Foreign Effects of Higher U.S. Interest Rates *

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Abstract

We analyze the effects of higher U.S. interest rates on economic activity in a large panel of 50 advanced and emerging economies. We allow the response of GDP in each country to vary according to its exchange rate regime, trade openness, and a vulnerability index that includes current account, reserves, inflation, and external debt. We document large heterogeneity in the response of advanced and emerging economies to U.S. interest rate surprises. In response to a U.S. monetary tightening, GDP in foreign economies drops about as much as in the U.S., with a larger decline in emerging economies than in advanced economies. In advanced economies, trade exposure to the U.S. and exchange rate regime account for a large portion of the contraction in activity. In emerging economies, the responses do not depend on exchange rate regime and trade openness, but are larger when vulnerability is high.

Keywords: U.S. Monetary Policy, Foreign Spillovers, Local Projection, Macroeconomic Transmission, Panel Data.

JEL Classification: F4, E5, C3

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1 Introduction

This paper presents new empirical evidence on the cyclical response of foreign economies to U.S. monetary shocks. We make use of a large dataset exploiting the time-series and cross-sectional variation of foreign economies in their trade exposure with the U.S., exchange rate regime with the U.S., and an index of their external vulnerability. Our goal is to gain some empirical sense of the differential importance of trade, exchange rate, and broad "financial" channels in response to changes in U.S. interest rates. Unlike previous studies that have focused on limited time periods, a few countries, or limited controls, we rely on a comprehensive dataset containing observations on quarterly GDP and time-varying country characteristics for 50 foreign economies for over 50 years. While data quality in international datasets varies systematically across countries and over time, we believe this is a reasonable price to pay for a dataset that, by exploiting nearly 10,000 observations, ends up being about two orders of magnitude larger than the typical dataset used to study the domestic effects of U.S. monetary shocks.

Figure 1 shows the Fed Funds Rate from 1965 through 2016. The shaded areas denote periods of rising interest rates. Figure 2 zooms in on the six tightening episodes prior to the Global Financial Crisis. The figure shows GDP growth in foreign economies for each episode relative to what one could have predicted using a simple forecasting model.[1] The bars for each country or country cluster measure average GDP growth (surprises) from the beginning of the respective episode until one year after its end. For instance, in panel 1, Canadian GDP growth from 1978q1 through 1982q2 was about 1 percentage point lower, on average, than what one could have predicted using data up to 1977q4.[2]

The non-uniform pattern of the bars across countries and episodes illustrates how the foreign aftermath of U.S. monetary tightenings varies greatly. The high interest rates of the late 1970s–early 1980s eventually led to lackluster growth in the U.S. and most foreign economies (panel 1). The tightenings of the 1980s were followed by weaker growth in many emerging market economies (EMEs, panels 2 and 3), but the situation was reversed with the higher interest rates of the mid–1990s, which were followed by stronger growth across the board (panel 4). The higher interest rates of the late 1990s were followed by lower growth among some emerging economies (panel 5). Finally, the most recent tightening period was followed by an acceleration in growth across all

[1] The forecasting model is, for each country, a univariate AR model for log GDP with 4 lags and a time trend for each country. To avoid cluttering, some economies are grouped ex post into regional clusters, with a bar for the average GDP response across them. Black bars denote the U.S., blue bars denote advanced economies, and red bars denote emerging economies.

[2] For each country, the regressions start in 1960q1 or later depending on data availability, and are estimated using the full sample. The forecasts are computed dynamically – using the coefficients estimated for the full sample – starting from the last observation prior to the monetary tightening. The dynamic forecasts do not use actual data but exploit the hindsight of knowing the estimated trend growth and AR coefficients for the full sample.

global economies (panel 6). Averaging across episodes, growth in U.S. and advanced economies was slightly higher than forecasted (+0.2 and +0.3 percent, respectively), whereas growth in emerging economies was slightly lower (-0.4 percent) in the years after these episodes. Additionally, the dispersion across episodes for emerging economies was twice as large as for advanced economies (2 vs 0.9 standard deviation). This large dispersion —across and between countries— suggests that not all tightenings are created equal. The nature of the tightening episode as well as country or region-specific characteristics could account for their heterogeneous responses.

