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Abstract

How does domestic monetary policy in systemic countries spillover to the rest of the world? This paper examines the transmission channel of domestic monetary policy in the cross-border context. We use exogenous shocks to monetary policy in systemically important economies, including the U.S., and local projections to estimate the dynamic effect of monetary policy shocks on bilateral cross-border bank lending. We find robust evidence that an increase in funding costs following an exogenous monetary tightening leads to a statistically and economically significant decline in cross-border bank lending. The effect is weakened during periods of high uncertainty. In contrast, the effect is found to not vary according to the degree of borrower country riskiness, further weakening support for the international portfolio rebalancing channel.

Keywords: Monetary policy spillovers; International bank lending channel; Cross-border banking flows; Global financial cycles; Local projections

JEL codes: E52; F21; F32; F42.

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I. INTRODUCTION

Do domestic monetary policy actions affect cross-border bank lending? If so, what is the transmission channel of monetary policy and what are the factors affecting this channel? Despite the importance of understanding cross-border spillovers of monetary policy, there has been a lack of empirical consensus on these questions. We contribute to the literature by employing a dynamic and flexible empirical framework to analyze the cross-border effects of domestic monetary policy in systemically important countries, as well as by offering a new set of empirical findings, which encompasses the contrasting evidence in the recent literature. We argue that identifying exogenous monetary policy surprises from an overall monetary policy stance is key to reconciling the lack of empirical consensus and we find a negative effect of monetary policy tightening on cross-border banking flows, in line with the bank lending and the risk-taking channels.

Rising financial integration has stimulated research on the cross-border effects of domestic monetary policy actions in systemically-important economies. In particular, the sharp increase in cross-border banking flows since the 1990s has led recent research to focus on the role of global banks in explaining the international transmission of monetary policy (Bruno and Shin, 2015b; Correa et al., 2017; Avdjiev et al., 2018; Bräuning and Ivashina, 2019; Temesvary et al., 2018; Argimon et al., 2019; Avdjiev and Hale, 2019; Morais et al., 2019). We contribute to this emerging literature by investigating the dynamic effect on cross-border bank lending of exogenous monetary policy actions in systemically-important economies, including the United States.

The reason for focusing on cross-border banking flows is threefold. First, while most previous studies focused on net capital flows, the rapid expansion of gross international asset and liability positions calls for a deeper understanding of the spillovers through gross flows that better reflect the impact on national balance sheets (Milesi-Ferretti and Tille, 2011; Broner et al., 2013). Second, to the extent that cross-border banking flows have meaningful implications for economic and financial conditions in recipient countries, as suggested by the recent empirical studies (Popov and Udell, 2012; Schnabl, 2012; Bruno and Shin, 2015a; Bräuning and Ivashina, 2019; Morais et al., 2019), examining the effect of monetary policy shocks on these flows helps identify the transmission channel of monetary policy spillovers. Third, the bilateral nature of cross-border banking flow data permits a cleaner identification of the international transmission channel of monetary policy since it allows controlling for credit demand factors in a recipient country (Cetorelli and Goldberg, 2011; Correa et al., 2017; Avdjiev et al., 2018).

While the monetary policy in systemically-important economies, such as the U.S., has proven to be a robust driver of international capital flows and risky asset prices across the globe (Rey, 2013), there is no consensus on the sign of the effect of monetary policy actions on cross-border banking flows. In principle, the credit channel of the monetary policy suggested by Bernanke and Gertler (1995) amplifies the effect of monetary policy shocks through frictions in the liability-side (a bank lending channel) or the asset-side (a portfolio rebalancing channel) of financial intermediaries or both. In either case, monetary policy tightening would result in a decline in bank lending. Additionally, Borio and Zhu (2012) and Coimbra and Rey (2017) show that monetary policy influences agents' risk-taking behavior, thereby increasing the credit supply during periods of easing. Bruno and Shin (2015b) model this risk-taking channel in an international context, specifically looking at the banking sector, and show that U.S. expansionary monetary policy increases cross-border bank capital flows through higher leverage of international banks.

However, monetary policy actions do not always have the same effect on bank lending in the domestic and international context. For example, according to the portfolio rebalancing channel (Den Haan et al., 2007; Dell'Ariccia et al., 2017), domestic monetary policy tightening may increase cross-border bank lending by eroding the net worth and collateral value of domestic borrowers and thus leading to a reallocation of lending toward relatively safer borrowers abroad (Correa et al., 2017; Argimon et al., 2019).

The existing empirical evidence on the effect of monetary policy on cross-border bank lending is mixed. Using data from the Bank for International Settlements (BIS)' Locational Banking Statistics (LBS) for the period 1995–2007, Bruno and Shin (2015a) find that higher U.S. interest rates have a negative impact on cross-border bank lending, which is consistent with an international bank lending channel of monetary policy. Temesvary et al. (2018) and Bräuning and Ivashina (2019) corroborate this finding using banks-firms matched loan-level data. Miranda-Agrippino and Rey (2019) find evidence for the so-called global risk aversion channel as a tightening in U.S. monetary policy triggers a surge of aggregate risk aversion and consequent retrenchments of international credit flows, particularly in the banking sector.

In contrast, Cerutti at al. (2017), also using the data from the BIS LBS, find that higher U.S. short-term interest rates are associated with an increase in cross-border bank lending. Correa et al. (2017) and Avdjiev et al. (2018) extend this finding to a large sample of lender countries, providing supporting evidence for the international portfolio rebalancing channel. Using Dutch, Spanish, and U.S. confidential supervisory data, Argimon et al. (2019) also find that global banks increase cross-border lending in response to domestic monetary tightening. Avdjiev and Hale (2019) find mixed evidence about the effect of monetary policy on international bank lending depending on the prevailing international capital flow regimes (high vs. low bank lending growth) and on the drivers of the monetary policy rate (macroeconomic fundamentals vs. monetary policy stance).[5]

We show that this lack of empirical consensus is mostly due to the use of short-term policy rates in testing the contrasting theoretical channels and argue that our empirical framework can reconcile the mixed evidence in the literature. Because monetary policy is typically guided by a rule, the largest part of the variation in monetary policy actions is due to the systematic component of monetary policy—that is, the response of the central bank to the current and expected future state of the economy. As discussed by Ramey (2016), identifying the causal effect of monetary policy requires looking at the exogenous deviations from the monetary rule. Earlier studies often identified exogenous shocks to monetary policy when investigating the credit channel of monetary policy. Surprisingly, however, most of the existing studies on cross-border bank lending have not properly addressed this issue.[6] Rather, they have typically examined the effect of an increase in the policy rate, which is confounded by the endogenous response of monetary policy to underlying economic conditions.

To address the endogeneity concern, we employ exogenous monetary policy shocks in the U.S.—the shocks identified by a narrative approach of Romer and Romer (2004) and those identified by external instruments using high-frequency data of Gürkaynak et al. (2005) and Gertler and Karadi (2015)[7] —and, in other eight advanced economies, the exogenous shocks series constructed by Furceri et al. (2018)[8] and apply the local projection method (Jordà, 2005) in estimating the dynamic effect of monetary policy on cross-border bank lending. We pay particular attention to the effect of U.S. monetary policy shocks given the dominance of U.S. monetary policy in shaping international capital flows and the special role of U.S. dollars in the international financial system. Thus, our analysis

[5] Avdjiev and Hale (2019) decompose changes in the Federal funds rate into what is predicted by the Taylor rule (the "macro fundamentals component") and the difference between the Federal funds rate and the one implied by the Taylor rule (the "monetary policy stance component"). However, they find that an increase in both components has positive effects on cross-border bank lending from U.S. banks, especially when lending to advanced economies, which is in sharp contrast to our findings.

[6] With the exeption of Miranda-Agrippino and Rey (2019), where the US monetary policy shock is identified using an external instrument constructed with high-frequency data following Gürkaynak et al. (2005) and Gertler and Karadi (2015) (see section B. *High-frequency identification with external instruments* of this paper).

[7] The authors also thank Peter Karadi who has kindly provided with the updated set of high-frequency financial surprises.

[8] The eight advanced economies are Canada, Germany, Italy, Japan, the Netherlands, Spain, Sweden, and the United Kingdom.

complements the voluminous literature on the real, monetary, and financial spillover effects of U.S. monetary policy (Kim, 2001; Canova, 2005; Bruno and Shin, 2015b; Dedola et al., 2017; Bräuning and Ivashina, 2019; Miranda-Agrippino and Rey, 2019).

Given the ample empirical evidence on the nonlinear effect of monetary policy shocks on economic and financial activity (Cover, 1992; Tenreyro and Thwaites, 2016; Castelnuovo and Pellegrino, 2018), we further investigate whether the effect of monetary policy shocks on cross-border banking flows depends on the underlying state of business cycles (expansions vs. recessions) in the source economy, global financial risks or uncertainty (low vs. high), and the sign of the shocks (tightening vs. easing). In addition, we analyze whether the riskiness of a recipient country strengthens or weakens the international bank lending channel of monetary policy, which bears significant policy implications.

The key results of the paper are the following:

- Exogenous monetary policy tightening in systemically important source economies leads to an economically and statistically significant decline in cross-border bank lending. This holds for the U.S. as well as the other advanced economies analyzed. These results sharply contrast with the evidence presented in previous studies using similar data but relying on the level of policy rates as a measure of monetary policy actions (Correa et al., 2017; Avdjiev et al., 2018; Argimon et al., 2019).

- U.S. monetary policy shocks have a statistically and economically significant effect on cross-border bank lending even when controlling for global financial risks or uncertainty (proxied by the VIX) or liquidity risks (proxied by the LIBOR-OIS spread), implying that U.S. monetary policy is an independent source of the so-called "global financial cycle."[9]

- The effect tends to be larger during periods of lower global uncertainty (proxied by the VIX index of implied volatility on the U.S. equity options), consistent with the monetary policy ineffectiveness during the period of high uncertainty (Aastveit et al., 2017; Castelnuovo and Pellegrino, 2018).

[9] See Rey (2013) and Cerutti et al. (2019) for contrasting evidence on the existence of the global financial cycle.

- We find that the effect of monetary policy tightening on cross-border bank lending does not depend on the riskiness of borrower countries (proxied by political risk index or income status), against the predictions of the international portfolio rebalancing channel of monetary policy.

The remainder of the paper is organized as follows. Section II describes the data on cross-border banking and exogenous measures of monetary policy shocks. Section III illustrates the empirical methodology and provides a thorough analysis of the international bank lending channel of monetary policy, including various robustness tests and additional exercises. Section IV concludes.

II. DATA

A. Cross-border banking flows

We use data on cross-border claims from the BIS' LBS to test the international bank lending channel of monetary policy in systemically important countries. This dataset provides a geographical breakdown of reporting banks' counterparties and the information about the currency composition of their balance sheets. The LBS dataset captures outstanding claims and liabilities of internationally active banks located in reporting countries against their counterparties residing in more than 200 countries. The data is compiled following the residency principle that is consistent with the BoP (Balance of Payments) statistics.

As the conventional bank lending channel relates to conditions in the location where banks make funding and lending activities, the residency principle has a conceptual appeal over the nationality principle used in Consolidated Banking Statistics (CBS). Moreover, to the extent to which foreign affiliates are subject to host-country regulation or have access to local bank liquidity facilities (Avdjiev et al., 2018), the residency principle is more appropriate than the nationality principle in identifying the international bank lending channel of monetary policy.

The major advantage of the BIS LBS data, compared to the banking flows collected from the BoP statistics, is the detailed breakdown of the reported series by recipient countries.[10] Banks record their positions on an unconsolidated basis, including intragroup positions between offices of the same banking group. Currently, banking offices located in 46 countries, including many offshore financial centers, report the LBS. The LBS dataset captures around 95 percent of all cross-border interbank

[10] Wang (2018) shows that banking inflows constructed using the BIS data move in tandem with the aggregate capital inflows from the BoP statistics. Moreover, flows to banking sectors reported in the BoP closely track the banking flows reported by BIS.

business (Bank for International Settlement, 2017). The bulk of cross-border bank claims and liabilities takes a form of loans and securities of the domestic banking sector vis-à-vis all counterparty sectors (including banks and non-banks, and the private and public sector).

Another advantage of the BIS LBS dataset is that the currency composition of cross-border claims and liabilities is available so that cross-border banking flows expressed in U.S. dollars are adjusted for movements in exchange rates. The adjustment for exchange rate movements turns out to be crucial in our setup since fluctuations in the exchange rate, which are influenced by monetary policy shocks, also affect cross-border bank lending. The availability of a currency breakdown enables the BIS to calculate break- and exchange rate- adjusted changes in amounts outstanding. Such adjusted changes approximate underlying flows during each quarter.[11]

The adjusted change is calculated by first converting U.S. dollar-equivalent amounts outstanding into their original currency using the end-of-period exchange rates, then calculating the difference in amounts outstanding in the original currency, and finally converting the difference into a U.S. dollar-equivalent change using the average period exchange rates.[12] As the BIS LBS only report the exchange rate-adjusted flows, we construct the exchange rate-adjusted stock of the cross-border claims from country i to country j as the cumulated sum of the exchange rate-adjusted flows, where the initial value of the exchange rate-adjusted stock is set equal to the exchange rate-unadjusted claims—directly available from the BIS LBS.[13]

The time-series coverage of LBS database varies significantly across countries. Some advanced economies such as the U.S. have reported these statistics since 1977, while some emerging market economies started reporting the statistics only after the 2000s. We first analyze the international bank lending channel of U.S. monetary policy using data from 1990Q1 to 2012Q4 due to its extensive availability of cross-border banking flow data and well-identified exogenous monetary policy shock as

[11] Adjusted changes in amounts outstanding are calculated as an approximation for flows. In addition to exchange rate fluctuations, the quarterly flows in the locational datasets are corrected for breaks in the reporting population.

[12] Nevertheless, the adjustment practice by the BIS cannot eliminate the possibility of under- or overestimation of actual flows. Adjusted changes could still be affected by changes in valuations, writedowns, the underreporting of breaks, and differences between the exchange rate on the transaction date and the quarterly average exchange rate used for conversion. See Avdjiev and Hale (2019) for further details.

[13] Figure A.1 in the appendix shows the exchange rate-unadjusted and adjusted U.S. cross-border claims. While the two series co-move very closely (the correlation is 0.75) over the entire sample, accounting for the valuation effect results in a more pronounced decline in cross-border bank lending from the U.S. during the global financial crisis (GFC), suggesting that the appreciation of U.S. dollars during this period partially offsets a larger decline in "real" cross-border bank lending originally denominated in U.S. dollars. The correlation between the exchange rate-adjusted and unadjusted series in the other eight advanced economies is about 0.6.

well as its dominance in shaping international capital flows and the special role of U.S. dollars in the international financial system.[14]

Throughout the analysis, we drop offshore financial centers using the IMF classification from our sample because their behaviors might differ substantially from the rest of the sample. Following Correa et al. (2017) and Choi and Furceri (2019), we further drop observations with the size of cross-border positions less than \$5 million, or with negative total outstanding claims. Observations of the dependent variable in the upper and lower one percentile of the distribution are excluded from the sample to reduce the influence of outliers.[15]

Table A.1 in the appendix lists the final sample of countries used in the analysis, together with their income status, an indicator whether they belong to the euro area, and their average status regarding the exchange rate regime, monetary policy independence, and capital account openness during the sample period using the trilemma index constructed by Aizenman et al. (2013).[16] The details on this index will be discussed in the online appendix B. We use these country-specific characteristics to investigate factors affecting the international bank lending channel of monetary policy.

To provide a first look at the pattern of cross-border bank lending, we present the size of total cross-border claims and liabilities as a share of the GDP in 2010Q4 for the 9 reporting countries in Table A.2 in the appendix. When normalized to the size of domestic GDP, the predominant role of European countries in the cross-border banking system is apparent. Cross-border claims of global banks in advanced economies are, on average, larger than liabilities, suggesting that they are net lenders in this market.

