsub_i + \varepsilon_{i,t} \tag{4}$$

Since the substitutability measure is scaled to lie between 0 and 1, the coefficient on the mpu interaction term can be interpreted as the marginal effect of an mpu shock on the 10 year term premium of a country with perfect substitutability (i.e. correlation$=1$), relative to a country with the least substitutability (correlation$=-1$). Table 7 displays the mpu coefficients (κ_2 and κ_4) for all countries pooled together, only advanced countries and only emerging countries. For the pooled sample, the coefficient on the interaction term is positive and significant. This implies that it is indeed the case that countries whose bonds are more substitutable with US bonds on non-FOMC days also display a larger term premium response to changes in US monetary policy uncertainty on FOMC days. We see the same pattern when we restrict the regression to the advanced country sample but not when we do that for emerging countries. Advanced countries whose bonds are more substitutable with US bonds are also more sensitive to mpu shocks. We have also plotted the distribution of our bond substitutability measures. As expected, the bonds of advanced countries have noticeably higher substitutability with US bonds than do emerging market countries. The figure is omitted for space considerations.

[30]The models of Kabaca (2016) and Alpanda and Kabaca (2019) generate the feature that high substitutability between domestic and foreign bonds results in strong positive comovement between domestic and foreign term premia. See Bernanke (2015) for further discussion of the term premium and the factors that move it.

[31]For robustness, we also calculate the bond substitutability measure using non-FOMC days between January 1995 and the FOMC meeting on day t. Appendix Table A.7 shows the results for this alterrnative bond substitutability measure. Our results are also robust to using changes in the 10 year term premium (rather than levels) to compute the correlations and alternatively using a logistic transformation or by using a non-linear specification, e.g. binning by quantiles.

To summarize, the response of advanced country bond yields to *mpu* is driven by an international portfolio balance channel with the high degree of substitutability between advanced country bonds with the US being the crucial factor. Next, we turn to why emerging country bonds also respond significantly to *mpu*.

4.3.2 Response in emerging countries

In the previous section we discussed the international portfolio balance channel to understand the response of advanced country yields to *mpu*. But what explains the transmission of *mpu* through the expected component of bond yields for emerging markets? In this section we provide evidence on the response of capital flows in emerging countries that is consistent with a flight to safety channel.

We use data from the Treasury International Capital (TIC) reporting system, following the methodologies of Bertaut and Tryon (2007) and Bertaut and Judson (2014). Bertaut and Tryon (2007) construct a monthly measure of US holdings of foreign securities by combining annual TIC survey data with monthly TIC S flow data. Bertaut and Judson (2014) improve upon the measure by incorporating monthly TIC SLT holdings data, which becomes available in December 2011. We use the Bertaut and Tryon (2007) measure from 1995 to 2011 and the Bertaut and Judson (2014) measure from 2012-2018.[32]

This data only measures holdings by US residents of foreign assets; thus, our analysis is limited and we cannot observe the response of non-US investors to the monetary shocks. Another important caveat is that the TIC data are available at a monthly frequency and thus our regression specification is not as clean as the higher frequency specification used in the rest of the analysis. Nevertheless, we believe the data provides some interesting evidence.

We study the response of US holdings of foreign bonds to *mps* and *mpu* together with the interaction of the difference in the 3 month interest rates of the foreign country and the US (labeled $idiff$)

$$y_{i,t} = \gamma_0 + \gamma_1 mps_t + \gamma_2 mpu_t + \gamma_3 mps_t * idiff_{i,t} + \gamma_4 mpu_t * idiff_{i,t} + \varepsilon_{i,t} \tag{5}$$

The sample runs from 1995 to 2018 for a total of 187 FOMC meetings and excludes the financial crisis period from December 2007 to June 2009.[33]

Table 8 shows that for emerging countries an increase in *mpu* leads to a reduction in bond

[32] The data can be accessed here: https://www.federalreserve.gov/econres/ifdp/2014.htm. See Bertaut and Tryon (2007) and Bertaut and Judson (2014) for details.

[33] The literature has documented a large and abnormal reduction in international capital flows during the Great Recession, and in crisis periods generally. See, for example, Milesi-Ferretti and Tille (2011) and Broner et al. (2013).

holdings. Moreover, the interaction coefficient between *mpu* and the interest rate differential is negative and significant. This means that more capital flows out of emerging countries which have a higher interest rate differential with the US (consistent with the results in Ahmed and Zlate (2014)). Table A.8 in the Appendix confirms this result holds when including time fixed effects in the specification. Overall, these results are consistent with a flight to safety/quality channel where investors are pulling money out of countries that are perceived to be riskier than the US. These results are consistent with Bhattarai et al. (2019) who use a VAR framework and also find a flight to safety response of emerging countries to an increase in US uncertainty. They use VIX to capture a broader measure of US uncertainty. However as discussed in Bauer et al. (2019), *mpu* drives a substantial amount of variation in the VIX on FOMC meeting days, which is the sample that we focus on here. Thus our results are pointing to the role of US monetary policy specific uncertainty in driving this result.

In addition to the mechanism described above, there is a testable implication of the emerging country expected component response to changes in *mpu*. In response to an increase in monetary policy uncertainty, financial markets are expecting interest rates to rise in the future in emerging countries but not in advanced countries. Assuming that the markets are not systematically wrong, we can check to see if short rates do indeed move in the expected direction. We test this implication using the local projections framework outlined in Section 4.2 to map out the dynamic response of 3 month bond yields.

Results from this exercise are presented in Figure 3 with confidence intervals that use Driscoll-Kraay standard errors. Short rates in emerging markets do indeed move in the direction markets expect, as the 3 month yield is significantly higher for most of the time in the one and a half years after the *mpu* shock.[34] In contrast, the 3 month yield shows essentially no change a year after the *mpu* shock in advanced countries. Thus, it appears markets are correctly expecting short rates to respond to US monetary policy uncertainty in emerging countries, but not in advanced. These results reinforce that uncertainty is transmitted to advanced and emerging bond yields through fundamentally different mechanisms.

We also find that the emerging market response to *mpu* is suggestive of the framework put forth by Rey (2013). As shown above in Table 6, exchange rates of emerging countries depreciate in response to a contractionary *mpu* shock. From a Mundell-Fleming perspective, a flexible exchange rate should be enough to shield a country to financial spillovers from the US. Rey (2013) suggests that this would only be the case if there are additional restrictions on capital mobility. In the next section we show that it is indeed the case that emerging countries whose capital account is more unrestricted are the ones that respond more to *mpu*.