This is the perspective adopted here. In the first step, we extract interest rate surprises using quarterly data from 1965 through 2016 to isolate exogenous movements in U.S. interest rates that are unlikely to be correlated with either domestic or global economic conditions.[3] In the second step, we study how the spillover of the interest rate surprises to foreign economies depends on three factors: exchange rate regime against the dollar, trade openness with the U.S., and an index of external vulnerability. We use a panel for 50 advanced and emerging economies, and estimate spillovers using a local projections method (Jorda, 2005). The interest rate spillovers are allowed to differ over time according to these three factors, and are allowed to differ across emerging and advanced economies.

The paper's main results can be summarized as follows:

1. The foreign effects of higher U.S. interest rates are large, and on average nearly as large as the U.S. effects. A monetary policy-induced rise in U.S. rates of 100 basis points reduces GDP in advanced economies by 0.5 percent, and GDP in emerging economies by 0.8 percent, after about three years. For reference, these magnitudes are in the same ballpark as the domestic effects of a U.S. monetary shock, which reduce U.S. GDP by about 0.7 percent after two years.

2. In advanced economies, the transmission mechanism from higher U.S. interest rates operates through standard trade and exchange rate channels. In particular, the responses within advanced economies are larger when a country's currency is (de facto) pegged to the dollar, or when its trade volume with the United States is high.

3. In emerging economies, trade and exchange rate channels explain little of the differential GDP responses within economies. Instead, a vulnerability index that we interpret as capturing a country's financial fragility explains a sizable component of differences across economies, with GDP in more vulnerable economies falling much more in response to a U.S. monetary tightening. This vulnerability index is constructed combining current account, reserves, inflation, and external debt.

[3]Most of our focus is on interest rate increases driven by monetary policy shocks. However, Section 6.1 discusses the effect of higher U.S. interest rates due to improved economic conditions.

Our estimation methodology exploits both the between- and the within-country variation in a set of observables that are often viewed as important determinants of the foreign spillovers of U.S. interest rate changes. Several studies that have recently examined the international effects of U.S. monetary actions using vector autoregressions or event studies (see e.g. Arteta, Kose, Ohnsorge, and Stocke (2015), Dedola, Rivolta, and Stracca (2017), Georgiadis (2016)) have relied on the implicit assumption that many country characteristics that determine such effects are fixed across the sample. Such an assumption is invalidated by the data for virtually all the variables that we consider in our sample, with all our indicators exhibiting far more variation within than across country borders. For instance, in the 1960s and 1970s, Mexico had a lower level of trade openness with the U.S. than Korea did, but Mexico's trade exposure grew by a factor of four in the decades since the NAFTA trade agreement, while Korea's openness remained constant. In a similar vein, several advanced economies were effectively pegged to the dollar prior to the collapse of the Bretton Woods system in 1971, and adopted a floating exchange rate regime afterwards. More recently, China abandoned its peg to the dollar in 2010, increasing its exchange rate flexibility. Studies that ignore time-variation in these country characteristics are likely to estimate the effects of interest rate changes with a large amount of noise.

Section 2 reviews the theoretical underpinnings on the international transmission of interest rate shocks. Section 3 describes the data. Section 4 discusses methodology and results on the effect of U.S. interest rates shocks. Section 5 extends our methodology to look at state-dependent effects of interest rate shocks. Section 6 contains robustness analysis. Section 7 contains a historical quantification of U.S. monetary shocks effect on foreign economies. We conclude in section 8.

2 Channels of International Interest Rate Transmission

2.1 The Channels...

Models of international interest rate transmission typically emphasize exchange rate channels, demand channels, and "financial" channels as key determinants of the response of foreign economies to changes in interest rates in another country.[4] The first two channels are a staple of virtually all general equilibrium, intertemporal models of macroeconomic policy transmission that merge Keynesian pricing assumptions and international market segmentation building on the Mundell-Fleming-Dornbusch framework.[5] The financial channels have been emphasized in recent work that

[4]We borrow this classification from Ammer, De Pooter, Erceg, Kamin, et al. (2016). Blanchard, Das, and Faruqee (2010) discuss a similar set of channels in accounting for the impact of the Global Financial Crisis on emerging economies. See also Kim (2001).

[5]See for instance the work of Obstfeld and Rogoff (1995) for a modern, micro-founded exposition of this framework.

has studied the international implications of various types of credit market frictions.[6]

The exchange rate channel is predicated on the idea of demand substitution between home and foreign-produced goods, and implies that higher interest rates in the U.S. may lead to an expansion of activity abroad. Consider, for instance, an increase in interest rates in the United States. Via the UIP condition, higher U.S. interest rates lead to an appreciation of the dollar. In turn, the stronger dollar moves the composition of world demand away from U.S. goods and towards goods produced in other countries. With flexible exchange rates, GDP in foreign economies should rise, boosted by cheaper exports. By contrast, a country that pegs its exchange rate to the dollar should experience an appreciation that lowers its GDP.