We further illustrate the bilateral structure of the data by presenting examples of bilateral cross-border claims between the U.S. and six countries in Figure A.2 in the appendix. Given the confidentiality of the data, we do not reveal the identity of the individual counterparties, but the first four recipient countries are advanced economies and the last two recipient countries are emerging market economies. Some observations stand out from the figure. First, the different scales of the y-axis

[14] Data before 1990 are sparse and with gaps.

[15] The qualitative results are robust to the inclusion of the observations less than \$5 million. They are also robust to (i) dropping the dependent variables at the top/bottom 2.5 percentile, (ii) winsorizing the dependent variables at the 1 or 2.5 percentile of the distribution, and (iii) including all the observations.

[16] For each country, we take the time-series average of each measure to summarize the overall characteristics during the period between 1990 and 2012. The exchange rate regime and monetary policy independence are defined vis-à-vis the U.S. A country with * denotes that it is also a source country where monetary policy shocks are originated in the second part of the analysis.

in these graphs re-emphasize the dominance of advanced economies in accounting for these flows. Second, the pattern of cross-border lending is quite heterogeneous across countries.

B. Identification of monetary policy shocks

As discussed earlier, the proper identification of the causal effect of monetary policy actions on cross-border bank lending requires using monetary policy actions that are orthogonal to current and expected future macroeconomic conditions (Ramey, 2016). This is the main novelty of the paper compared to many existing studies on the spillover effects of monetary policy through cross-border banking flows.

Measures of exogenous U.S. monetary policy shocks. In the baseline analysis, we use the exogenous monetary policy shock series constructed by Coibion (2012) who extends the monetary policy shocks identified by Romer and Romer (2004) using a narrative approach. Romer and Romer (2004) extract measures of the change in the Fed's target interest rate at each meeting of the Federal Open Market Committee (FOMC) and regress these policy changes on the Fed's real-time forecasts of relevant macroeconomic variables in the Greenbooks prior to each FOMC meeting. Then, they identify exogenous monetary policy shocks as the residuals from this regression. Specifically, they estimate the following equation:

$$\Delta ff_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i F_m \Delta y_{m,i} + \sum_{i=-1}^{2} \lambda_i \left(F_m \Delta y_{m,i} - F_{m-1} \Delta y_{m,i}\right) + \sum_{i=-1}^{2} \varphi_i F_m \pi_{m,i} + \sum_{i=-1}^{2} \theta_i (F_m \pi_{m,i} - F_{m-1} \pi_{m,i}) + \mu_i F_m un_0 + \varepsilon_m, \quad (1)$$

where m denotes the FOMC meeting, ffb_m is the target federal funds rate going into the FOMC meeting, $F_m \Delta y_{m,i}$ is the Greenbook forecast from meeting m of real output growth in quarters around meeting m, $F_m \pi_{m,i}$ is the Greenbook forecast of GDP deflator inflation, and $F_m un_0$ is the Greenbook forecast of the current quarter's average unemployment rate.

The estimated residuals $\hat{\varepsilon}_m$ are then defined as exogenous monetary policy shocks, purged of anticipatory effects related to economic conditions. Our quarterly measure of monetary policy shocks comes from summing the orthogonalized innovations to the Federal funds rate from each meeting within a quarter. As a robustness check, we also use the identification strategy of Gertler and Karadi (2015) based on high-frequency data used as external instruments (see next section).

Measures of exogenous monetary policy shocks in other advanced economies. We follow the methodology of Furceri et al. (2018) to construct quarterly measures of exogenous monetary policy shocks for other eight advanced economies. They identify monetary policy shocks in two steps, which closely follow the work by Auerbach and Gorodnichenko (2013) in identifying fiscal shocks in advanced economies. First, they compute the unexpected changes in policy rates (proxied by short-term rates) using the forecast errors of the policy rates provided by *Consensus Economics*.[17] Second, they regress for each country the forecast errors of the policy rates on similarly-computed forecast errors of inflation and output growth and identify the shocks as the residuals of this regression. We follow this approach, but we further purify these surprises of any predictable components by projecting it on current and lagged GDP growth and inflation, in order to eliminate any remaining endogeneity issue. Specifically, we estimate

$$FE_{i,t}^{r} = \alpha_i + \beta FE_{i,t}^{\Delta y} + \gamma FE_{i,t}^{\pi} + \sum_{j=0}^{4} \delta_j \Delta y_{i,t-j} + \sum_{j=0}^{4} \theta_j \pi_{i,t-j} + \varepsilon_{i,t}, \tag{2}$$

where $FE_{i,t}^{X}$ $(X = r, \Delta y, \pi)$ is the unexpected changes in policy rates (proxied by short-term rates), real GDP growth, and the inflation rate, respectively—defined as the difference between the actual value at the end of the quarter and the value expected by analysts as of the beginning of the last quarter for each country i. $\Delta y_{i,t}$ and $\pi_{i,t}$ are corresponding actual real GDP growth and the inflation rate. The estimated residuals $\hat{\varepsilon}_{i,t}$ are then defined as exogenous monetary policy shocks for advanced economies other than the U.S.[18]

As discussed by Furceri et al. (2018), this methodology has two main advantages. First, it overcomes the issue of "policy foresight" (Leeper et al., 2013) where economic agents receive news about possible changes in monetary policy and alter their behavior before the actual changes in policy happen. Changes in actual policy rate cannot capture this policy foresight of economic agents, leading to inconsistent estimates of the effect of monetary policy shocks on cross-border bank lending. Our approach, on the contrary, is free from this issue since it uses forecast errors which already reflect policy foresight by its construction. Second, this methodology reduces endogeneity issues as the shocks are orthogonal to unexpected changes in economic activity as well as to current and lagged endogenous variables.

[17] The Consensus Economics publications report forecasts for short-term (3-months) rates at the end of the next three months.

[18] While we use monetary policy shocks identified using forecast data in the eight advanced economies, countries in the euro area are subject to the same policy rate. As such, the shocks for these countries capture their relative exposure to exogenous ECB monetary policy actions. To mitigate this issue, as a robustness check, we repeat our exercise after dropping the euro-area countries other than Germany from the sample.

Figure A.3 plots the distribution of the exogenous monetary policy shocks we constructed at a quarterly frequency. Table A.3 in the appendix shows the standard deviation of the country-specific exogenous monetary policy shock series, together with its correlation with the U.S. monetary policy shocks constructed by Furceri et al. (2018) and Coibion (2012), respectively. The correlation between the U.S. monetary policy shock series from Furceri et al. (2018) and that from Coibion (2012) is 0.62 for the overlapped sample. The correlation between the country-specific monetary policy shock series with the U.S. is typically small except for Canada, ensuring that the identification of international bank lending channel of monetary policy from other advanced economies is unlikely confounded by the effect of U.S. monetary policy on the short-term rates in these economies.[19]

III. Empirical Analysis

A. Local projection method

We use Jordà (2005)'s local projection method to estimate the dynamic effect of monetary policy shocks on cross-border bank lending. The local projection method has been advocated by Auerbach and Gorodnichencko (2012) and Ramey and Zubairy (2018), among others, as a flexible alternative to VAR specifications without imposing the pattern generated by structural VARs. In the bilateral panel data setting, we adopt the local projection method over commonly used VAR models for the following specific reasons.[20]

First, the exogenous shocks we use are already orthogonalized to contemporaneous and expected future macroeconomic conditions. For this reason, we do not need to further identify monetary policy shocks using restrictions in VAR models—a common approach in many empirical analyses in both domestic and international setups.

Second, our estimation entails a large international panel dataset with a constellation of the fixed effects, which makes a direct application of standard VAR models more difficult. In addition, the local projection method obviates the need to estimate the equations for dependent variables other than the variable of interest, thereby significantly economizing on the number of estimated parameters.

[19] The high correlation between the monetary policy shocks in the U.S. and Canada reflects the close economic ties between the two countries and is consistent with the recent finding that Canada is the only country among a group of advanced economies experiencing a near-complete passthrough of conventional U.S. monetary policy for short-term interest rate.

[20] See Choi et al. (2018) and Miyamoto et al. (2019) for the recent application of local projections to the estimation of nonlinearities and interaction effects of exogenous shocks using a large international panel dataset.

Third, the local projection method is particularly suited to estimating nonlinearities (for example, how the effect of monetary policy shocks differs during expansions and recessions in the source economy), as its application is much more straightforward compared to non-linear structural VAR models, such as Markov-switching or threshold-VAR models. Moreover, it allows for incorporating various time-varying features of source (recipient) economies directly and allow for their endogenous response to monetary policy shocks.

Lastly, the error term in the following panel estimations is likely to be correlated across countries. This correlation would be difficult to address in the context of VAR models, but it is easy to handle in the local projection method by either clustering standard errors by time period or using the Driscoll-Kraay standard errors allowing for arbitrary correlations of the errors across countries and time (Driscoll and Kraay, 1998).

Despite the advantages mentioned above, the local projection method has some drawbacks compared to structural VARs. First, since the iterated VAR method produces more efficient parameter estimates than the local projection method, the impulse response function estimated by local projections is often associated with large confidence intervals. This problem of less precise estimates is exacerbated as a forecast horizon increases due to the decreasing sample size in each estimation. Thus, we report both 68% and 90% confidence intervals in the following analyses.

Second, compared to a single equation framework in the local projection method, structural VARs allow tracing the dynamic endogenous response of various macroeconomic variables in the system to monetary policy shocks, which in turn can also affect the dynamics of cross-border bank lending. We enhance the credibility of the identified shock by analyzing separately the effect of U.S. monetary policy shocks on domestic economic variables including domestic bank lending. Figure B.1 in the online appendix confirms that output and investment decline, while the nominal exchange rate appreciates in response to the exogenous monetary policy tightening. Although we find a weak price puzzle, the effect on CPI is not statistically significant. Most importantly, we also find that domestic bank lending decreases following an increase in bank funding costs, consistent with the bank lending channel of monetary policy in the domestic context.

B. International bank lending channel of U.S. monetary policy shocks

The local projection method simply requires the estimation of a series of regressions for each horizon h for each variable. Following Auerbach and Gorodnichencko (2012) and Ramey and Zubairy (2018), we run a series of regressions for different horizons, $h =, 1, 2, \dots H$ as follows:

$$y_{j,t+h} - y_{j,t-1} = \alpha_j^h + \beta^h MPshock_t + \sum_{p=1}^{n} \gamma^h X_{j,t-p} + \varepsilon_{j,t+h}, \quad (3)$$

where $y_{j,t}$ is the log of exchange rate-adjusted cross-border bank claims from the U.S. to borrowers in countries j in time t; α_j^h is a recipient country-fixed effect, which controls unobserved time-invariant characteristics specific to a country j; $MPshock_t$ is the measure of exogenous U.S. monetary policy shocks; $X_{j,t}$ is a set of control variables including lags of the dependent variable and the monetary policy shocks, and various control variables in the recipient country j (for example, real GDP growth, the short-term interest rate, inflation, and the nominal exchange rate growth vis-à-vis the U.S.) and their lags.

While the impulse responses generated by the local projections are not an estimate of the total effects of U.S. monetary policy—due to a constellation of fixed effects—, the exogeneity of the monetary policy shock and controlling for the demand-side factors allow us to investigate the spillover channel of monetary policy. In the baseline analysis, we use four lags of control variables in $X_{j,t}$ (i.e., $n = 4$), however, the selection of the lag length does not affect our findings.[21]

We estimate equation (3) using OLS, which would result in the inconsistency of the least-squares parameter estimates due to the combination of lagged dependent variables and fixed effects (Nickell, 1981). However, because the time-series dimension of the panel dataset is quite large, the inconsistency is unlikely a major concern. Following Auerbach and Gorodnichencko (2012), standard errors are clustered by time to account for the fact that the shock is identical to all recipient countries in any given period. Equation (3) is estimated for h=0, 1, 2,…, 7 so that we trace the dynamic effect of monetary policy shocks over two years. After dropping outliers and missing observations following the criterion explained above, our baseline estimation of the U.S. monetary policy shocks covers cross-border lending to 45 recipient countries.

Baseline results. Figure 1 presents the dynamic response of cross-border bank lending to exogenous U.S. monetary policy shocks. The results provide evidence of a significant negative effect which is consistent with the cross-border bank lending and the risk-taking channels of monetary policy. In particular, a 100 basis-point (bp) exogenous tightening is found to lead to more than a 10 percent decline

[21] When policy rates are not available, we use interbank rates. When interbank rates are not available, we use money market rates. We also include a linear time trend, but it hardly changes the estimation results.

in cross-border bank lending after two quarters, which is not only statistically but also economically significant.[22]

Table 1 summarizes the full estimation results using exogenous U.S. monetary policy shocks above.[23] The coefficients on the lagged dependent variable are negative and highly statistically significant, suggesting that the growth rate of the cross-border bank lending is mean-reverting. The coefficients on a recipient country's real GDP growth are positive, although they are not statistically significant in most cases.[24]

The coefficients on the recipient country's short-term interest rate are not statistically significant. While this finding is in contrast to Bruno and Shin (2015a), who find that a higher interest rate in a recipient country increases cross-border bank lending toward this country, it is mostly driven by the emerging market recipient economies in the sample where the interest rates have been typically countercyclical. Indeed, when we restrict the set of recipient countries to advanced economies, we find a positive and statistically significant coefficient on the recipient country's short-term interest rate, consistent with the finding that interest rate differentials are a strong pull factor of cross-border banking flows.

The results on the exchange rate suggest that a depreciation of the local currency is associated with a decline in cross-border bank lending toward the recipient country, which is consistent with the findings from the existing studies (Cerutti et al., 2017; Correa et al., 2017; Choi and Furceri, 2019). Bruno and Shin (2015b) also show that U.S. dollar appreciation induces a contraction of cross-border bank lending due to an increase in the risk of global banks' balance sheets, suggesting a balance sheet channel of U.S. monetary policy spillovers. Overall, the signs of coefficients of recipient country variables are consistent with the literature on push vs. pull factors of cross-border banking flows.

Comparison with the literature. Previous studies have typically examined the response of cross-border bank lending to changes in the monetary policy instrument, using a static framework. To compare our results with those, we perform two exercises. First, we regress the quarterly growth of cross-border

[22] A 100 bp increase corresponds to an approximately two standard deviations of the exogenous monetary policy shock series.

[23] While we control for the four lags of the variables, we only report the estimation results up to one lag to save space here. The results are available upon request.

[24] Once we drop the exchange rate growth in the estimation, the coefficients on a recipient country's real GDP growth become statistically significant without any material change in the coefficients of the monetary policy shock. This finding is consistent with the stylized fact that local economic growth is a pull factor of international capital flows. The results are available upon request.

bank lending on the lagged level of the Federal funds rate, which follows closely the static specification in Correa et al. (2017).[25] Column (I) in Table 2 summarizes the estimation results. Consistent with many existing studies, an increase in the U.S. monetary policy rate is associated with an increase in cross-border bank lending. Column (II) provides the estimation results using the changes in the Federal funds rate instead of its lagged level, which deliver similar results although the estimated coefficient of interest is not statistically significant. Interestingly, the sign of the estimated coefficient of interest switches its sign when employing the exogenous U.S. monetary policy shocks (column III).[26]

Second, we examine the dynamic effect by re-estimating equation (3) using changes in the Federal funds rate as a measure of monetary policy shocks. Also, in this case, we do not find evidence of negative effects of monetary policy: the effect is not statistically significant over all the estimation horizons with a smaller magnitude and mixed signs (Figure 2).[27] These results suggest that simply controlling for domestic variables that might affect cross-border bank lending is not sufficient to identify the causal effect of monetary policy and test which channel of monetary policy is at play (the international bank lending and risk-taking vs. the portfolio rebalancing channel). Once the endogeneity in changes in the monetary policy stance is accounted for, even global banks are not insulated from domestic monetary policy. In addition, the responses of bank lending to monetary policy shocks are better captured by a dynamic framework than a static one mixing short- and medium-term effects.