[34]For example, after a year short rates are 0.15 standard deviations or 3.8 basis points higher.

4.4 Heterogeneity in response to monetary policy uncertainty

In this section, we explore potential country characteristics that are associated with the sensitivity to US monetary policy uncertainty transmission. Specifically, we test for differences in the response of asset prices conditional on country characteristics.

To establish noticeable heterogeneity in asset price responses to *mpu* shocks, we first plot the country-specific estimated coefficients on *mpu* for the full sample period. Appendix Figure A.5 displays the results for 2 and 10 year bond yields. Across both advanced and emerging countries, we see a mix of statistically significant and statistically insignificant responses. Within the two country groups, the most positive responses are significantly different than the least positive responses. This points toward a meaningful amount of heterogeneity that can potentially be explained, beyond the advanced versus emerging distinction.

We attempt to explain this heterogeneity by using time-varying country characteristics. Using time-varying, rather than fixed, country characteristics allows us to use both within-country and between-country variation in our identification. Our baseline observables include financial depth, exchange rate regime, trade openness and the change in the 3 month interest rate differential with the US on an FOMC day. For emerging market countries, we also include capital account openness.[35] Financial depth is the value of credit provided to the private sector, as a percentage of GDP. Exchange rate regime is defined as in Ilzetzki et al. (2019), where the categories are a flexible exchange rate, a partial peg and a fixed regime. Trade openness is the sum of total exports and imports divided by GDP. Capital account openness is defined as in Chinn and Ito (2006), with a higher value indicating greater openness (i.e. fewer capital controls).

Using this set of observables, our methodology most closely follows that of Iacoviello and Navarro (2019) by recursively orthogonalizing the regressors. Let $v \in V$ be our set of time-varying country characteristics for either the advanced country sample or the emerging market country sample. We estimate the following equation:

$$y_{i,t} = \alpha + \beta_1 mps_t + \beta_2 mpu_t + \sum_{v \in V} \gamma_1^v (e_{i,t}^v mps_t)^{\perp} + \sum_{v \in V} \gamma_2^v (e_{i,t}^v mpu_t)^{\perp} + \epsilon_{i,t} \quad (6)$$

where $e_{i,t}^v$ is the annual exposure index of variable v for country i on FOMC day t. The interaction terms $(e_{i,t}^v mps_t)^{\perp}$ and $(e_{i,t}^v mpu_t)^{\perp}$ are such that the β_1 and β_2 coefficients measure the response to an *mps* and *mpu* shock, respectively, when the exposure indices are at their 25th percentile values. The γ_1^v and γ_2^v coefficients capture the marginal response to an *mps*

[35] The capital accounts of advanced countries are almost exclusively the maximum degree of openness. Thus, virtually no variation exists to explain the heterogeneity in response and we exclude capital account openness as an observable variables for advanced countries.

and *mpu* shock, respectively, when the exposure index $e^v_{i,t}$ is at its 75th percentile value.[36]

Following Iacoviello and Navarro (2019), the orthogonalized interaction terms are constructed in the following manner. First, each exposure variable, v, is standardized, i.e. we subtract the sample mean and divide by the sample standard deviation, to make the scale of the exposure indices more comparable. Second, we perform a logistic transformation of the standardized exposure variables to collapse the variables to a unit interval. Third, we scale the transformed exposure variables to the distance between the 25th and 75th percentiles i.e. we subtract the 25th percentile value and divide by the difference between the 75th and 25th percentile values. At this stage, we now have our exposure indices, $e^v_{i,t}$. Next, we multiply our exposure indices by each of the shocks to calculate our interaction terms: $(e^v_{i,t} mps_t)$ and $(e^v_{i,t} mpu_t)$. For the final step, we recursively orthogonalize each of the interaction terms, starting with the *mps* interaction within each interaction term pairing. In other words, the interaction of the first exposure variable (v_1) and *mps* are orthogonalized with respect to mps_t and mpu_t, while the interaction of v_1 and *mpu* are orthogonalized with respect to mps_t, mpu_t and the interaction of v_1 with mps_t. Then, $(e^{v_2}_{i,t} mps_t)$ is orthogonalized with respect to *mps*, *mpu* and both of the orthogonalized v_1 interaction terms, while $(e^{v_2}_{i,t} mpu_t)$ is orthogonalized with respect to *mps*, *mpu*, both of the orthogonalized v_1 interaction terms and $(e^{v_2}_{i,t} mps_t)^{\perp}$. This continues for all subsequent exposure variables. In the following tables, the variables are orthogonalized with respect to those that appear above them, e.g. foreign exchange regime is orthogonalized with respect to financial depth and capital account openness in Table 9.

The above procedure has at least two advantages. First, the orthogonalization addresses the within-country correlation between the different characteristics. Without orthogonalizing, this collinearity would impact the precision of our estimates.[37] Second, since the orthogonalization is recursive, each additional characteristic's coefficient can be clearly interpreted as a marginal effect after controlling for the previous characteristics. In theory, our choice of variable ordering could affect the results. We show below that our main results are robust to the ordering of orthogonalization.

Focusing on the yield responses for emerging market countries, Table 9 shows that a more open capital account significantly explains differences in both 2 year and 10 year yield responses.[38] Specifically, a country at the 75th percentile of capital account openness experiences an additional 0.12 standard deviation (0.088 standard deviation) increase in the 2 year yield

[36]The 25th and 75th percentile values are calculated for the pooled (i.e. combined advanced and emerging) sample. For exchange rate regime, this is equivalent to moving from a floating regime to a fixed regime.

[37]Note, however, that our results are robust to orthogonalization.

[38]Appendix Table A.9 contains the results for advanced countries. It shows that the change in the 3 month interest rate differential with the US on an FOMC day is the only observable that significantly explains heterogeneity (2 year yield response only).

(10 year yield) in response to a US monetary policy uncertainty shock, relative to a country at the 25th percentile value of capital account openness. The relationship between emerging country capital account openness and responsiveness to US monetary policy uncertainty is consistent with the results of Bowman et al. (2015) for US monetary policy surprises.[39] As in Bowman et al. (2015), countries with a greater degree of capital account openness are more sensitive to US monetary policy changes.