The trade channel rests on the idea that higher U.S. interest rates reduce incomes and expenditures in the U.S., thus leading to lower U.S. demand for both domestically produced and imported goods, and reducing activity and GDP abroad.[7] Overall, the strength of this channel should depend on the share of exports and imports in economic activity (the trade exposure), especially with the United States.

Financial channels capture the idea that higher U.S. interest rates can spillover to the price of various financial assets and liabilities held abroad, thus affecting activity in foreign countries even after controlling for exchange rate and trade channels. For instance, when domestic agents are credit constrained and hold dollar denominated debt, an increase in U.S. interest rates may lead to a deterioration of domestic balance sheets in the presence of flexible exchange rates.[8] A common theme behind the financial channels is that frictions that prevent intertemporal smoothing through foreign borrowing and lending may magnify the impact of foreign shocks for economies that are integrated with the world markets. These frictions can be exacerbated when the fundamentals of a country are weak. For instance, high inflation may create political instability and constrain domestic monetary and fiscal responses to adverse shocks. Similarly, a large current account deficit or low foreign exchange reserves may make put a country at risk of facing financial pressure from foreign lenders.

Recent work has also highlighted the importance of global factors that can propagate changes in monetary conditions in one country to the rest of the world, especially when capital markets are highly integrated. Rey (2015) and Miranda-Agrippino and Rey (2017) show that changes in interest rates in "core" countries can trigger a global financial cycle that, regardless of the exchange rate regime, may generate positive global spillovers. Bruno and Shin (2015) find evidence

[6]See for instance Aghion, Bacchetta, and Banerjee (2004) and Gertler, Gilchrist, and Natalucci (2007).

[7]See Erceg, Guerrieri, and Gust (2005) for a two-country DSGE model where demand shocks in one country yield positive output spillovers to another country via the trade balance channel.

[8]These "financial accelerator" effects may work even with fixed exchange rates. When a country pegs its exchange rate, the required rise in domestic nominal interest rate rises which is required to maintain the peg may lead to a significant rise in the country's real borrowing costs, which can induce a contraction in output which is further magnified by asset price channels operating through the financial accelerator.

of monetary policy spillovers on cross-border bank capital flows and the U.S. dollar exchange rate through the banking sector. This work highlights channels that seem to operate independently, and above, more traditional trade and exchange rate channels.

2.2 ...And How to Tell Them Apart.

Is it possible to tell these channels apart? Without loss of generality, consider an increase in U.S. interest rates driven by an exogenous monetary shock.

If the exchange rate channel is important, the exchange rate regime should explain a substantial portion of the cross-country variation in GDP response following an increase in U.S. interest rates. In particular, the traditional version of this channel predicts that a country that pegs its exchange rate to the dollar should experience a larger negative GDP response.

If trade channels are important, trade intensity with the U.S. should matter for the cross-country GDP response to higher U.S. interest rates, even after controlling for the exchange rate response. In particular, this channel predicts that higher levels of trade with the United States will lead to a larger GDP contraction in response to an increase in U.S. interest rates, as the decrease in U.S. demand spills over to the exports of the largest U.S. trading partners.

All other transmission mechanisms fall under the category of financial channels. By financial channels, we mean mechanisms that stem from the presence of various forms of market imperfections and that operate above and beyond the standard Mundell-Fleming-Dornbusch model. Suppose that we have already controlled for exchange rate regime and trade openness with the United States in assessing the foreign GDP response to U.S. interest rate shocks. We conjecture that, if additional financial variables can explain residual differences across countries in how they respond to U.S. interest rate changes, these additional variables are likely to capture the role of financial channels in international business cycles.

To what extent can we measure the strength of financial channels in the international transmission of monetary policy? Our strategy is to construct a summary indicator of variables that have a high probability of signaling the weakness in the economic fundamentals of a country. For practical purposes, these variables must be readily available and be somewhat consistently defined across countries and over time. In our empirical analysis, we focus on four variables—current account deficit, inflation, external debt and foreign reserves—. We combine these four variables in a summary indicator which combines them using equal weights, and which we label the **vulnerability index**.