High-frequency identification with external instruments. We verify the validity of our baseline results by further exploiting an alternative identification strategy based on high-frequency data used as external instruments (Gertler and Karadi, 2015; Cloyne et al., 2018, Miranda-Agrippino and Rey, 2019). This hybrid approach, proposed by Gertler and Karadi (2015), combines the high-frequency identification widely used in the finance literature (Kuttner, 2001; Gürkaynak et al., 2005) with external instrument methods (Mertens and Ravn, 2013). The main idea behind this approach is that changes in the Federal funds futures in a narrow window (e.g., 30 minutes) around the FOMC monetary policy announcements capture the unexpected Fed policy actions. The key assumption is that these financial market surprises are uncorrelated with shocks other than the monetary policy ones. Since these changes are a noisy

[25] For the ZLB period (since 2008Q4), we replace the federal funds rate with the Wu-Xia shadow federal funds rate (Wu and Xia, 2016).

[26] Column (IV) to (VI) summarize the estimation results when dropping the recipient country-fixed effect.

[27] Our findings are not driven by the inclusion of the GFC or ZLB periods. See Figure A.4 in the appendix.

measure of the monetary policy structural shock, Gertler and Karadi (2015) used them as instruments in a proxy-SVAR framework.[28]

One drawback of this approach is that it is not immune to policy foresight issues coming from the mismatch of the information set of the private agents and the policymakers. In other words, the FOMC may have additional information about the future path of the economy. Without accounting for these different information sets in the VAR, the shock may incorporate the endogenous response of the policy instrument to the expected future path of macroeconomic variables (Ramey, 2016). Furthermore, these shocks can be correlated with the Fed's real-time forecasts of relevant macroeconomic variables, and therefore not exogenous.[29] In contrast, the narrative approach used in the baseline analysis does not suffer from these problems, as the shocks are orthogonal to the Fed's real-time forecasts of relevant macroeconomic variables.

We estimate Gertler and Karadi (2015)'s monthly reduced-form VAR over the period 1990M1-2012M12. The VAR includes U.S. industrial production and the consumer price index (both in logarithm), the government bond yields at different maturities (the policy indicator), and the excess bond premium constructed by Gilchrist and Zakrajšek (2012), which is an indicator for refinancing conditions on the secondary corporate bond markets. We then apply Ramey (2016)'s three-step approach to extract the structural monetary policy shocks, and, following Cloyne et al. (2018), we aggregate these surprises at a quarterly frequency and use them as instruments in our analysis of cross-border banking flows. Specifically, we modify equation (3), substituting the Romer and Romer (2004) monetary policy shock with the policy instrument i_t (Treasury bond yield) instrumented with the VAR-estimated monetary policy shock:

$$y_{j,t+h} - y_{j,t-1} = \alpha_j^h + \beta^h i_t + \sum_{p=1}^{n} \gamma^h X_{j,t-p} + \varepsilon_{j,t+h}. \tag{4}$$

In terms of covariates, $X_{j,t}$ consists of the same set of control variables as in equation (3), namely the lags of the dependent variable, the lags of the estimated monetary policy shocks, and other control variables in the recipient country j. As any other instrumental variable framework, additionally to the exogeneity condition (i.e., the external instrument must be uncorrelated with the other structural shocks), the instrument must satisfy the relevance condition—namely, it should be contemporaneously and

[28] For a detailed discussion on the proxy-SVAR and the use of external instrument, see Mertens and Ravn (2013), Gertler and Karadi (2015), and Ramey (2016).

[29] Using FOMC-frequency data and regressing these financial surprises on all Greenbook variables that Romer and Romer (2004) used to create their shocks, Ramey (2016) found that these surprises are predicted by Greenbook projections.

highly correlated with the instrumented variable. Following Gertler and Karadi (2015), we test different combinations of policy indicators (three and six-month government bond yields as well as one/two/three/five/seven/ten-year government bond yields) and instruments (six/nine-month and one-year ahead on three-month Eurodollar deposits, current/one/two-month Fed funds futures). Based on the F-test of the joint model (the F-statistic on the first stage) and the Stock and Yogo (2005) critical values, we chose the combinations that pass the weak instrument test.

Figure 3 presents the results obtained using the two-year government bond yield as a policy indicator and surprises in the three-month ahead futures as an instrument. As argued by Gertler and Karadi (2015), the two-year government bond yields better capture monetary policy actions during forward guidance. The F-statistic far exceeds the Stock and Yogo (2005) critical values and the results confirm that exogenous U.S. monetary policy tightening leads to a statistically and economically significant decline in cross-border bank lending.[30] Figure A.5 in the appendix shows the evolution of the structural shocks from the proxy-SVAR over the sample period, using the above-mentioned combination of policy indicator and instrument, and compares it with the shock identified through the narrative approach and the changes in the Federal funds rate. Our finding is robust to a larger set of non-weak instruments and treasuries yield combinations (see Figure A.6 in the appendix) as well as restricting the sample to 2008Q4.[31]

Robustness checks. In this section, we further test the robustness of our baseline findings to various sensitivity tests: (i) including domestic control variables, (ii) using different lag length selections, (iii) using an alternative way of computing standard errors, and (iv) controlling for time-varying country-pair variables such as bilateral trade flows. To save space, the results from robustness checks are reported in the appendix.

First, since our measures of monetary policy shocks are exogenous, we do not control for any other macroeconomic variables in the U.S. economy in the baseline analysis. Indeed as shown in Panel A in Figure A.7 in the appendix, the inclusion of additional control variables (U.S. real GDP growth, inflation rate, and stock returns) does not result in any material changes in the estimated impulse response functions.

[30] First-stage F-statistic for each horizon h=0, 1, 2,…, 7 is as follows: 330.42, 364.23, 358.67, 317.37, 332.79, 364.67, 333.84, 336.06.
[31] Consistent with the baseline case, F-statistics for all horizons in Figure A.6 far exceed the threshold, ensuring strong instruments.

Second, we have used four lags of the dependent variable and the control variables in the baseline analysis. We demonstrate that our findings do not depend critically on the selection of lags. Panel B in Figure A.7 shows that our results hardly change with the selection of eight lags.

Third, while we have clustered standard errors at the time level in the baseline specification, we test the robustness of our findings by clustering standard errors at the recipient country level or at the recipient country-time level. We also compute Driscoll-Kraay standard errors that allow arbitrary correlations of the errors across countries and time. We only report the results from using Driscoll-Kraay standard errors in Panel C in Figure A.7 to save space, but the results obtained using standard errors clustered at the recipient country level and at the recipient country-time level are similar to those clustered at the time level. In sum, the statistical significance of our findings does not hinge on the way we account for the correlations in the error term.

The use of the recipient country-fixed effects and a recipient country's macroeconomic variables cannot fully control for potential time-varying factors affecting cross-border banking flows at the bilateral level. One obvious candidate for such factors is bilateral trade flows between the U.S. and its counterpart countries. This variable is particularly relevant for the study of international capital flows, as the current account and the financial account are tightly related by the accounting identity. While banking flows correspond to only a subset of total capital flows, therefore mitigating this problem, we test the robustness of our findings by controlling for bilateral trade flows.[32] We take bilateral trade flow data from the IMF Directions of Trade Statistics. We add the growth of U.S. imports and exports (and their lags) from and to country j and re-estimate equation (3). Panel D in Figure A.7 shows that our results are nearly identical when controlling for bilateral trade flows.

Controlling for global financial and liquidity risks. We test whether our findings are robust to controlling for two additional global factors: financial and liquidity risks. First, given the importance of the VIX in driving the price of risky assets and international capital flows worldwide (Rey, 2013), a natural question is whether our findings are biased due to the omission of this global factor. In a related context, Bekaert et al. (2013) find that U.S. monetary policy and the VIX are systematically related. Moreover, the VIX has been recently found to be an important driver of cross-border bank lending regardless of its precise interpretation as global uncertainty, risk appetite, or financial distress (Bruno and Shin, 2015a; Cerutti et al., 2017; Correa et al., 2017; Wang, 2018; Choi and Furceri, 2019). Second,

[32] The category "other investment" is the residual in the balance of payment statistics and includes loans, currency and deposits, and trade credits.

the recent empirical literature has also documented an important role of liquidity shocks in driving cross-border banking flows (Cetorelli and Goldberg, 2011; Schnabl, 2012; Correa et al., 2015; Shim and Shin, 2018). Following Correa et al. (2015), we use the LIBOR-OIS spread—the rate at which banks use lending to one another—to measure liquidity conditions in interbank markets.[33]

To address these issues and disentangle the importance of U.S. monetary policy shocks in driving cross-border banking flows from that of global financial and liquidity shocks, we augment equation (3) with the log level of the VIX (and their four lags) and the level of the LIBOR-OIS spread (and their four lags), respectively. Figure A.8 in the appendix confirms that the effect of U.S. monetary policy shocks on cross-border bank lending is independent of global financial and liquidity risks.[34]

State-dependency in the international bank lending channel of U.S. monetary policy. There exists vast empirical evidence that the effect of monetary policy shocks on real and financial variables is state-dependent (Tenreyro and Thwaites, 2016). The average response of cross-border bank lending presented in the previous section may mask substantial heterogeneity depending on the underlying economic regime at the time of the monetary policy shock (expansions vs. recessions). To examine this possibility, we estimate the following equation in which the dynamic response is allowed to vary with the state of the economy:

$$y_{j,t+h} - y_{j,t-1} = F(z_t)\left(\alpha_{R,j}^h + \sum_{p=1}^{n} \gamma_R^h X_{j,t-p} + \beta_R^h MPshock_t\right) + (1 - F(z_t))\left(\alpha_{E,j}^h + \sum_{p=1}^{n} \gamma_E^h X_{j,t-p} + \beta_E^h MPshock_t\right) + \varepsilon_{j,t+h} \quad (5)$$

with $F(z_t) = \frac{exp(-\theta z_t)}{1+exp(-\theta z_t)}$ and $\theta > 0$,

where z_t is an indicator of the state of the economy normalized to have zero mean and unit variance. The estimated parameters depend on the average behavior of the economy in the historical sample between t and $t+h$, given the shock, the initial state, and the control variables.

Since the parameter estimates on the control variables incorporate the average tendency of the economy evolving between the states, the estimates incorporate both natural transitions and endogenous transitions from one state to the other that occur in the data. The indicator of the state of the economy

[33] The LIBOR-OIS spread is calculated as the average, within a quarter, difference between the three-month U.S. dollar LIBOR and the OIS rate for the Federal funds.

[34] The response of cross-border bank lending to U.S. monetary policy shocks hardly changes when we replace the VIX with U.S. economic policy uncertainty constructed by Baker et al. (2016).

is the five-quarter moving average of real GDP growth and $F(z_t)$ is a smooth transition function used to estimate the effect of monetary policy shocks in expansions vs. recessions.[35] We choose $\theta = 1.5$ following Auerbach and Gorodnichencko (2012) so that the economy spends about 20 percent of the time in a recessionary regime.[36] As shown in Figure A.9 in the appendix, the probability of a recession regime we estimate using a smooth transition function captures well the official NBER recession dates.

This approach is equivalent to the smooth transition autoregressive model developed by Granger and Teräsvirta (1993) and has the following advantages. First, compared with a model in which each dependent variable would interact with a measure of the business cycle position, it permits a direct test of whether the effect of monetary policy shocks on cross-border banking flows varies across different regimes. Second, compared with estimating structural VARs for each regime, it allows the effect of monetary policy shocks to change smoothly between recessions and expansions by considering a continuum of states to compute the impulse response functions, thus making the response more stable and precise. Third, we can use the full sample for estimation, which makes our estimates more precise.

The coefficients β_E^h and β_R^h trace the dynamic response to monetary policy shocks when the economy is in expansions and recessions, respectively. Figure 4 presents the dynamic responses during recessions and expansions using exogenous monetary policy shocks and changes in the Federal funds rate. We do not find a meaningful state-dependent effect of monetary policy shocks on cross-border bank lending in the former, although the response is weaker and less precisely estimated during recessions (top panel). In contrast, the sign of the response of cross-border bank lending in the latter differs between expansions and recessions (bottom panel). While an increase in the Federal funds rate is associated with a decrease in cross-border banking flows in expansions, the effect is positive in recessions. This difference further suggests an identification issue when using changes in the policy rate to measure monetary policy shocks.

The effect of U.S. monetary policy on cross-border banking flows may also depend on global financial conditions. To test this hypothesis, we repeat a similar exercise to the one for the state of the business cycles but identifying global financial condition regimes based on the VIX.[37] Figure 5 shows that the international bank lending channel of U.S. monetary policy tends to be weaker during the high-

[35] The results, available upon request, are similar when considering a measure of output gap.

[36] Our results hardly change when using alternative values of the parameter θ, between 1 and 6.

[37] Consistent with the previous exercise, we calibrate the parameters so that the U.S. economy spends about 20 percent of the time in a high-uncertainty period.

uncertainty period (high-VIX period), consistent with the recent findings that heightened uncertainty reduces the effectiveness of monetary policy (Aastveit et al., 2017; Castelnuovo and Pellegrino, 2018).

Monetary policy tightening vs. easing. The effect of monetary policy on economic activity is found to be larger for monetary policy tightening than easing (Cover, 1992; Tenreyro and Thwaites, 2016). To test for a similar asymmetry on its effects on cross-border banking flows, we estimate the following specification:

$$y_{j,t+h} - y_{j,t-1} = \alpha_j^h + \beta_+^h D_t MPshock_t + \beta_-^h (1 - D_t) MPshock_t + \sum_{p=1}^{n} \gamma^h X_{j,t-p} + \varepsilon_{j,t+h}, \qquad (6)$$

where D_t is a dummy variable that takes a value of one for monetary policy tightening and zeroes otherwise, and β_+^h and β_-^h capture the effect of a monetary tightening and easing, respectively. The results presented in the top panel of Figure A.10 in the appendix do not point to significant evidence of asymmetric effects of monetary policy shocks on cross-border bank lending in this case.

While the previous exercise implicitly assumes that the occurrence of monetary policy tightening and easing does not depend on the underlying state of the business cycles, it is likely that easing (tightening) is more common during recessions (expansions). Thus, we further consider the underlying state of the business cycles and the type of shocks jointly. The bottom panel in Figure A.10 in the appendix compares the effect of monetary tightening during expansions with that of monetary easing during recessions. If anything, monetary policy tightening during expansions seems to have a more persistent effect than monetary easing during recessions, consistent with the asymmetry found in the domestic effect of monetary policy shocks.

Borrower country riskiness and international portfolio rebalancing channel of U.S. monetary policy. In this section, we investigate whether borrower country riskiness affects the effect of U.S. monetary policy on cross-border bank lending by utilizing the heterogeneity in the pool of foreign borrowers. Correa et al. (2017) and Argimon et al. (2019) argue that domestic monetary policy tightening may increase cross-border bank lending because tighter monetary policy actions, by eroding the net worth and collateral value of domestic borrowers, can lead to a reallocation of lending toward relatively safer borrowers abroad. If this mechanism is at work, we would observe a larger decline in cross-border bank lending toward relatively riskier recipient countries. Since measuring ex-ante riskiness of borrowers at a country level is a challenging task we take two complementary approaches to enhance the credibility of our results. First, we adopt the Political Risk Index of ICRG (International Country Risk Guide) and separate the recipient countries into two groups based on their sample average of the total ICRG index. A country with higher than the above median value is considered as a safe borrower, and vice versa.