Other than capital account openness, a country's exposure to dollar-denominated debt also appears to matter for yield responses (see Appendix Table A.10).[40] The 10 year yield for countries with a larger share of debt denominated in US dollars responds more sensitively to *mpu* shocks. Since an increase in US monetary policy uncertainty is expected to appreciate the dollar, this increases the real value of dollar-denominated debt and, thus, the likelihood of binding borrowing constraints.

Recursively orthogonalizing our variables allows us to estimate the marginal contribution of each exposure variable, *after we have controlled for any exposure variables that enter the regression first*. As a result, the ordering of the variables can theoretically impact the results. In practice, our main results are generally unaffected by the choice of variable ordering. The significance of capital account openness for the 2 year yield results does not depend on the ordering of the orthogonalization. For the 10 year yield results, financial depth must enter the regression prior to capital account openness, but otherwise the ordering of the variables does not matter.[41]

4.5 Response of international equity indices to US monetary policy uncertainty

In this section we investigate the effects of *mpu* on international stock markets. We use the same specification from Equation 3 with the 2-day return in the international equity indices as the dependent variable. Table 10 shows the result for the full sample, pre-crisis sample ending in November 2007 and a post-crisis sample starting in December 2007.

An increase in *mpu* leads to a fall in stock prices in both advanced and emerging countries.

[39]Bowman et al. (2015) use monthly changes in 10 year US sovereign yields to identify monetary policy surprises and monthly changes in emerging 10 year sovereign yields as the response variable of interest.

[40]Dollar debt exposure is the value of dollar-denominated debt as a % of GDP. Dollar debt exposure data is available only through 2012 and the measure is significant for 10 year yields only; thus, we did not include dollar debt exposure in our baseline table.

[41]Appendix Figure A.6 displays the coefficient for the capital account openness interaction with mpu for all 24 unique variable orderings with financial depth listed first. Note that the magnitude and statistical significance of capital account openness generally become stronger as capital account openness is orthogonalized with respect to more variables, i.e. enters the regression later.

For emerging countries the pattern is similar to the bond yield response: no effect in the pre-crisis sample but a strong and significant effect in the post-crisis sample. A one standard deviation increase in *mpu* reduces stock prices by 0.65%. The advanced country response also follows this sub-sample pattern, with essentially zero effect in the pre-crisis sample and a 0.37% fall in the post-crisis sample.[42] Thus, the spillover of US monetary policy uncertainty to international equity markets appears to largely be a post-crisis phenomenon. This result generalizes the pattern documented in Lakdawala (2018) for Indian stock markets. We also tried to explain the heterogeneity in the country-level response of equity markets using the country characteristics described above but did not find anything significant. A potential channel could be the growing role of foreign institutional investors in domestic equity markets as discussed in Lakdawala (2018) for Indian stock markets. We leave this topic for future research.

As with the bond yield results, we see a similar pattern in the effect of *mps* after accounting for *mpu*. Focusing on the post-crisis sample, after including *mpu* in the regression, the response of stock prices to *mpu* falls by about one-third in advanced countries and about one-half in emerging countries. Moreover, accounting for *mpu* in the regression leads to roughly a doubling of the R^2 for both advanced and emerging countries. This again highlights the importance of *mpu* even if one is only interested in the transmission of US monetary policy through first-moment shocks.

4.6 Robustness Checks

We conduct a variety of robustness checks for the results presented above. First, we show that our results are not driven by the zero lower bound (ZLB) period from December 2008 to December 2015. Table 11 shows that results from the non-ZLB sample are very similar to the full sample results. Next, we re-estimate equation 3 with the asset price changes and monetary shock measures calculated over a one day window, rather than the two day window used in the baseline results. Estimates using this narrower window are presented in Appendix Table A.11 and show that overall the results are essentially unchanged.

Since the construction of our measure of monetary policy uncertainty relies on Eurodollar futures where the underlying interest rate is the LIBOR rate and not the Fed's main policy tool (federal funds rate), we want to make sure that instability in this spread is not driving our results. The best way to measure this spread is using the LIBOR-OIS spread. To this end, we re-estimate our baseline estimates from Equation 3 but also control for changes in this LIBOR-OIS spread. The sample begins in December 2001 when LIBOR-OIS data is available.

[42] Recall that advanced country bond yields responded to *mpu* both in pre- and post-crisis samples.

The estimates in Appendix Table A.12 show that our results are robust to this particular concern.

In this paper we have highlighted that, in addition to first-moment effects of *mps*, there is a role of *mpu* through which US monetary policy can affect international markets. In Appendix Tables A.13 and A.14 we show that our results are robust to using longer-term measures of *mps*: changes in the 2 and 10 year Treasury yields, respectively. In earlier work, Gürkaynak et al. (2005) show that two separate factors better characterize the first-moment shocks (a target and a path factor), while we just use the first principal component (i.e. only one factor) to construct our *mps* measure. In Appendix Table A.15 we show that controlling for these two factors does not change the effect of *mpu* on international asset prices.

One concern with the FOMC day event-study approach is the issue of unscheduled FOMC meetings. These are meetings outside the regular FOMC calendar and are typically responses to unusual circumstances in the economy. In Appendix Table A.16 we show that our results are robust to excluding these unscheduled meetings. Another common concern is whether the results are affected by the so-called "information effect" where the Federal Reserve signals its private information about the underlying economic fundamentals. In Appendix Table A.17 we control for this by cleansing the monetary shocks using the methodology used by Campbell et al. (2012) and Lakdawala and Schaffer (2019). The results show that information effects are not playing a role in driving the transmission of *mpu* to international bond yields.

In the baseline specification we do not include country fixed effects. In Appendix Table A.18 we present results including it and find that the results are essentially unchanged. Finally, we explore the sensitivity of our results to outliers across both countries and FOMC dates. Online Appendix figures A.7 and A.8 plot coefficients and confidence intervals from the baseline specification while removing one country and one FOMC date at a time, respectively. The coefficients and confidence intervals remain similar regardless of which countries or dates are removed from the sample, eliminating the concern that the results are driven by extreme observations.