Second, we simply group the recipient countries into advanced and emerging market economies based on their IMF classification.

Figure 6 shows the results using the ICRG index as a proxy for borrower riskiness. The effects on cross-border bank lending are negative and statistically significant in both cases. Moreover, their magnitudes are similar and the difference is not statistically significant. Figure A.11 in the appendix also confirms that the effects are similar when using alternative measures of riskiness.[38] Although detailed counterparty-level data is required to draw a more complete picture of the underlying mechanism, the evidence from the recipient-country level data does not support the prediction of the international portfolio rebalancing channel.

C. International bank lending channel of monetary policy in other advanced economies

So far, we have focused on the international bank lending channel of U.S. monetary policy. However, a natural question is whether we can generalize the U.S. results to other systemically important advanced economies. Despite its paramount importance in policymaking, the existing studies have not reached a consensus on this issue.

For example, Correa et al. (2017) find that monetary policy tightening—identified by an increase in the policy rate—in a panel of 29 (mostly advanced) economies induces an increase in cross-border bank lending toward recipient countries during the similar sample period to our study and propose the international portfolio rebalancing channel as an alternative explanation. Other studies document an asymmetric effect on cross-border lending of monetary policy between the U.S. and other countries. For example, Avdjiev et al. (2018) find that while U.S. monetary easing fuels cross-border lending in U.S. dollars, a monetary tightening in other lender countries increases international dollar lending, as global banks turn to U.S. dollars for cheaper funding and lend toward borrowers abroad. Argimon et al. (2019) also show that the transmission channel of monetary policy through a banking system in Spain or the Netherlands can be quite different from that in the U.S.

To shed light on this issue, we extend equation (3) to incorporate the bilateral panel structure of the data as follows:

[38] We also test whether there is an asymmetry in cross-border lending toward borrowers in euro vs. non-euro area in response to U.S. monetary policy shocks. Figure A.12 in the appendix shows that the spillover tends to be stronger toward euro-area borrowers.

$$y_{i,j,t+h} - y_{i,j,t-1} = \alpha_{i,j}^{h} + \alpha_{j,t}^{h} + \beta^{h} M\,Pshock_{\,i,t} + \sum_{p=1}^{n} \gamma^{h} X_{i,j,t-p} + \varepsilon_{i,j,t+h}, \tag{7}$$

where *i* and *j* indicate source and recipient country, respectively; $y_{i,j,t}$ is the log of cross-border lending from global banks located in country *i* to borrowers in country *j* in time *t*; $\alpha_{i,j}^{h}$ is a source-recipient fixed effect; $\alpha_{j,t}^{h}$ is a recipient-time fixed effect; $M\,Pshock_{\,i,t}$ is the measure of exogenous monetary policy shocks in country *i* described earlier; $X_{i,j,t}$ is a set of control variables, including four lags of the dependent variable and of the monetary policy shocks.

Equation (7) is estimated using the bilateral cross-border banking data between the eight source countries with the available data on exogenous monetary policy shocks (Canada, Germany, Italy, Japan, the Netherlands, Spain, Sweden, and the U.K.) and their (maximum of) 45 recipient countries from 2001Q1 to 2012Q4. A shorter time span of the other advanced economy data compared to the analysis of the U.S. monetary policy is compensated by a larger cross-sectional dimension of the data. The identification strategy in equation (7) relies on the existence of bank lending from multiple source countries to one given recipient country at a given point in time, which resembles the identification strategy in Cetorelli and Goldberg (2011). The advantages of having a bilateral panel dataset in our context are threefold.

First, it mitigates concerns about reverse causality. While it is difficult to identify causal effects of country-specific shocks using aggregate capital flows, it is much more likely that domestic monetary policy shocks in country *i* affect cross-border bank lending toward a particular country *j* than the other way around. Second, the inclusion of the country-pair fixed effects allows us to control for any unobserved time-invariant characteristic between two countries, such as a set of gravity factors.[39] The inclusion of recipient country-time fixed effects further allows us to control for any macroeconomic shocks affecting recipient countries, including external and idiosyncratic recipient-specific shocks as well as the indirect impact of monetary tightening through other recipient countries. Together with the exogenous nature of monetary policy shocks in each lender country, the inclusion of these two-way fixed effects gives a clear identification of the international bank lending channel of monetary policy, largely immune to endogeneity issues. Third, the inclusion of recipient country-time fixed effects

[39] The inclusion of $\alpha_{i,j}^{h}$ is more flexible than controlling for any set of common time-invariant regressors which is commonly used in the Gravity model of international finance. Also, it simultaneously controls for any time-invariant characteristics specific to country *i* and country *j*, respectively.

allows us to maximize the sample coverage of our analysis because some recipient countries might not have sufficient time-series data on some of the control variables.

Baseline results. Figure 7 shows the response of cross-border lending to the exogenous monetary policy shocks in the eight advanced economies for which the exogenous monetary policy shocks are available. To demonstrate the importance of using exogenous monetary policy shocks in identifying the international bank lending channel of monetary policy, we also present the results using changes in the policy rate as a measure of monetary policy shocks. Consistent with the U.S. evidence, we do not find any effect of monetary policy actions in the short run when using changes in the policy rate, whereas we find negative and significant effects of an exogenous monetary tightening on cross-border bank lending, suggesting that there is no asymmetry about the bank lending channel of monetary policy between the U.S. and other advanced economies.

A one percent point exogenous tightening in monetary policy leads to an about 5 percent decline in cross-border bank lending after one quarter and the decline reaches more than 10 percent after one year, suggesting that the cross-border bank lending channel of monetary policy is not only statistically but also economically significant for other systemically important economies. While these findings are in sharp contrast to those in Correa at al. (2017) and Avdjiev et al. (2018), they further demonstrate that the identification of the causal effect of monetary policy on cross-border banking flows hinges on separating the exogenous component in policy rates from the endogenous response to changes in the economic environment.

Robustness checks and additional exercises. As for the U.S. analysis, we conduct various robustness checks and additional exercises to confirm the validity of our findings. First, while we use monetary policy shocks identified using forecast data in the eight advanced economies, countries in the euro area are subject to the same policy rate. Thus, heterogeneity in the identified shocks is only driven by forecast errors on economic development, not policy rates, resulting in potential correlation in the error term across countries. To address this issue, we repeat our exercise after dropping the euro-area countries other than Germany from the sample. Second, the inclusion of the two-way fixed effects in equation (7) does not control for economic conditions in lender countries that might affect cross-border bank lending simultaneously. To confirm the exogeneity of the identified monetary policy shocks and disentangle their effect from other confounding factors, we control for domestic macroeconomic variables (real GDP growth, inflation, stock returns, and the growth rate of the exchange rate vis-à-vis the U.S.) in the eight lender countries. Figure A.13 in the appendix confirms that the results are robust to these alternative specifications.

We further conduct the following sensitivity tests: (i) alternative standard error clustering; (ii) including more lags; and (iii) controlling for bilateral trade flows. Our findings are largely unaffected by these alternative specifications, and the results are available upon request. We test whether the spillover effect of monetary policy is asymmetric between the low-uncertainty and the high-uncertainty periods. Consistent with the evidence from the spillover effect of U.S. monetary policy shocks in the previous section, the results tend to be stronger during the former, further suggesting a monetary policy ineffectiveness in the presence of heightened uncertainty (Figure A.14 in the appendix).

Lastly, given the central role of European banks in shaping global banking flows (Cetorelli and Goldberg, 2011; Ivashina et al., 2015), an interesting question is whether the international bank lending channel of monetary policy in the euro area operates differently toward borrowers in the euro and non-euro area. A common monetary policy framework and currency in the euro area might weaken the cross-border effect of monetary policy shocks. To answer this question, we conduct a subsample analysis for cross-border bank lending from euro-area countries to (i) euro-area countries and (ii) non-euro area countries. If anything, the results suggest a stronger spillover toward the non-euro area economies (Figure A.15 in the appendix).

IV. CONCLUSION

We examine the international bank lending channel of monetary policy by employing exogenous changes in the policy rate in systemically important advanced economies, including the U.S. We estimate the dynamic effect of monetary policy shocks on cross-border bank lending using the local projection method. The results suggest that exogenous monetary policy tightening in systemically-important advanced economies leads to an economically and statistically significant decline in cross-border bank lending, consistent with the bank lending as well as the risk-taking channels in the international setup. These results sharply contrast with the evidence presented in the previous studies using similar data but relying on imperfect measures of exogenous monetary policy actions. These results also echo Ramey (2016), which emphasizes the importance of distinguishing exogenous surprises from the endogenous response in monetary policy stance when evaluating the effect of monetary policy.

When jointly estimated with measures of global financial risks or liquidity risks, U.S. monetary policy shocks still have a significant effect on cross-border bank lending, implying that U.S. monetary policy is an independent source of the so-called "global financial cycles." This finding is important since demand factors for cross-border bank lending are already controlled in our empirical framework so that our findings provide a conservative estimate on the size of the spillover effect of U.S. monetary policy shocks. We also find the ineffectiveness of monetary policy under high uncertainty in the cross-border context. By exploiting the heterogeneity in borrower riskiness, we further reject the international portfolio rebalancing channel of monetary policy in explaining cross-border bank lending behavior. Taken together, our findings bear significant implications for both policymakers (central banking policies and international monetary and financial coordination) and academics.

Stretching somewhat further, we make some methodological innovation, which is useful for future applied works. The dynamic estimation framework of local projections applied to the bilateral dataset allows estimating impulse response functions, which are not straightforward using a large bilateral dataset. The impulse response functions we estimate are also consistent with the spirit of earlier works on the domestic bank lending channel of monetary policy using VARs. Our findings suggest that a static estimation framework adopted in the existing studies using the LBS may not be adequate to identify the channel of monetary policy spillovers. To our best knowledge, this paper is one of the first kind to apply such a dynamic estimation framework to a large international bilateral dataset, thereby advancing an econometric framework for empirical researchers.

Two areas of future research we believe are important. First, we should enhance our understanding of the international transmission channel of monetary policy by further disentangling the bank lending and the risk-taking channel. Second, we should test whether the effect of unconventional monetary policy has been different than that of conventional monetary policy presented in this paper and in previous studies.

Table 1. Baseline estimation results from a dynamic framework

	h=0	h=1	h=2	h=3	h=4	h=5	h=6	h=7
Log cross-border claims (-1)	-22.059***	-25.402***	-33.609***	-28.551***	-30.937***	-39.549***	-40.845***	-33.768***
	(2.950)	(2.885)	(3.712)	(2.953)	(3.413)	(3.706)	(3.460)	(3.820)
Monetary policy shock	-2.429	-10.953**	-12.077**	-7.190	-3.251	-3.059	-0.464	2.391
	(3.625)	(4.282)	(4.890)	(4.624)	(6.368)	(6.090)	(7.450)	(6.299)
Monetary policy shock (-1)	-5.659*	0.279	5.548	9.389*	6.796	8.397	8.043	11.608*
	(3.376)	(4.616)	(5.060)	(5.620)	(7.433)	(7.612)	(7.167)	(6.353)
Recipient GDP growth	0.809*	0.415	0.807	0.886	0.619	1.256	1.352	0.574
	(0.486)	(0.643)	(0.734)	(0.869)	(0.874)	(0.996)	(1.057)	(1.136)
Recipient GDP growth (-1)	-0.333	0.349	-0.021	-0.305	0.670	0.738	0.217	0.551
	(0.502)	(0.536)	(0.736)	(0.732)	(0.905)	(1.025)	(1.039)	(0.995)
Recipient interest rate	0.042	0.025	-0.139	0.167	-0.109	-0.013	-0.196	-0.307
	(0.132)	(0.141)	(0.238)	(0.174)	(0.207)	(0.227)	(0.243)	(0.269)
Recipient interest rate (-1)	-0.051	-0.196	0.228	-0.303	0.178	0.047	0.099	-0.095
	(0.154)	(0.179)	(0.196)	(0.187)	(0.234)	(0.247)	(0.282)	(0.304)
Recipient exchange rate	-0.292**	-0.373**	-0.633***	-0.829***	-0.542**	-0.567**	-0.643***	-0.748***
	(0.113)	(0.158)	(0.175)	(0.184)	(0.226)	(0.263)	(0.243)	(0.272)
Recipient exchange rate (-1)	-0.233**	-0.191	-0.285*	-0.047	-0.100	-0.344	-0.307	-0.232
	(0.115)	(0.137)	(0.149)	(0.181)	(0.226)	(0.228)	(0.240)	(0.260)
Recipient inflation rate	0.307	0.114	0.832	1.517**	0.328	1.109	0.483	0.755
	(0.448)	(0.579)	(0.834)	(0.643)	(0.705)	(0.884)	(0.703)	(0.770)
Recipient inflation rate (-1)	0.272	0.626	0.131	-1.243*	0.114	-1.403	0.059	0.813
	(0.507)	(0.778)	(0.896)	(0.728)	(0.919)	(1.072)	(0.845)	(0.829)
Obs	3,064	3,018	2,979	2,934	2,889	2,855	2,807	2,770
R-squared	0.09	0.11	0.14	0.14	0.16	0.20	0.23	0.24
Recipient country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

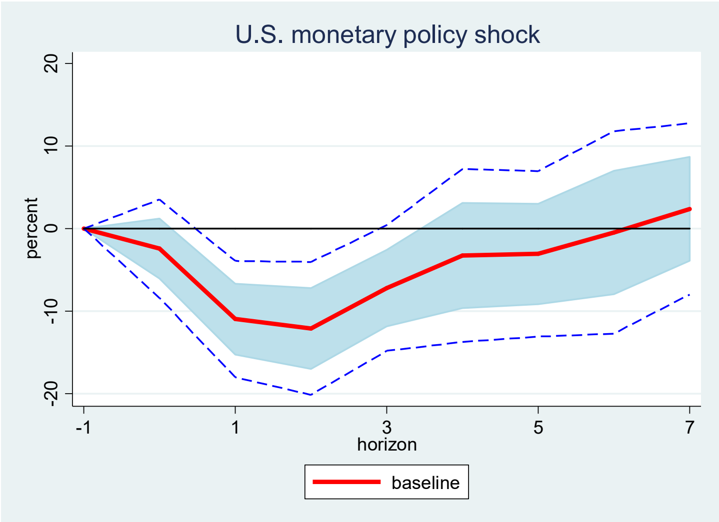
Note: Estimates are based on equation (3). Autocorrelation and heteroskedasticity-consistent standard errors are clustered at the time levels. *** denotes 1% significant level, ** denotes 5% significance level, and * denotes 10% significance level. While we control for the four lags of the variables, we only report the estimation results up to one lag to save space here.

Table 2. Results using a static framework

Independent variables	(I)	(II)	(III)	(IV)	(V)	(VI)
The lagged Federal funds rate	0.714**			0.616**		
	(0.301)			(0.285)		
Changes in the Federal funds rate		0.083			0.120	
		(1.529)			(1.489)	
Monetary policy shock			-0.349			-0.323
			(3.212)			(3.183)
Lagged GDP growth (U.S.)	0.636	0.970	0.996	0.516	0.847	0.884
	(1.434)	(1.651)	(1.527)	(1.427)	(1.625)	(1.516)
Lagged stock returns (U.S.)	0.190	0.178	0.180	0.195	0.184	0.186
	(0.133)	(0.135)	(0.134)	(0.132)	(0.133)	(0.133)
Lagged inflation rate (U.S.)	-3.257	-2.433	-2.421	-3.318*	-2.504	-2.489
	(1.964)	(1.862)	(1.858)	(1.913)	(1.802)	(1.799)
Lagged GDP growth (recipient)	-0.560	-0.435	-0.427	-0.341	-0.300	-0.293
	(0.629)	(0.629)	(0.633)	(0.605)	(0.603)	(0.606)
Lagged short-term interest rate (recipient)	0.005	0.071	0.071	0.036	0.077	0.077
	(0.094)	(0.091)	(0.091)	(0.080)	(0.080)	(0.080)
Lagged inflation (recipient)	0.257	0.219	0.216	0.254	0.168	0.164
	(0.449)	(0.454)	(0.456)	(0.404)	(0.406)	(0.409)
Lagged exchange rate growth (recipient)	-0.370***	-0.337**	-0.334**	-0.372***	-0.338**	-0.336**
	(0.129)	(0.128)	(0.131)	(0.129)	(0.128)	(0.132)
Obs	3,281	3,281	3,281	3,281	3,281	3,281
R-squared	0.02	0.02	0.02	0.01	0.01	0.01
Recipient country-fixed effect	Yes	Yes	Yes	No	No	No

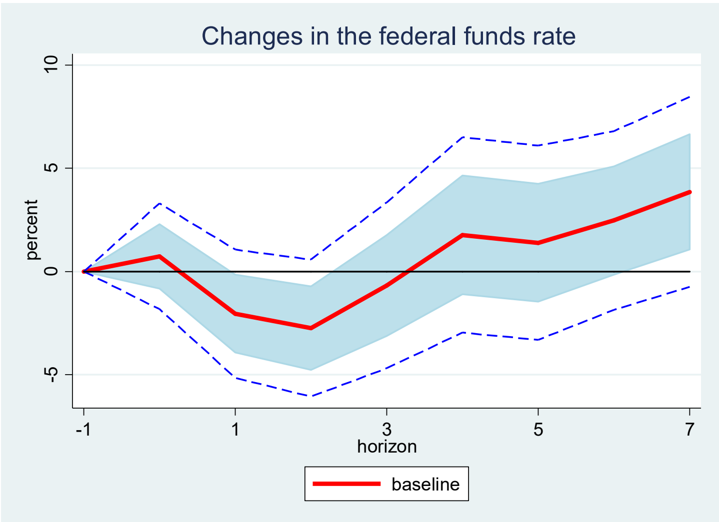
Note: The dependent variables are the growth rate of exchange rate-adjusted U.S. bilateral cross-border claims. The measure of monetary policy shocks is the lagged Federal funds rate in column (I) and (IV), the changes in the Federal funds rate in column (II) and (V), and the exogenous monetary policy shocks from Coibion (2012) in column (III) and (VI). Heteroskedasticity-robust standard errors are clustered at the time levels. *** denotes 1% significant level, ** denotes 5% significance level, and * denotes 10% significance level.

Figure 1. Effect of a U.S. monetary policy shock on cross-border bank lending



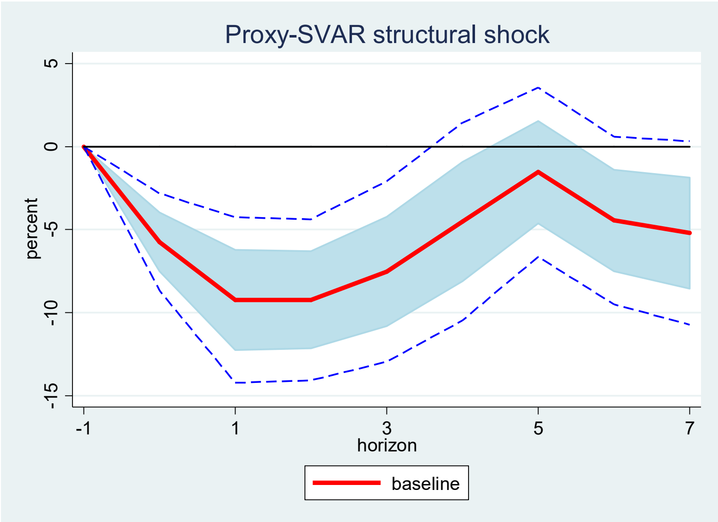
Note: The graph shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure 2. Effect of a change in the Federal funds rate on cross-border bank lending



Note: The graph shows the response of cross-border bank lending to a 100 bp increase in the Federal funds rate and their 68% and 90% confidence bands. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

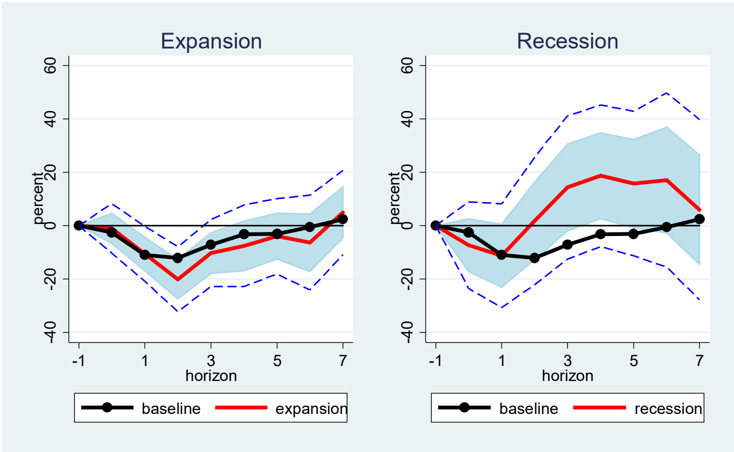
Figure 3. Effect of a U.S. monetary policy shock (proxy-SVAR structural shock) on cross-border bank lending



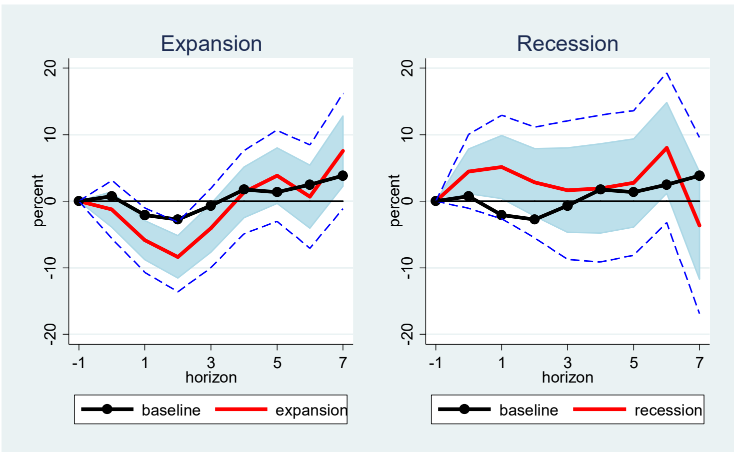
Note: Response of cross-border bank lending to a 100 bp U.S. monetary policy structural shock identified via proxy-SVAR and their 68% and 90% confidence bands. Horizon h=0 captures the impact of the shock, and the units are in percentage.

Figure 4. Effect of a U.S. monetary policy shock on cross-border bank lending: expansions vs. recessions

A) Exogenous monetary policy shocks

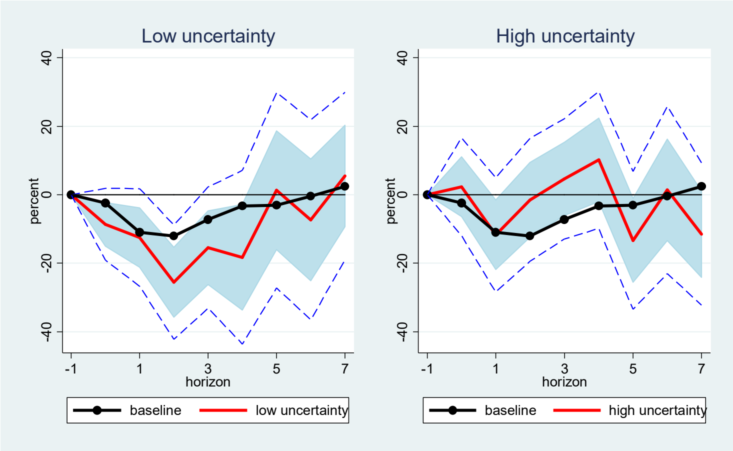


B) Changes in the Federal funds rate



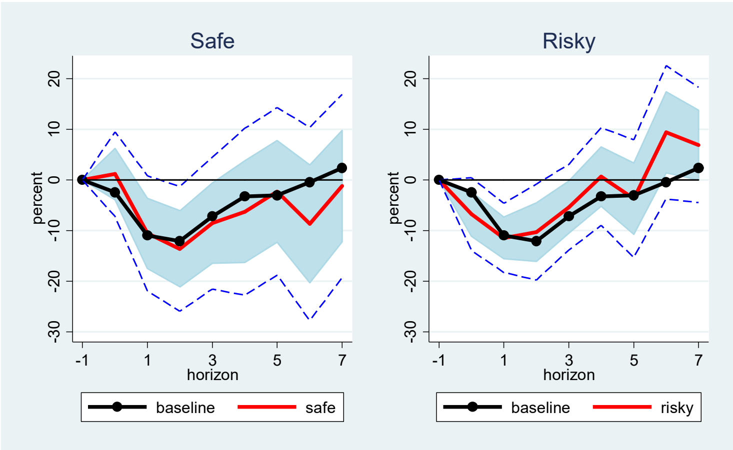
Note: The top panel shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands during expansions (left) and recessions (right). The bottom panel shows the response of cross-border bank lending to a 100 bp increase in the Federal funds rate and their 68% and 90% confidence bands during expansions (left) and recessions (right). Horizon h=0 captures the impact of the shock, and the units are in percentage.

Figure 5. Effect of a U.S. monetary policy shock on cross-border bank lending: low uncertainty vs. high-uncertainty periods



Note: The graph shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands during low-uncertainty (left panel) and high-uncertainty (right panel) periods using the exogenous monetary policy shocks. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure 6. Effect of a U.S. monetary policy shock on cross-border bank lending: safe vs. risky borrower countries



Note: The graph shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands. The left (right) panel shows the response of cross-border bank lending to borrowers in safe (risky) economies based on the ICRG index. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure 7. Effect of a monetary policy shock on cross-border bank lending from eight OECD countries

Note: The graph shows the response of cross-border bank lending to a 100 bp change in the policy rate and their 68% and 90% confidence bands (left) and monetary policy shock (right) in the eight OECD countries. Horizon h=0 captures the impact of the shock, and the units are in percentage.

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Appendix A. Additional figures and tables

Table A.1. List of countries in the final sample

Recipient countries	=1 if advanced economy	=1 if euro area	=1 if fully pegged	=1 if capital account is fully open	=1 if monetary policy is fully independent
Argentina	0	0	0.66	0.44	0.41
Australia	1	0	0.27	0.81	0.35
Austria	1	1	0.27	0.96	0.38
Belgium	1	1	0.27	0.96	0.38
Brazil	0	0	0.29	0.25	0.58
Bulgaria	0	0	0.26	0.50	0.33
Canada*	1	0	0.37	1.00	0.34
Chile	0	0	0.33	0.49	0.46
China	0	0	0.87	0.14	0.45
Colombia	0	0	0.38	0.25	0.55
Czech Republic	1	0	0.27	0.81	0.30
Denmark	1	0	0.27	0.99	0.38
Finland	1	1	0.27	0.96	0.38
France	1	1	0.27	0.94	0.38
Germany*	1	1	0.27	1.00	0.38
Greece	1	1	0.27	0.73	0.38
Hungary	0	0	0.27	0.61	0.36
India	0	0	0.49	0.17	0.42
Indonesia	0	0	0.43	0.77	0.40
Israel	1	0	0.35	0.65	0.50
Italy*	1	1	0.27	0.94	0.38
Japan	1	0	0.27	0.99	0.38
Korea	1	0	0.38	0.41	0.44
Lithuania	0	0	0.29	0.94	0.28
Malaysia	0	0	0.56	0.54	0.45
Mexico	0	0	0.36	0.63	0.47
Netherlands*	1	1	0.27	1.00	0.38
New Zealand	1	0	0.27	1.00	0.35
Norway	1	0	0.27	0.87	0.38
Pakistan	0	0	0.59	0.16	0.48
Peru	0	0	0.43	0.87	0.43
Philippines	0	0	0.38	0.40	0.48
Poland	0	0	0.26	0.29	0.36
Portugal	1	1	0.27	0.90	0.38
Romania	0	0	0.25	0.47	0.48
Russia	0	0	0.40	0.38	0.61
Slovak Republic	1	1	0.29	0.44	0.18
South Africa	0	0	0.26	0.17	0.56
Spain*	1	1	0.27	0.88	0.38
Sweden*	1	0	0.27	0.93	0.38
Thailand	0	0	0.45	0.36	0.39
Turkey	0	0	0.27	0.29	0.50
U.K.*	1	0	0.27	1.00	0.38
U.S.*	1	0	0.00	1.00	0.00
Venezuela	0	0	0.58	0.39	0.51

Note: We compute the time-series average of the status regarding the exchange rate regime, capital account openness, and monetary policy independence. A country with "*" denotes that it is also a source country where monetary policy shocks are originated in the second part of the analysis.

Table A.2. Total cross-border claims and liabilities as a share of GDP

	Total cross-border claims as a share of GDP	Total cross-border liabilities as a share of GDP
Canada	88.99	66.26
Germany	289.92	130.79
Italy	101.95	127.21
Japan	162.92	72.29
Netherlands	524.19	469.70
Spain	135.20	171.35
Sweden	278.91	169.49
U.K.	643.95	379.29
U.S.	63.55	49.65

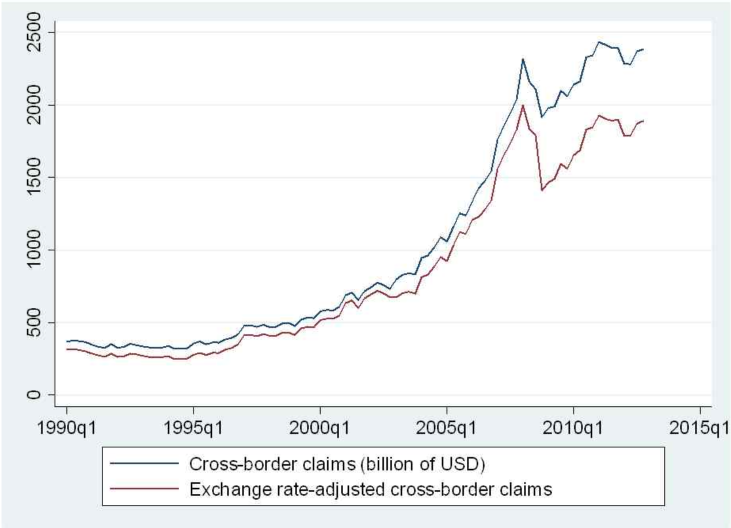
Note: Total cross-border claims and liabilities as a share of the domestic GDP in 2010Q4 under locational banking statistics with the residency principle.

Table A.3. Summary of exogenous monetary policy shocks in 9 OECD countries: 2001Q1-2012Q4

Source country	Standard deviation	Correlation with U.S. monetary policy shocks (Furceri et al., 2018)	Correlation with U.S. monetary policy shocks (Coibion, 2012)
Canada	0.215	0.592	0.441
Germany	0.169	0.120	0.098
Italy	0.238	0.076	-0.004
Japan	0.065	0.211	-0.101
Netherlands	0.192	0.181	0.069
Spain	0.198	0.011	-0.071
Sweden	0.184	0.107	-0.026
U.K.	0.231	0.160	-0.041
U.S.	0.341	1.000	0.619

Note: The quarterly exogenous monetary policy shock series are constructed following Furceri et al. (2018).