5 Conclusion

How does US monetary policy spillover to international financial markets? A common approach in the literature is to use an event-study framework and first-moment shocks (i.e. unexpected changes in the expected path of the policy rate) to study this question. In this paper we argue that this typical approach is not sufficient to capture the complete breadth of the international transmission of US monetary policy actions. We show that changes in uncertainty around the Federal Reserve's expected policy path have important consequences for global bond and equity markets. Moreover, omitting uncertainty from event-study regressions could lead to over-estimation of the first moment effect, since changes in first and second moments are positively correlated.

An increase in the market perceived uncertainty raises bond yields and lowers equity prices in both advanced and emerging countries. However, the transmission works through different channels. The yield response in advanced countries is driven by changes in term premia and we provide evidence for an international portfolio balance channel whereby bonds of countries that are considered to be more substitutable vis-à-vis the US respond more to uncertainty. For emerging countries, the yield response is driven by changes in the expected (or risk-neutral) component. Using capital flows data we show that uncertainty changes affect capital outflows in a manner consistent with a flight to safety channel. Moreover, for emerging countries the responsiveness to uncertainty is closely related to the country's financial openness.

Our results have implications for the design of monetary policy. We show that the uncertainty spillover is substantially larger when the FOMC deliberately made changes to the forward guidance language about future policy decisions. This suggests that the FOMC has an additional tool for influencing international financial conditions, namely by influencing the market's perceived uncertainty about the future path of the short rate. Moreover, in an environment where interest rates are more likely to be constrained by the zero lower bound, changing uncertainty will likely take on increasing importance in the FOMC's toolkit.

Our work raises some natural questions that are worth exploring. We find that the transmission of US monetary policy uncertainty has gotten stronger since the financial crisis, especially for emerging countries. There is some evidence that an increase in financial openness in emerging countries has played a role in the higher responsiveness, but a more detailed analysis is warranted. While we focus on the high-frequency response of financial markets, evaluating the spillover effects of US monetary policy on lower frequency macroeconomic variables in advanced and emerging countries appears to be a fruitful area for future research.

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Table 1: Summary Statistics

	Mean	Median	Std Dev	Min	Max	Observations
Panel (a): US monetary policy shocks						
mps	0.00	0.08	0.91	-4.37	3.08	204
mpu	-0.49	-0.39	1.00	-4.96	2.07	204
Panel (b): International asset prices						
2 year yield						
Advanced	-0.01	-0.01	0.09	-1.28	2.04	4,154
Emerging	-0.01	0.00	0.16	-3.14	1.04	1,270
10 year yield						
Advanced	-0.01	-0.01	0.08	-0.98	0.41	4,154
Emerging	-0.02	-0.01	0.18	-2.19	0.81	1,270
Stock return						
Advanced	0.19	0.20	1.98	-12.21	13.86	5,129
Emerging	0.29	0.17	2.40	-18.41	18.41	3,102
Exchange rate						
Advanced	0.03	0.01	0.93	-10.05	7.10	5,709
Emerging	0.02	0.00	1.20	-13.74	30.76	3,130

Panel (a) shows summary statistics for the monetary policy surprise (*mps*) and monetary policy uncertainty (*mpu*) shock measures calculated in a two day window around FOMC announcements. Panel (b) shows summary statistics for changes in 2 and 10 year government bond yields, stock returns, and exchange rate returns (foreign currency relative to US dollar) for the countries in our sample. All changes and returns are calculated in a two day window around FOMC announcements. We have government yield data for 22 advanced countries and 8 emerging countries. For exchange rates and stock prices we have data for 28 advanced countries and 16 emerging countries, see Appendix Table A.2 for details.

Table 2: Response of US asset prices to monetary shocks

Jan-1995 to Jun-2019	2 year yield		10 year yield		S&P 500	
mps	0.882***	0.876***	0.548***	0.382***	-0.179*	-0.137
	[0.097]	[0.104]	[0.106]	[0.095]	[0.093]	[0.096]
mpu		0.013		0.365***		-0.091
		[0.069]		[0.081]		[0.078]
Constant	-0.112***	-0.106*	-0.087	0.093	0.161**	0.116
	[0.042]	[0.056]	[0.061]	[0.070]	[0.069]	[0.085]
Observations	204	204	204	204	204	204
R-squared	0.646	0.646	0.249	0.359	0.027	0.033

Jan-1995 to Nov-2007	2 year yield		10 year yield		S&P 500	
mps	0.911***	0.874***	0.573***	0.450***	-0.181	-0.216
	[0.087]	[0.102]	[0.119]	[0.125]	[0.139]	[0.141]
mpu		0.096		0.322***		0.091
		[0.072]		[0.113]		[0.099]
Constant	-0.059	-0.012	-0.056	0.100	0.314***	0.358***
	[0.051]	[0.063]	[0.082]	[0.100]	[0.095]	[0.112]
Observations	108	108	108	108	108	108
R-squared	0.724	0.732	0.286	0.377	0.029	0.036

Dec-2007 to Jun-2019	2 year yield		10 year yield		S&P 500	
mps	0.840***	0.875***	0.547***	0.331**	-0.212*	-0.070
	[0.165]	[0.170]	[0.194]	[0.158]	[0.123]	[0.123]
mpu		-0.065		0.395***		-0.259**
		[0.110]		[0.116]		[0.110]
Constant	-0.203***	-0.236***	-0.115	0.085	0.018	-0.113
	[0.069]	[0.090]	[0.090]	[0.100]	[0.101]	[0.116]
Observations	96	96	96	96	96	96
R-squared	0.552	0.555	0.234	0.353	0.035	0.087

The table shows the response of 2 and 10 year Treasury bond yields and the S&P 500 to a monetary policy surprise and monetary policy uncertainty shock. All variables have been normalized to have unit standard deviation. The full sample consists of 204 FOMC announcements from January 1995 to June 2019, the pre-crisis sample consists of 108 FOMC announcements from January 1995 to November 2007, and the post-crisis sample consists of 96 FOMC announcements from December 2007 to June 2019. All changes are calculated in a two day window around FOMC announcements. Heteroskedasticity-robust standard errors are reported in parentheses.

Table 3: Response of international bond yields to monetary shocks

	Advanced countries			
	2 year yield		10 year yield	
	(1)	(2)	(1)	(2)
mps	0.410***	0.360***	0.345***	0.221***
	[0.065]	[0.061]	[0.080]	[0.069]
mpu		0.107**		0.264***
		[0.048]		[0.059]
Constant	-0.103***	-0.051	-0.115**	0.014
	[0.036]	[0.042]	[0.048]	[0.054]
Observations	4,154	4,154	4,154	4,154
R-squared	0.137	0.146	0.097	0.154

	Emerging countries			
	2 year yield		10 year yield	
	(1)	(2)	(1)	(2)
mps	0.238***	0.159***	0.214**	0.129*
	[0.050]	[0.043]	[0.070]	[0.056]
mpu		0.158***		0.171***
		[0.038]		[0.045]
Constant	-0.077**	-0.000	-0.108***	-0.025
	[0.031]	[0.033]	[0.028]	[0.030]
Observations	1,270	1,270	1,270	1,270
R-squared	0.044	0.065	0.036	0.060

The table shows the response of 2 and 10 year government bond yields to a monetary policy surprise (*mps*) and monetary policy uncertainty (*mpu*) shock. All variables have been normalized to have unit standard deviation. Column (1) has only *mps* as a regressor, while column 2 adds *mpu* to this specification. The sample consists of 204 FOMC announcements from January 1995 to June 2019. All changes are calculated in a two day window around FOMC announcements. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

Table 4: Response of international bond yields to monetary and macro data news shocks

	Advanced countries		Emerging Countries	
	2 year yield	10 year yield	2 year yield	10 year yield
mps	0.382***	0.239***	0.163***	0.127**
	[0.066]	[0.074]	[0.045]	[0.053]
mpu	0.111**	0.283***	0.174***	0.179***
	[0.051]	[0.065]	[0.048]	[0.049]
Observations	4,154	4,154	1,270	1,270
R-squared	0.145	0.155	0.069	0.055
Unemployment	-0.004	0.017	-0.010	-0.007
	[0.019]	[0.017]	[0.010]	[0.012]
Observations	5,562	5,562	1,681	1,681
R-squared	0.000	0.001	0.000	0.000
GDP	0.023	0.010	0.018	-0.003
	[0.017]	[0.017]	[0.017]	[0.014]
Observations	1,900	1,900	573	573
R-squared	0.008	0.002	0.004	0.000
Retail Sales	0.099***	0.064***	0.019	0.005
	[0.029]	[0.020]	[0.013]	[0.015]
Observations	5,583	5,583	1,685	1,685
R-squared	0.045	0.019	0.001	0.000
CPI	0.037*	0.007	0.009	0.012
	[0.019]	[0.021]	[0.013]	[0.016]
Observations	5,583	5,583	1,685	1,685
R-squared	0.007	0.000	0.000	0.001
PPI	0.016	0.017	0.007	-0.004
	[0.017]	[0.020]	[0.013]	[0.020]
Observations	5,495	5,495	1,654	1,654
R-squared	0.001	0.001	0.000	0.000

The table shows the response of 2 and 10 year government bond yields in advanced and emerging countries to a monetary policy surprise (*mps*), monetary policy uncertainty (*mpu*) and news shocks. All variables have been normalized to have unit standard deviation. For the employment report, we use non-farm payrolls, for CPI and PPI we use headline inflation, retail sales are the total sales including automobiles, GDP is the advance GDP release. The sample runs from January 1995 to June 2019. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

Table 5: Response of expected component and term premium component of international bond yields to monetary shocks

Panel (a)	Advanced countries				Emerging countries			
	2y ec	10y ec	2y tp	10y tp	2y ec	10y ec	2y tp	10y tp
mpu	-0.012	-0.004	0.129**	0.241***	0.094*	0.128***	0.070	0.056
	[0.049]	[0.052]	[0.048]	[0.060]	[0.044]	[0.034]	[0.039]	[0.040]

Panel (b)	Advanced countries				Emerging countries			
	2y ec	10y ec	2y tp	10y tp	2y ec	10y ec	2y tp	10y tp
mpu	0.041	0.040	0.037	0.067	0.109*	0.124***	0.044	0.036
	[0.045]	[0.053]	[0.035]	[0.053]	[0.047]	[0.030]	[0.035]	[0.046]
US 10y tp	-0.122**	-0.100*	0.210***	0.402***	-0.034	0.008	0.058*	0.043
	[0.048]	[0.051]	[0.044]	[0.046]	[0.031]	[0.029]	[0.029]	[0.041]

Panel (a) shows the response of the expected component (ec) and term premium (tp) of 2 and 10 year government bond yields to a monetary policy uncertainty (*mpu*) shock. The monetary policy surprise (*mps*) and a constant are included in the regressions, the coefficients are left out for space considerations. Yields are decomposed into the expected component and term premium using the methodology of Joslin et al. (2011). All variables have been normalized to have unit standard deviation. Panel (b) adds the US 10 year yield term premium to the specification. The sample consists of 204 FOMC announcements from January 1995 to June 2019. All changes are calculated in a two day window around FOMC announcements. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

Table 6: Response of exchange rates to monetary shocks

	Advanced		Emerging	
	(1)	(2)	(1)	(2)
mps	0.240***	0.281***	0.130***	0.085*
	[0.064]	[0.067]	[0.044]	[0.041]
mpu		-0.091		0.098**
		[0.062]		[0.044]
Constant	0.034	-0.011	0.008	0.056
	[0.049]	[0.058]	[0.035]	[0.034]
Observations	5,709	5,709	3,130	3,130
R-squared	0.048	0.054	0.014	0.022

The table shows the response of international exchange rate returns to a monetary policy surprise (*mps*) and monetary policy uncertainty (*mpu*) shock. The sample consists of 204 FOMC announcements from January 1995 to June 2019. Exchange rate returns have been normalized to have unit standard deviation. Exchange rates are in units of foreign currency per US dollar such that an increase represents a depreciation of the foreign currency relative to the dollar. All changes are calculated in a two day window around FOMC announcements. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

Table 7: Response of term premium component of international bond yields to monetary shocks (bond substitutability interaction)

	10 year term premium		
	All Countries	Advanced	Emerging
mpu	-0.33***	-0.16***	-0.12
	(0.080)	(0.044)	(0.302)
mpu x bond sub.	0.72***	0.53***	0.29
	(0.148)	(0.077)	(0.526)
Observations	5,410	4,140	1,270
R-squared	0.045	0.062	0.008