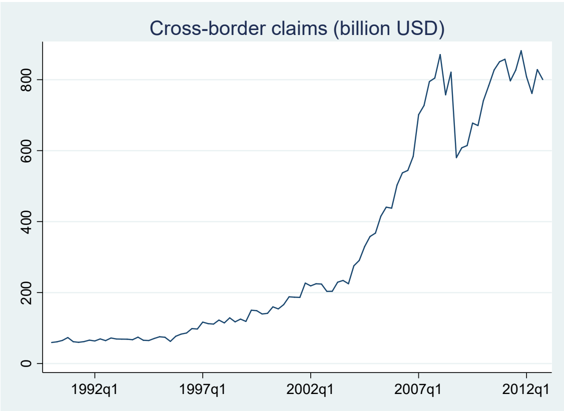
Figure A.1. Total U.S. cross-border bank claims: raw stock vs. exchange rate-adjusted stock



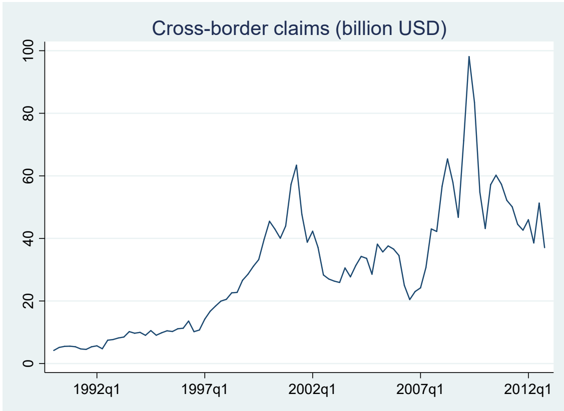
Note: The graph shows total U.S. cross-border bank claims (both exchange rate-unadjusted and adjusted) from 1990Q1 to 2012Q4.

Figure A.2. Exchange-rate adjusted U.S. cross-border bank claims to individual countries

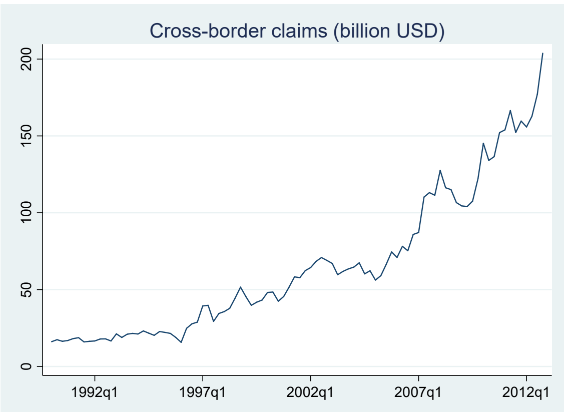
a) country A



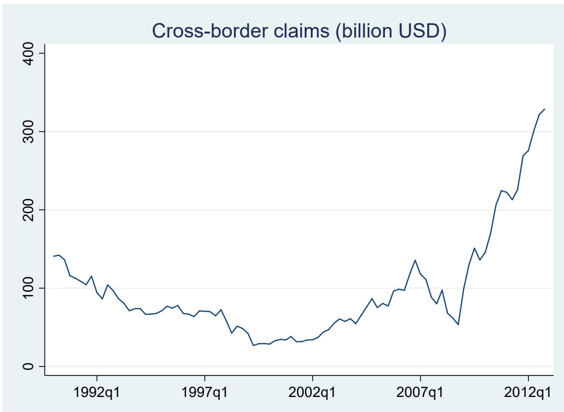
b) country B



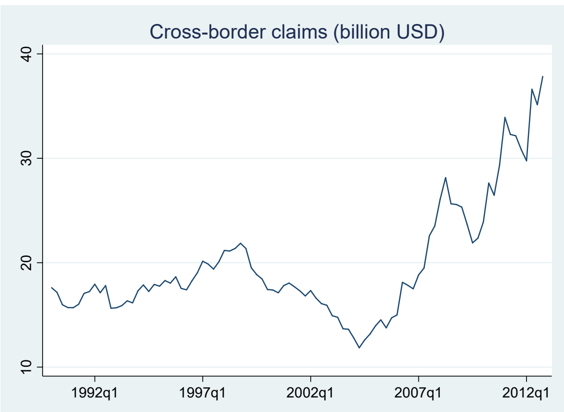
c) country C



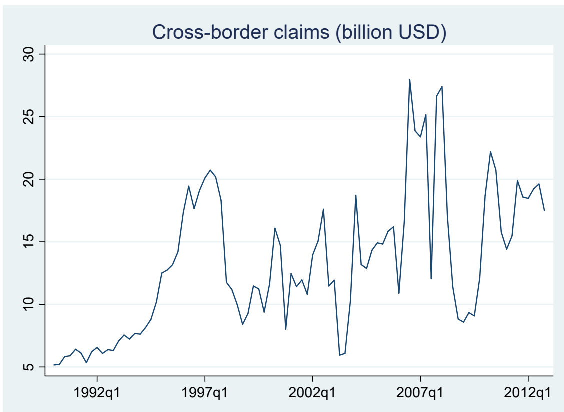
d) country D



e) country E

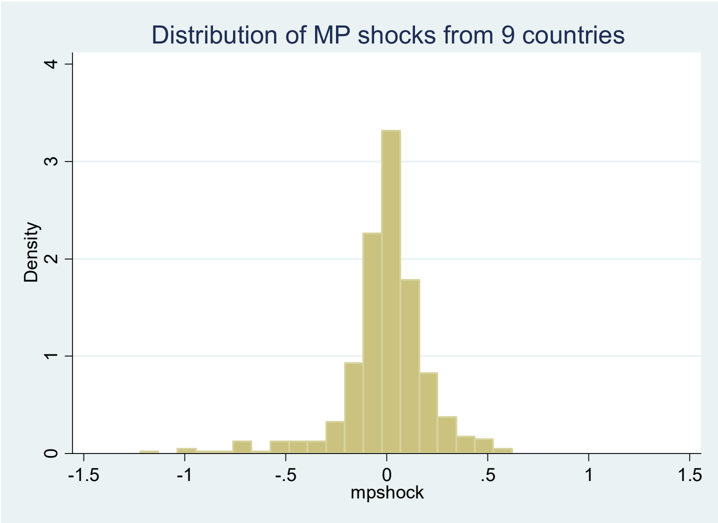


f) country F



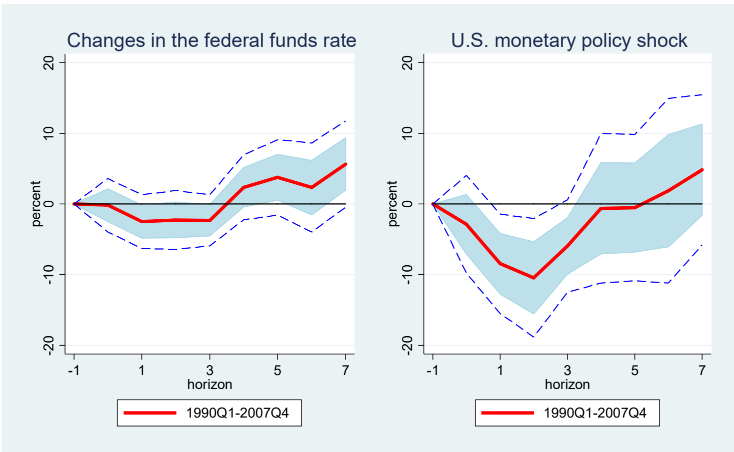
Note: Each graph shows bilateral exchange rate-adjusted cross-border claims between the U.S. and the corresponding recipient country from 1990Q1 to 2012Q4.

Figure A.3. Distribution of monetary policy shocks in 9 OECD countries (2001Q1-2012Q4)



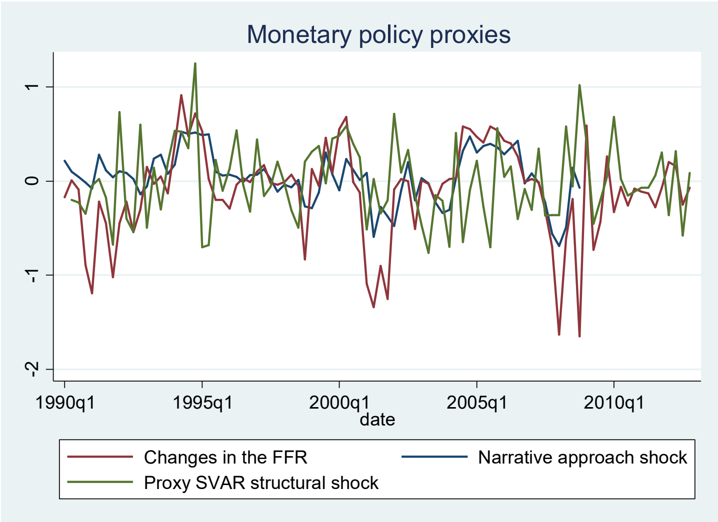
Note: The graph shows the distribution of exogenous monetary policy shocks in the nine OECD countries: Canada, Germany, Italy, Japan, the Netherlands, Spain, Sweden, the U.K, and the U.S. from 2001Q1 to 2012Q4.

Figure A.4. Effect of a U.S. monetary policy shock on cross-border bank lending (1990Q1-2007Q4)



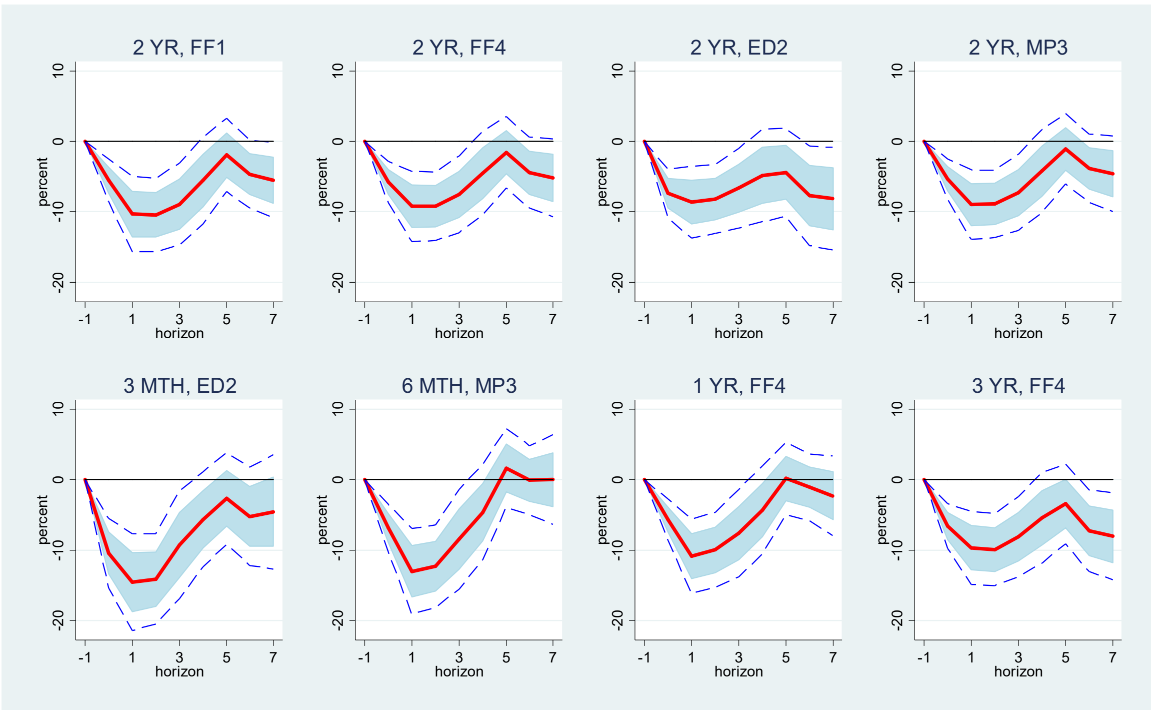
Note: The graph shows the response of cross-border bank lending to a 100 bp increase in the Federal funds rate (left panel) and the U.S. monetary policy shock (right panel) and their 68% and 90% confidence bands when the sample is restricted to 1990Q1-2007Q4. Horizon h=0 captures the impact of the shock, and the units are in percentage.

Figure A.5. U.S. monetary policy shock (narrative approach), U.S. monetary policy shock (proxy-SVAR structural shock), change in the Federal funds rate



Note: Measures of monetary policy changes: changes in the Federal funds rate, narrative shocks identified by Romer and Romer (2004) and Coibion (2012), proxy-SVAR identified shock using two-year treasury yield, instrumented with three-month ahead Fed funds futures.

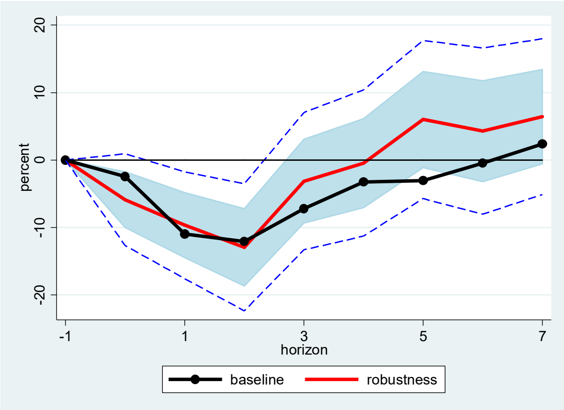
Figure A.6. Effect of a U.S. monetary policy shock (proxy-SVAR structural shock) on cross-border bank lending using a combination of policy indicators and instruments



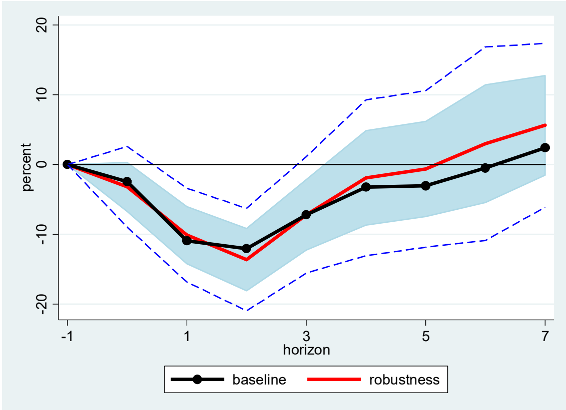
Note: Response of cross-border bank lending to a 100 bp U.S. monetary policy structural shock identified via proxy-SVAR and their 68% and 90% confidence bands. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure A.7. Effect of a U.S. monetary policy shock on cross-border bank lending: robustness checks