The table shows the response of 10 year government bond yield term premia to a monetary policy uncertainty (*mpu*) shock and the interaction with a measure of bond substitutability with the United States. The monetary policy surprise (*mps*), its interaction with bond substitutability and a constant are included in the regressions, the coefficients are left out for space considerations. The term premium is calculated using the methodology of Joslin et al. (2011). Bond substitutability is calculated as the correlation between the 10 year term premium for country i and the United States using all non-FOMC days for the entire sample period of January 1995 to June 2019. Bond substitutability is standardized to the interval 0 to 1, representing a range in the correlation between -1 and 1. The sample consists of 204 FOMC announcements from January 1995 to June 2019. All term premium changes are calculated in a two day window around FOMC announcements. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

Table 8: Response of US holdings of foreign bonds to monetary shocks

	Advanced	Emerging
mps	-0.032*	0.083
	[0.019]	[0.103]
mpu	-0.019	-0.220**
	[0.032]	[0.068]
idiff	-0.002	-0.021
	[0.012]	[0.018]
mps x idiff	0.001	0.014
	[0.010]	[0.016]
mpu x idiff	0.007	-0.023***
	[0.008]	[0.005]
Constant	0.128***	-0.023
	[0.024]	[0.095]
Observations	3,528	928
R-squared	0.052	0.060

The table shows the response of changes in US holdings of foreign bonds to a monetary policy surprise (*mps*), monetary policy uncertainty (*mpu*) shock, and their interaction with the interest rate differential between the 3 month rate in foreign countries relative to the US (idiff). US holdings of foreign bonds are from the monthly TIC data. Country fixed effects and year dummies are included in the specification. The sample runs from January 1995 to December 2018 for a total of 187 FOMC meetings, which excludes the financial crisis period from December 2007 to June 2009. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

Table 9: Understanding the cross-country heterogeneity of asset price responses: Emerging countries

	2 year yield	10 year yield
mpu	0.155***	0.168***
	[0.030]	[0.045]
FinDepth**mpu*	0.010	0.022
	[0.040]	[0.056]
KAopen**mpu*	0.120**	0.088**
	[0.039]	[0.033]
FXRegime**mpu*	0.077	0.221
	[0.128]	[0.159]
IRDiff3mChg**mpu*	-0.037	-0.026
	[0.039]	[0.031]
TradeOpen**mpu*	-0.059	-0.085*
	[0.034]	[0.040]
Observations	1,056	1,056
R-squared	0.0784	0.0739

The table shows the response of 2 and 10 year government bond yields to a monetary policy uncertainty (*mpu*) shock and the interactions with measures for financial depth (FinDepth), capital account openness (KAopen), exchange rate regime (FXRegime), the change in the 3 month interest rate differential with the US on an FOMC day (IRiff3mChg), and trade openness (TradeOpen). The monetary policy surprise (*mps*), its interactions with the country measures and a constant are included in the regressions, the coefficients are left out for space considerations. These observables are orthogonalized recursively as in Iacoviello and Navarro (2019). See Section 4.4 for details on the specification and variable creation. The sample consists of 204 FOMC announcements from January 1995 to June 2019. All changes are calculated in a two day window around FOMC announcements. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

Table 10: Response of international equity indices to monetary shocks

	Advanced countries					
	Full sample		Pre-crisis		Post-crisis	
mps	-0.081	-0.042	-0.031	-0.047	-0.157*	-0.052
	[0.064]	[0.068]	[0.085]	[0.093]	[0.085]	[0.078]
mpu		-0.084		0.044		-0.191**
		[0.062]		[0.078]		[0.085]
Constant	0.098*	0.057	0.217***	0.237***	-0.010	-0.106
	[0.048]	[0.059]	[0.067]	[0.076]	[0.066]	[0.076]
Observations	5,129	5,129	2,441	2,441	2,688	2,688
R-squared	0.005	0.011	0.001	0.002	0.019	0.047

	Emerging countries					
	Full sample		Pre-crisis		Post-crisis	
mps	-0.175***	-0.125**	-0.125**	-0.123**	-0.270**	-0.144*
	[0.056]	[0.048]	[0.056]	[0.053]	[0.098]	[0.071]
mpu		-0.110*		-0.005		-0.228**
		[0.061]		[0.061]		[0.101]
Constant	0.128***	0.074	0.208***	0.206***	0.043	-0.071
	[0.041]	[0.048]	[0.050]	[0.060]	[0.062]	[0.065]
Observations	3,102	3,102	1,592	1,592	1,510	1,510
R-squared	0.025	0.034	0.013	0.013	0.055	0.094

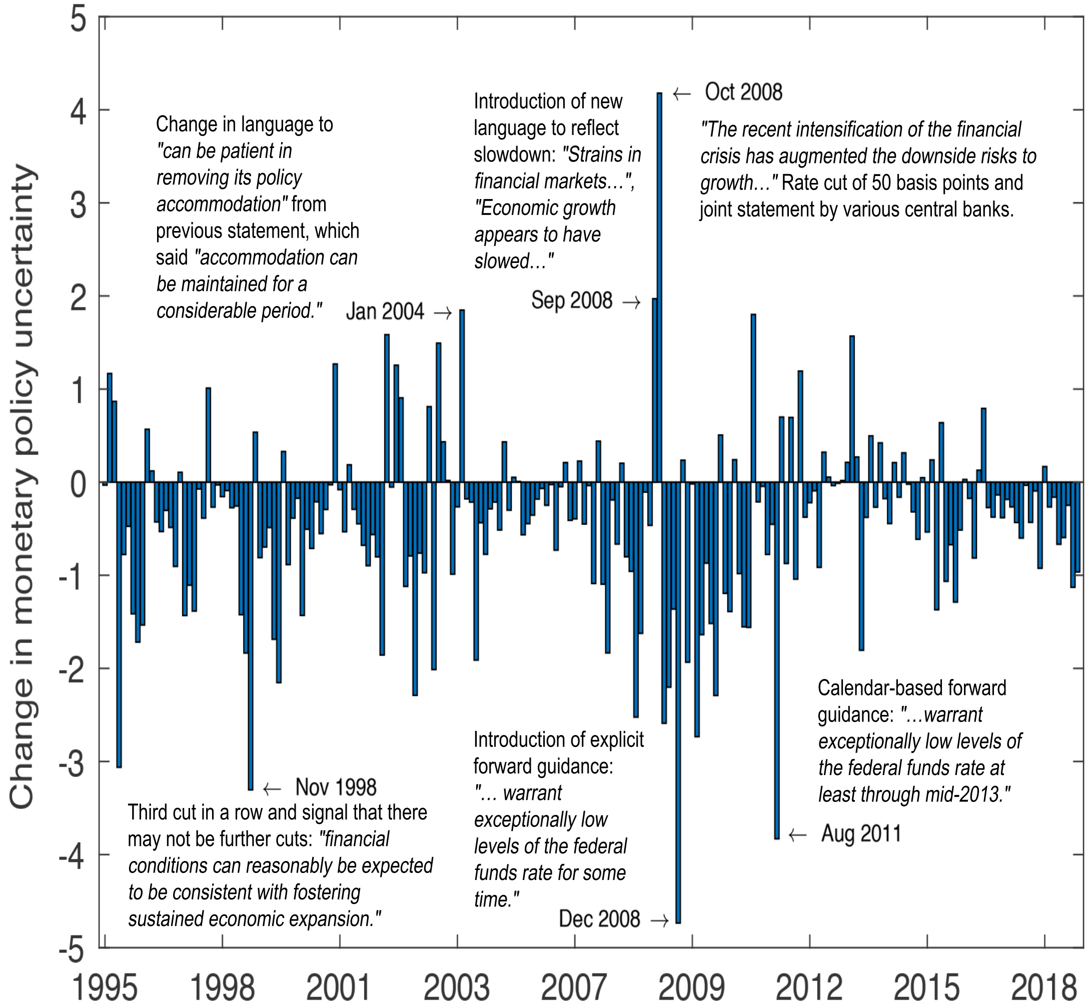
The table shows the response of returns on international equity indices to a monetary policy surprise (*mps*) and monetary policy uncertainty (*mpu*) shock. The full sample consists of 204 FOMC announcements from January 1995 to June 2019, the pre-crisis sample has 108 announcements from January 1995 to November 2007 and the post-crisis sample has 96 announcements from December 2007 to June 2019. Equity returns have been normalized to have unit standard deviation. All changes are calculated in a two day window around FOMC announcements. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

Table 11: Response of international bond yields accounting for zero lower bound

	Advanced countries		Emerging countries	
	2 Year Yield	10 Year Yield	2 Year Yield	10 Year Yield
mps	0.386***	0.224***	0.156**	0.110*
	[0.064]	[0.072]	[0.047]	[0.056]
mpu	0.065	0.226***	0.165**	0.113***
	[0.067]	[0.079]	[0.062]	[0.032]
*mps**ZLB	-0.431***	-0.076	0.031	0.187
	[0.134]	[0.232]	[0.100]	[0.172]
*mpu**ZLB	0.252**	0.113	-0.022	0.051
	[0.100]	[0.151]	[0.098]	[0.110]
ZLB	-0.006	-0.061	0.073	0.113
	[0.085]	[0.133]	[0.077]	[0.090]
Constant	-0.033	0.031	-0.027	-0.083***
	[0.053]	[0.058]	[0.037]	[0.021]
Observations	4,154	4,154	1,270	1,270
R-squared	0.158	0.159	0.066	0.067

The table shows the response of 2 and 10 year government bond yields to a monetary policy surprise (*mps*) and monetary policy uncertainty (*mpu*) shock. All variables have been normalized to have unit standard deviation. The sample consists of 204 FOMC announcements from January 1995 to June 2019. All changes are calculated in a two day window around FOMC announcements. The zero lower bound (ZLB) dummy takes on a value of one from December 2008 to December 2015. Standard errors reported in parentheses are calculated with two-way clustering (along the country and time dimension).

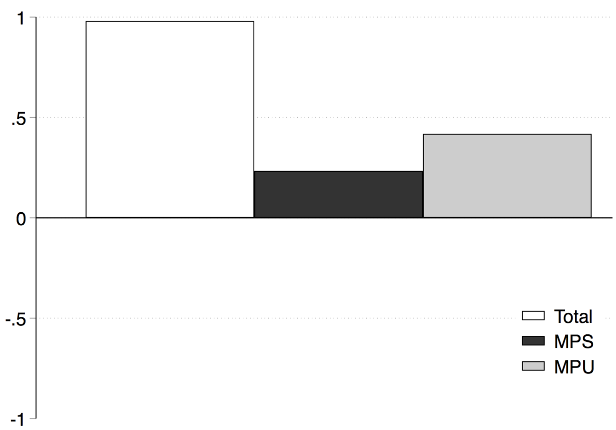
Figure 1: Monetary policy uncertainty changes (mpu) on FOMC meeting days



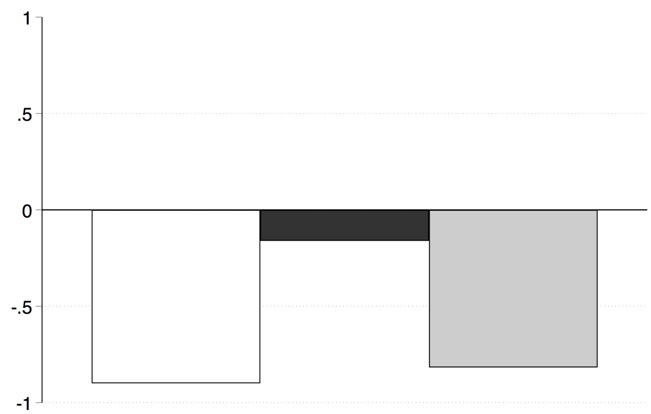
The figure shows the two-day change in the standard deviation of the 1 year ahead rate on FOMC meeting days (our baseline mpu measure). The measure has been normalized to have unit standard deviation. The labeled dates are the three largest declines and three largest increases in mpu.