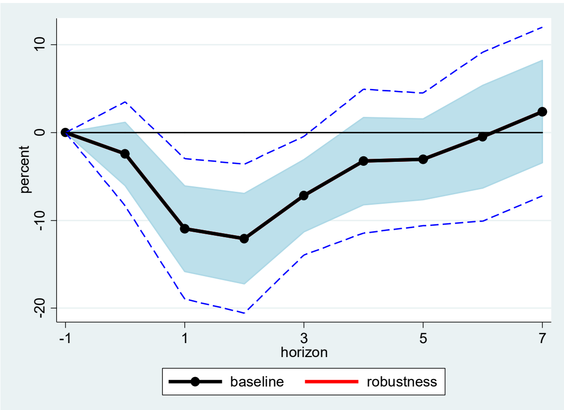
A) Controlling for domestic variables



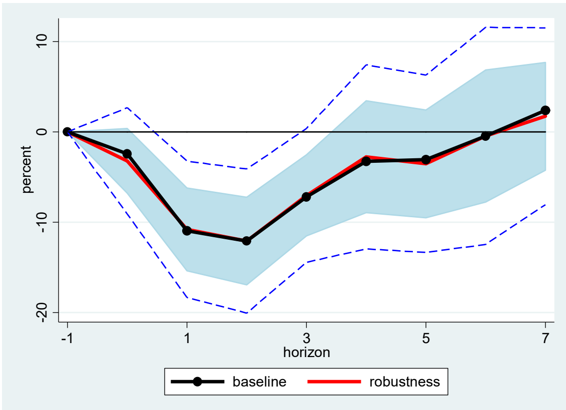
B) Using eight lags



C) Driscoll-Kraay standard errors

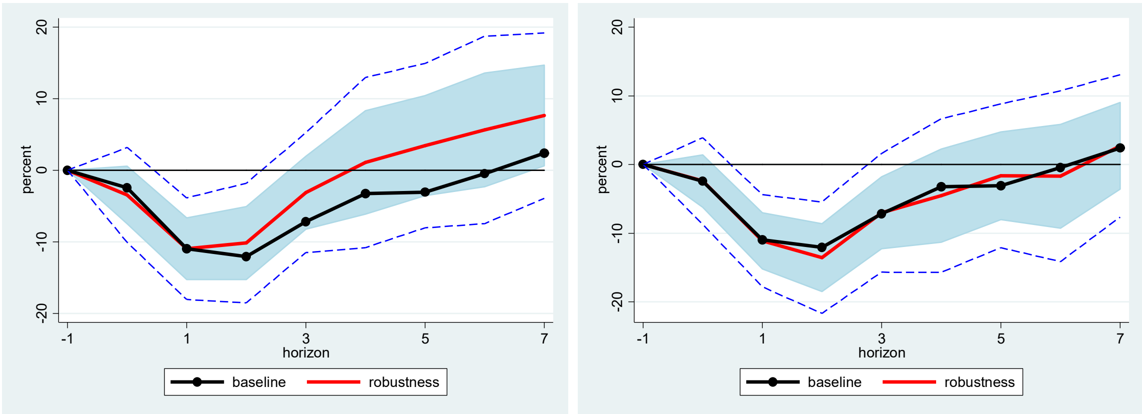


D) Controlling for bilateral trade flows



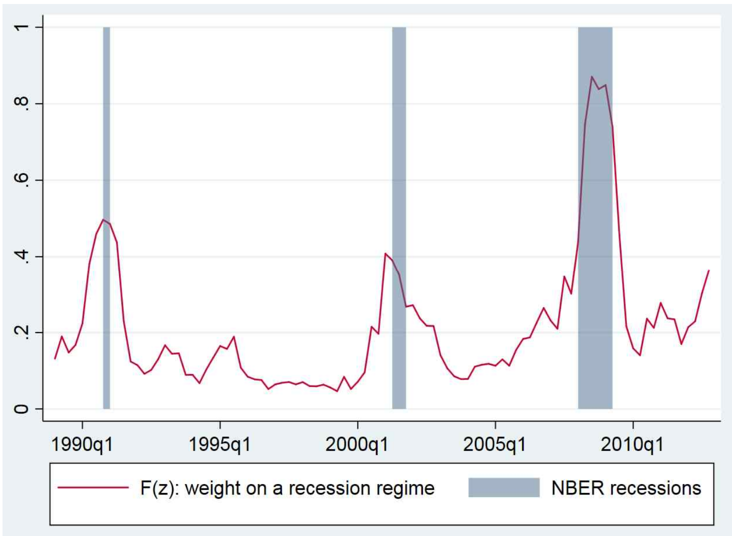
Note: Each panel shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure A.8. Effect of a U.S. monetary policy shock on cross-border bank lending: controlling for global financial risks (left) and liquidity risks (right)



Note: The graph shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands after controlling for global financial risks (left panel) and liquidity risks (right panel). Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

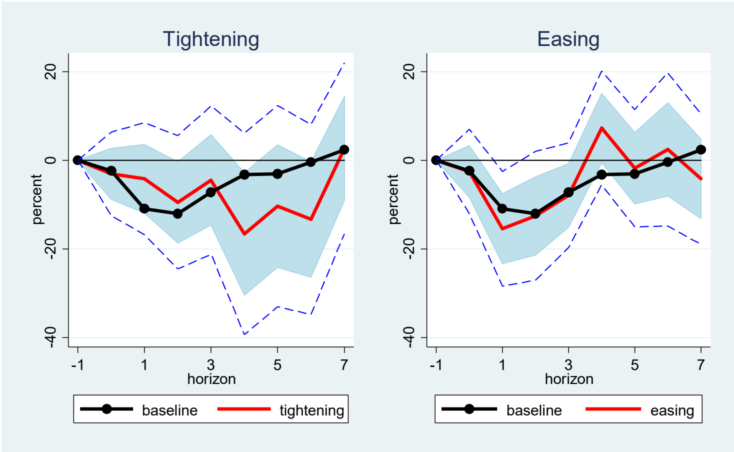
Figure A.9. NBER recession dates and the weight on a recession regime



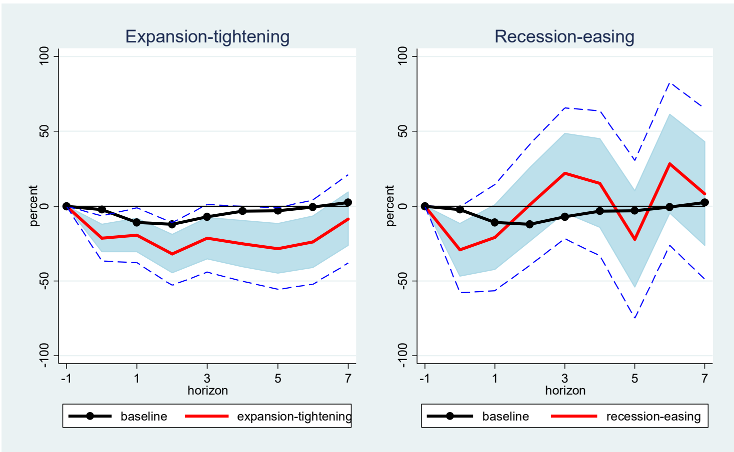
Note: The shaded areas indicate NBER recessions, while the red solid line denotes the weight on a recession regime.

Figure A.10. Non-linear effect of a U.S. monetary policy shock on cross-border bank lending

A) Tightening vs. easing

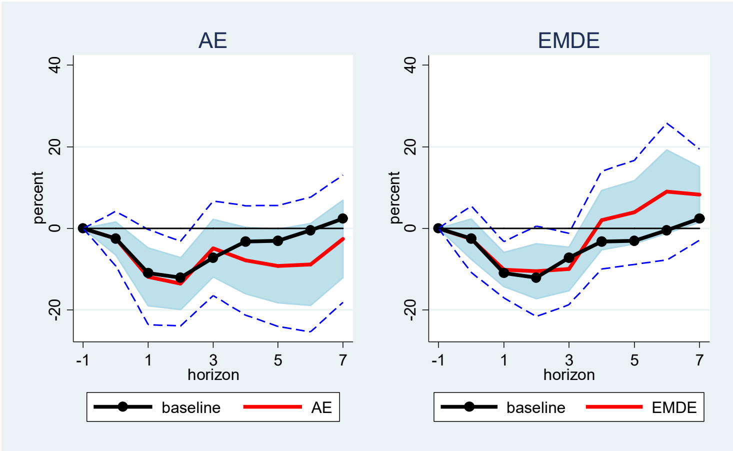


B) Tightening during expansions vs. easing during recessions



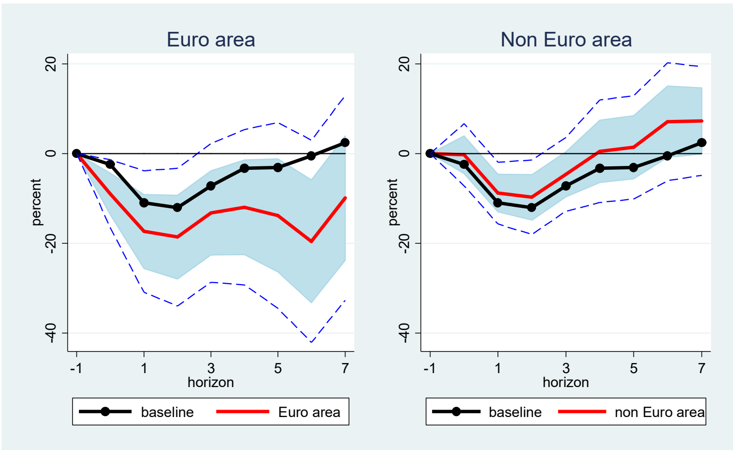
Note: The graph shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock of tightening (left) and easing (right) and their 68% and 90% confidence bands in the top panel and of tightening during expansions (left) and easing during recessions (right) in the bottom panel. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure A.11. Effect of a U.S. monetary policy shock on cross-border bank lending: advanced vs. emerging market recipient countries



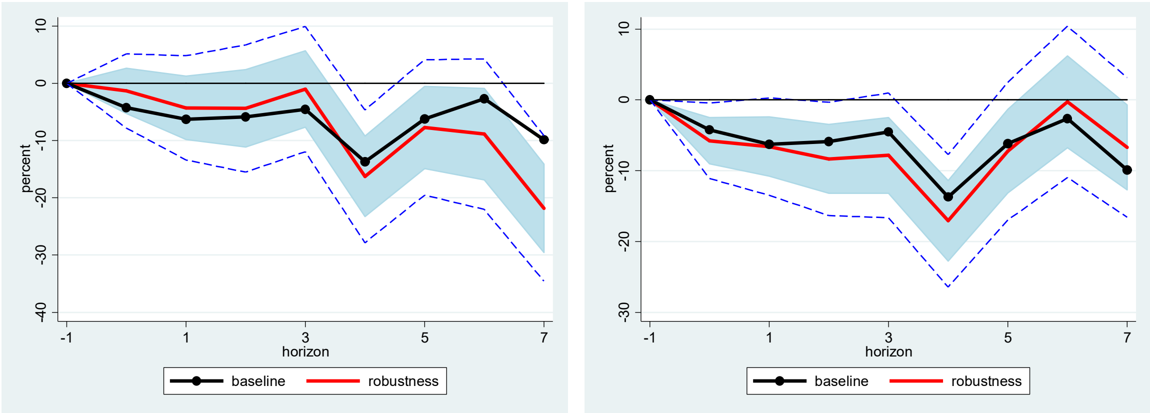
Note: The graph shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands. The left (right) panel shows the response of cross-border bank lending to borrowers in advanced (emerging market) economies. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure A.12. Effect of a U.S. monetary policy shock on cross-border bank lending: euro vs. non-euro area recipient countries



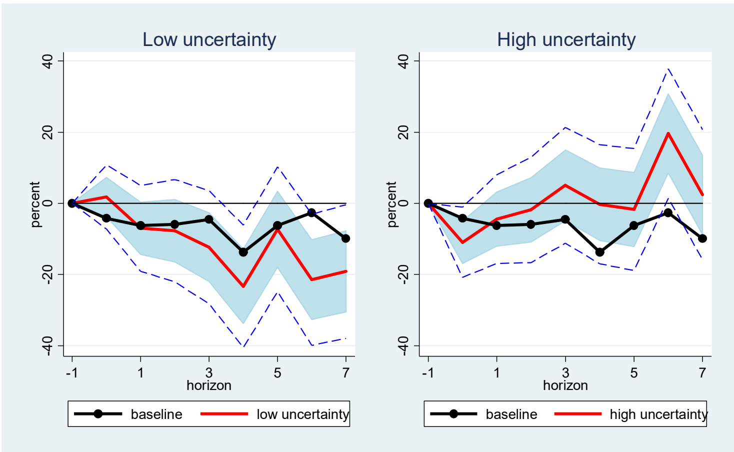
Note: The graph shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands. The left (right) panel shows the response of cross-border bank lending to borrowers in euro (non-euro) area countries. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure A.13. Effect of a monetary policy shock on cross-border bank lending from eight OECD countries: excluding other euro-area countries (left) and controlling for domestic controls (right)



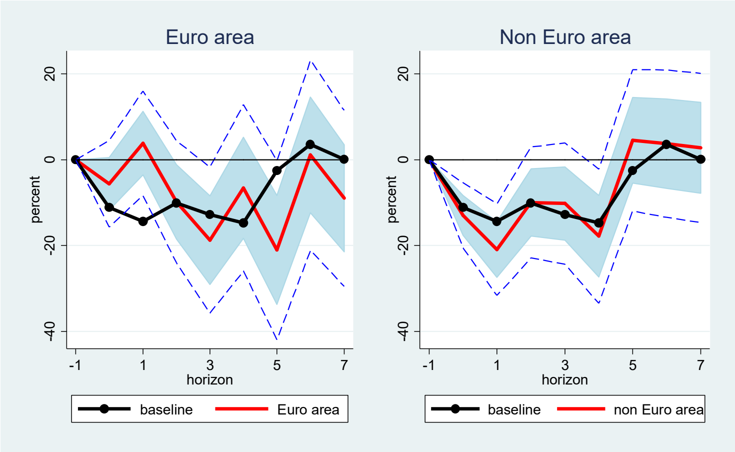
Note: The graph shows the response of cross-border bank lending to a 100 bp monetary policy shock and their 68% and 90% confidence bands in the eight OECD countries. The left panel corresponds to the case where the euro-area countries other than Germany (Italy, the Netherlands, and Spain) are dropped, while the right panel corresponds to the case where additional domestic control variables are included. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure A.14. Effect of a monetary policy shock on cross-border bank lending from eight OECD countries: low-uncertainty vs. high-uncertainty periods



Note: The graph shows the response of cross-border bank lending to a 100 bp monetary policy shock and their 68% and 90% confidence bands in the eight OECD countries during the low-uncertainty (left panel) and high-uncertainty (right panel) periods using the exogenous monetary policy shocks. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure A.15. Effect of a monetary policy shock on cross-border bank lending from the four euro-area countries: borrowers in euro vs. non-euro area countries



Note: The graph shows the response of cross-border bank lending to a 100 bp monetary policy shock and their 68% and 90% confidence bands in the four euro-area countries. The left (right) panel shows the response of cross-border bank lending to borrowers in euro (non-euro) area countries. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Appendix B. Estimation results from additional exercises

In this online appendix, we provide the estimation results from several additional exercises. While these results are not first-order important, they still provide some insights on the interpretation of the main results.

Domestic effect of U.S. monetary policy shocks. We enhance the credibility of the identified shocks by analyzing separately the effect of monetary policy shocks on domestic economic variables and check whether the responses are consistent with the theoretical prediction. As shown in Figure B.1, the results are generally consistent with Romer and Romer (2004) and Coibion (2012) despite some differences in the sample period. Consistent with the theoretical prediction, output and investment decline, while the nominal exchange rate appreciates in response to exogenous monetary policy tightening. Although we find a weak price puzzle on impact, the increase in CPI is not statistically significant.

We also analyze the response of domestic bank lending to the monetary policy shock to deepen the understanding of our findings. Under the bank lending channel of monetary policy, domestic bank lending must also decrease due to an increase in a bank's funding costs. We download domestic bank lending data "Bank credit to the private non-financial sector" from BIS and deflate them using U.S. CPI to obtain a real measure of bank lending.

Consistent with the prediction of the bank lending channel of monetary policy, we find a significant decline in domestic bank lending following monetary policy tightening. However, one should note that the magnitude of the response cannot be directly compared to the case of cross-border bank lending in the main text for two reasons. First, counterparty entities for domestic claims are the non-financial private sector, which is narrower than those in cross-border claims. Second, the estimation results in the main text are derived after controlling for a variety of fixed effects and covariates in recipient countries.