Figure 2: 10 Year Yield Response on Prominent Monetary Policy Uncertainty Dates

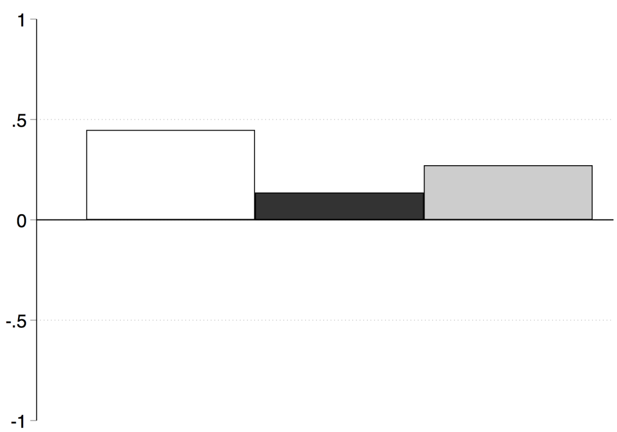
(a) Advanced: MPU Increase Dates



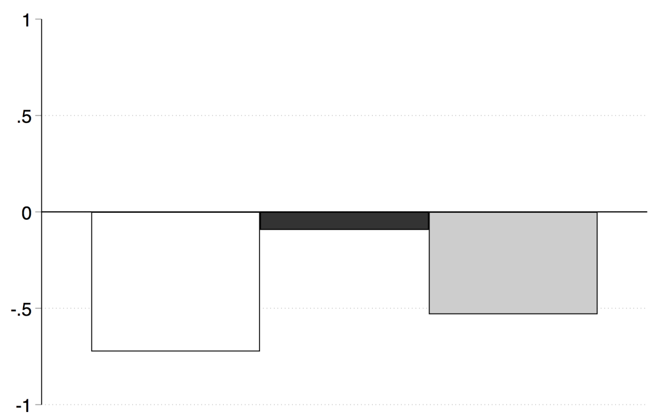
(b) Advanced: MPU Decrease Dates



(c) Emerging: MPU Increase Dates

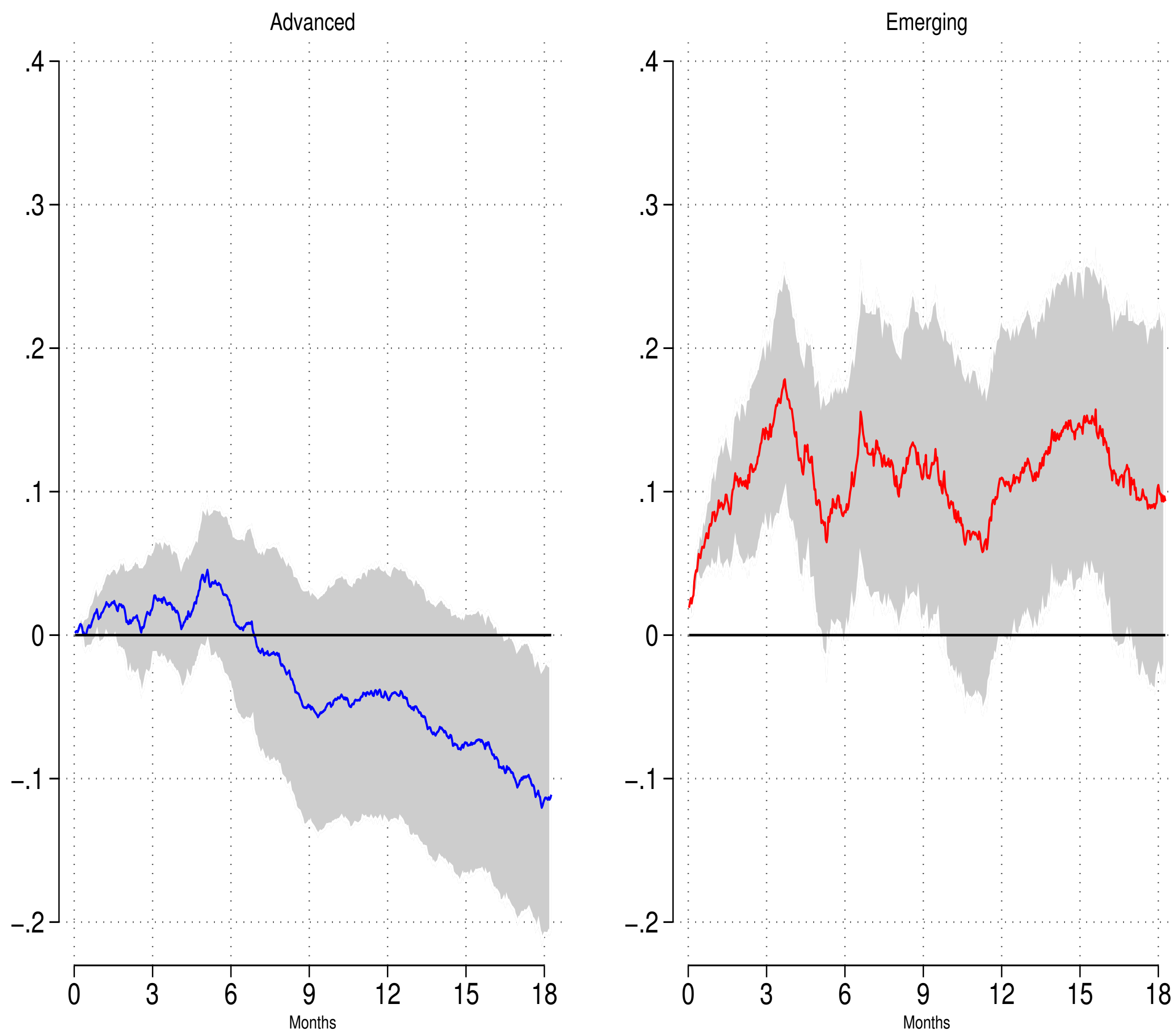


(d) Emerging: MPU Decrease Dates



The figure shows the average total change in 10 year bond yields on ten FOMC dates with the largest increase or decrease in the monetary policy uncertainty (*mpu*) shock, along with the average predicted component due to *mpu* and the average predicted component due to the monetary policy surprise (*mps*). The average predicted components are based on the coefficients estimated in Equation 3.

Figure 3: Response of 3 month yield to monetary policy uncertainty



The figure shows the dynamic response of 3 month government bond yields to a monetary policy uncertainty (*mpu*) shock over an 18 month horizon from the local projection estimation. The change in 3 month yields has been normalized to have unit standard deviation. The sample consists of 204 FOMC announcements from January 1995 to June 2019. All changes are calculated in a two day window around FOMC announcements. 68% confidence bands are constructed from Driscoll and Kraay standard errors.