Econometric issues in the analysis of regressions with generated regressors. Econometric issues regarding the consistency in the estimated standard errors may arise because the shocks used in the baseline regression is an estimate (generated regressors). However, one should note that the shocks we use are the residuals, not the predictor from the first-stage regression. When the residuals are used as a shock, even an OLS estimate of the standard error is consistent (see Pagan, 1984 for detailed discussions on the issue of generated regressors). Nevertheless, we test the robustness of our findings by instrumenting changes in the federal funds rate using Romer and Romer (2004)'s exogenous shocks (i.e. residuals). For the analysis of other advanced economies, we also instrument policy rates using Furceri et al. (2018)'s exogenous shocks (i.e. residuals). These exercises not only alleviate the concern regarding the generated regressors but also allow more direct comparison with the literature using an IV approach. Figure B.2 confirms that our findings hardly change when this alternative approach is taken.

International transmission of monetary policy through the lens of Mundellian Trilemma. The increasing spillover effect of U.S. monetary policy and the importance of global financial cycles put the mighty Mundellian trilemma—which establishes the impossibility of the coexistence of a fixed exchange rate, free capital movements, and independent monetary policy—into a question and invoke heated debates regarding its relevance. On the one hand, Rey (2013) and Miranda-Agrippino and Rey (2019) claim that the floating exchange rate regime does not insulate a country from cross-border spillovers anymore. On the other hand, Aizenman et al. (2016) argue that trilemma policy arrangements, including exchange rate flexibility, continue to affect the sensitivity of recipient countries to policy changes and shocks in the center economies. In a related study, Han and Wei (2018) provide some reconciling evidence that the role of a recipient country's exchange rate regime, thereby the relevance of trilemma, depends on the sign of monetary policy shocks in the center countries. To further shed light on this debate, we expand equation (3) as follows:

$$y_{j,t+h} - y_{j,t-1} = \alpha_j^h + \beta_1^h D_{j,t} MPshock_t + \beta_2^h (1 - D_{j,t}) MPshock_t + \sum_{p=1}^{n} \gamma^h X_{j,t-p} + \varepsilon_{j,t+h}, \quad \text{(B.1)}$$

where $D_{j,t}$ is an indicator variable regarding the trilemma status of each recipient country j in time t and $X_{j,t}$ includes the four lags of $D_{j,t}$ in addition to the previous control variables.

As emphasized by Dedola et al. (2017), to the extent that the exchange rate regime or capital account openness varies over time, using the time-invariant characteristics—a common practice in VAR studies—could bias the results toward finding less stark difference driven by monetary policy shocks across country groups. In this case, the results in Rey (2013) and Miranda-Agrippino and Rey (2019) might be driven by a lack of statistical power to reject the dilemma hypothesis, rather than the ineffectiveness of a floating exchange rate regime in mitigating cross-border spillovers. Our local projections provide a fresh look on this debate in the literature since they allow the individual country's trilemma characteristics to change over time, thereby reducing potential measurement errors latent in the previous studies using VARs, such as Canova (2005), Dedola et al. (2017), and Miranda-Agrippino and Rey (2019).

We use the trilemma index constructed by Aizenman et al. (2013) to test how the Mundellian trilemma characterizes the degree of spillovers of U.S. monetary policy through the international bank lending channel. Their index quantifies the degree of achievement along the three dimensions of the trilemma hypothesis: exchange rate stability, monetary policy independence, and financial openness, thereby providing a comprehensive and consistent overview of an individual recipient country's trilemma status. Here, we describe each of the three indices only briefly. See Aizenman et al. (2013) for further details about the construction of the index and some caveats in its interpretation.

In principle, annual standard deviations of the monthly exchange rate between the home country and the base country are calculated to measure exchange rate stability and the index is normalized between zero and one.[40] The extent of monetary independence is measured as the reciprocal of the annual correlation of the monthly money market rates between the home country and the base country and normalized between zero and one. We use the updated version of the Chinn-Ito index (KAOPEN) to measure capital account openness (Chinn and Ito, 2008). Since KAOPEN is based upon reported restrictions, it is necessarily a de jure index of capital account openness.[41] Since a recipient country fixed effect will absorb any time-invariant recipient country characteristic in our specification, it is important to note that what we identify is the within variation in the time-varying trilemma index.

Figure B.3 reports the results from the first exercise and show that the effect of U.S. monetary policy shocks on cross-border bank lending does not significantly vary with the exchange rate regime and the degree of capital account openness. Consistent with Rey (2013) and Miranda-Agrippino and Rey (2019), the floating exchange rate regime does not insulate a country from cross-border spillovers of U.S. monetary policy shocks (as shown in panel A).[42] Although capital controls seem to moderate the spillovers, the difference between the two regimes is not statistically different (panel B). The only

[40] The base country is defined as the country that a home country's monetary policy is most closely linked with as in Shambaugh (2004). Since we are interested in the cross-border spillovers of U.S. monetary policy shocks, we use its base country's value with respect to the U.S. when the base country of a sample country is not the U.S. For example, since Belgium's base country is Germany, the Belgian exchange rate regime is floating vis-à-vis the U.S., although it is pegged to Germany.

[41] We focus on the KAOPEN measure of capital controls in Chinn and Ito (2008), updated in July 2017. KAOPEN is based on the four binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions: (i) capital account openness; (ii) current account openness; (iii) the stringency of requirements for the repatriation and/or surrender of export proceeds; and (iv) the existence of multiple exchange rates for capital account transactions. KAOPEN index's main merit is that it attempts to measure the intensity of capital controls insofar as the intensity is correlated with the existence of other restrictions on international transactions.

[42] We also use the updated version of binary regime classification by Shambaugh (2004) to sort out *de facto* pegged and floating exchange rate regimes for robustness checks. We use the most basic measure of the exchange rate regime employed in Shambaugh (2004). In Shambaugh's classification, a country is classified as pegged if its official nominal exchange rate stays within ±2 percentage bands over the course of the year against the base country. Non-pegs are also assigned a base determined by the country they peg to when they are pegging at other times in the sample. The floating regime does not necessarily include pure floats only but includes all sorts of non-pegged regimes. Probably due to the binary nature, we find even less stark difference in this case.

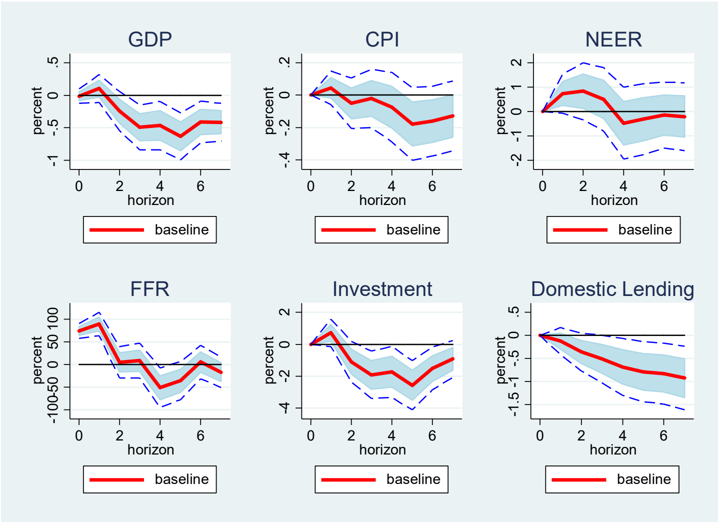
meaningful difference between the regime emerges when monetary policy independence is considered. Panel C shows that the spillover tends to be stronger when the recipient country maintains monetary policy independence (i.e., not increasing the interest rate in response to U.S. monetary policy tightening).

The insignificant difference across the exchange rate regime and the degree of capital controls might be driven by the high correlation between the two. Financial market development may lead a country to become more prepared to adopt greater exchange rate flexibility (i.e., abandoning peg) and open its capital markets to international investors. Indeed, the correlation between the average exchange rate stability index and the capital openness index is -0.54 (p-value of 0.005). Such a strong negative relationship is evidence of the so-called "binding" trilemma (Aizenman et al., 2013) and suggests that ignoring the mutual dependence would bias the estimation results.

Thanks to the flexibility provided by local projections, we can consider the effect of the exchange rate regime and capital account openness jointly. To sharpen the identification of the trilemma, we construct a two-by-two regime based on the interaction between the exchange rate stability index and capital account openness index. Figure B.4 shows that monetary policy spillovers tend to be the strongest in countries with a fixed exchange rate regime *and* open capital accounts than others. If anything, the spillover is close to zero over all the horizons for a recipient country with a floating exchange rate regime *and* closed capital account. Despite the large standard errors due to a decrease in the effective sample size in each regime, this finding corroborates the theoretical prediction of the trilemma. Thus, our findings somewhat reconcile the contrasting evidence regarding the dilemma vs. trilemma debate in recent literature.[43]

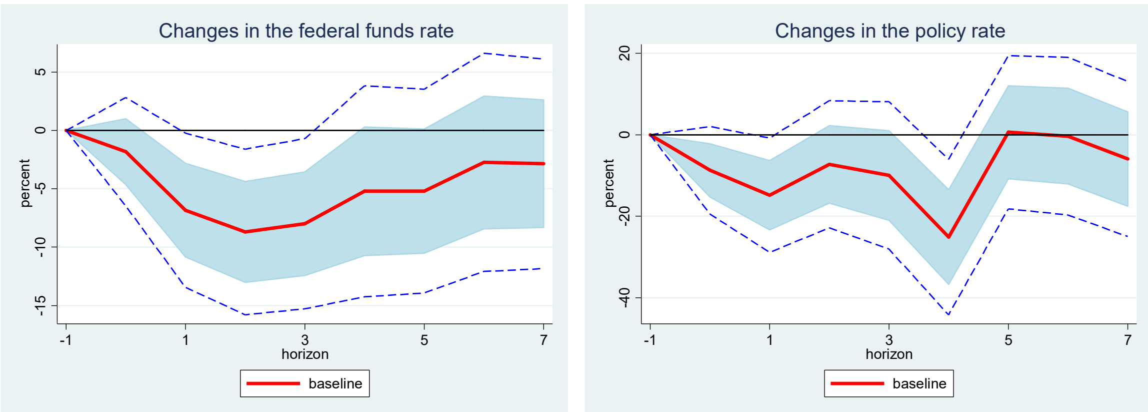
[43] Since the adoption of exchange rate regimes and measures of capital controls are an endogenous decision and certainly correlated with other structural characteristics of the economy, the evidence found in this paper is only suggestive and it calls for more careful analysis for future research.

Figure B.1. Effects of a U.S. monetary policy shock on domestic variables



Note: The graph shows the response of U.S. domestic variables to the 100 bp exogenous monetary policy shock. Horizon *h*=0 captures the impact of the shock, and the units are in percentage except for the Federal funds rate (in basis points).

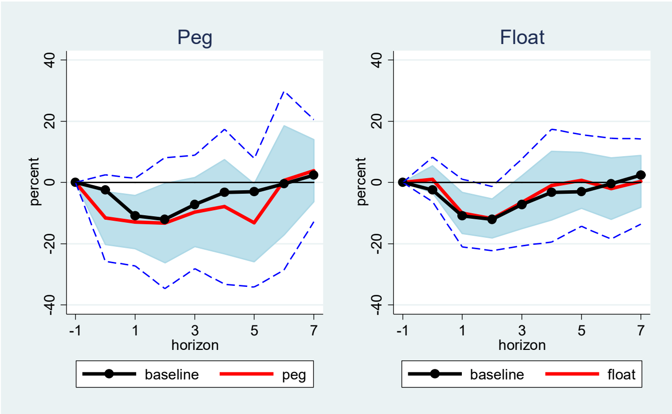
Figure B.2. Effect of a U.S. monetary policy shock (left) and other advanced economies' monetary policy shock (right) using an IV approach



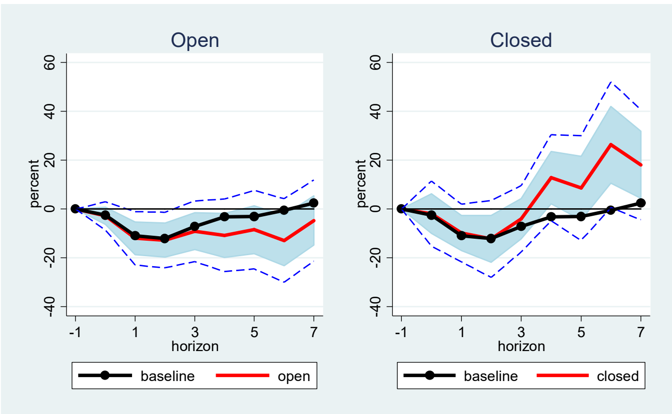
Note: The graph shows the response of cross-border bank lending to a 100 bp increase in the Federal funds rate using the exogenous variation from Romer and Romer (2004) as an instrument (left panel) and a 100 bp increase in policy rates in other advanced economies using the exogenous variation from Furceri et al. (2018) as an instrument (right panel). Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure B.3. Effect of a U.S. monetary policy shock on cross-border bank lending through the lens of Mundellian trilemma

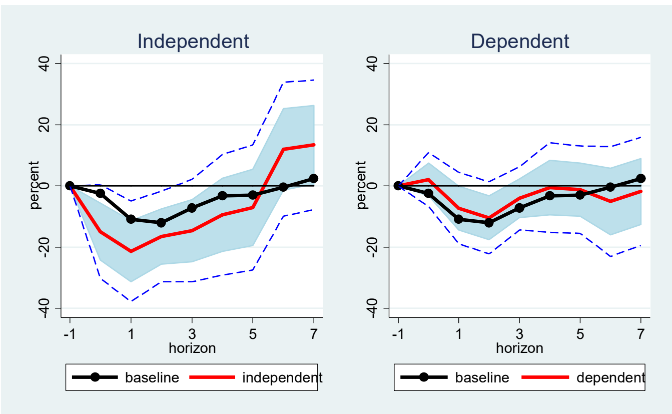
A) Exchange rate regime



B) Capital account openness

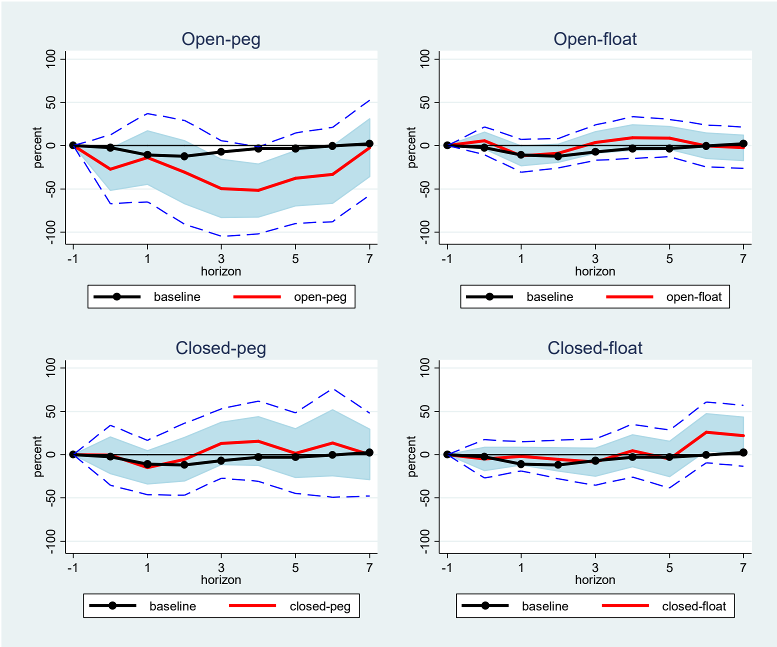


C) Monetary policy independence



Note: The graph shows the response of cross-border bank lending to 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

Figure B.4. Effect of a U.S. monetary policy shock on cross-border bank lending using the two-by-two regimes



Note: The graph shows the response of cross-border bank lending to a 100 bp U.S. monetary policy shock and their 68% and 90% confidence bands. Horizon *h*=0 captures the impact of the shock, and the units are in percentage.

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