The above classification is obviously a simplification, and we illustrate potential pitfalls with one example. It is possible that the exchange rate channel matters but not through the standard dollar anchoring classification that we use. For instance, the exchange rate channel might be

captured by trade invoicing, as discussed by Gopinath (2015).[9] U.S. monetary policy might matter because exports and imports are priced in U.S. dollars regardless of the exchange rate regime. Channels of this kind—or broadly-based confidence channels based on the outsize role of U.S. monetary policy—could also capture residual differences in the effects of higher U.S. interest rates, but we do not control for them in our analysis.

3 The Data

Our sample covers the period from 1965Q1 through 2016Q2.

3.1 GDP Data

Our main focus is on the effects of changes in U.S. interest rates on foreign real GDP. To this end, we put together a novel dataset containing quarterly GDP data for 50 foreign economies (25 advanced and 25 emerging) plus the United States. The coverage, which varies across countries, spans from as early as 1965Q1 to as late as 2016Q2.

Our benchmark analysis uses GDP data for the countries listed in Table 1 and spanning, for each country, the period between columns "first" and "last". For some emerging economies (and a few advanced ones), we extend backward the original, publicly available quarterly GDP series (available starting in the year listed in column "firstQ") using annual GDP data that are available from the World Bank's World Development Indicators. To convert the annual data into a quarterly frequency, we use Denton's proportional interpolation method (Chen et al., 2007). For emerging economies, the "indicator series" used for interpolation is PPP-weighted GDP of the emerging economies for which quarterly GDP data are available. A similar procedure is used for advanced economies, using PPP-weighted GDP of other advanced economies (excluding the United States).

3.2 Control Variables: Exchange Rate Regime, Trade Exposure, and Vulnerability Index.

Our analysis also focuses on how specific variables across countries affect the spillovers from interest rate changes to GDP outcomes. To this end, we compile data on exchange rate regime against the dollar, trade with the United States, and other variables for all the countries in the dataset. We use these data to construct indexes of (1) exchange rate exposure, (2) trade exposure, and (3) external vulnerability.

[9] Long-span information on trade invoicing is scant. Gopinath (2015)'s index of trade invoicing only starts in 1999.

1. For the exchange rate regime, we draw on the narrative analysis of Ilzetzki, Reinhart, and Rogoff (2017) and our own analysis of the literature to construct an index ranging from 0 to 1 for each country and period, where we classify a country as 0 if it maintains a flexible exchange rate against the U.S. dollar, 1/2 if it maintains an exchange rate band, and 1 if it pegs against the dollar. In other words, the index takes on higher values the "more" a country pegs its exchange rate to the dollar.

2. For each country, we measure its trade openness against the U.S. by taking the sum of exports to, and imports from, the United States, and dividing by GDP.

3. Our external vulnerability index is an equally-weighted average of four indicators that we use to measure the financial "health" of a country.[10] We refer to it as a vulnerability index.

   (a) Inflation is measured in each country by the year-on-year change in the headline consumer price index.

   (b) Current account deficit, expressed as a share of GDP.

   (c) External debt less foreign reserves, expressed as a share of GDP.

   (d) Foreign reserves, expressed as a share of GDP.

4 Average Effects of Higher U.S. Interest Rates

In this section, we estimate the foreign and domestic effects of higher nominal interest rates in the U.S. We consider higher rates as a scenario in which the policy rate is higher than what could have been forecasted by an estimated rule.[11] As we argue below, higher rates in the U.S. have sizable spillovers to foreign economics, especially for emerging market economies. In this section, we estimate the average international spillover of higher rates, while Section 5 discusses how this effect may depend on the economy's exposure to trade, exchange rate and financial vulnerability channels.

4.1 Identification of the U.S. Monetary Shock

We identify U.S. monetary shocks by regressing the Fed Funds Rate (FFR henceforth) on a set of controls, and then use the residual as the identified shock. In particular, we estimate shocks u_t as

[10] Some of these indicators are not available early in the sample, as shown in Table 1. To avoid dropping observations relative to our benchmark analysis, we fill in the missing observations using backward extrapolation. For instance, we assume that the current account position of a country in 1965-1969 is equal to its 1970 value. Repeating this analysis without filled-in observations yield nearly identical results to those reported in the paper.

[11] An alternative scenario of higher rates is one in which monetary policy endogenously responds to improved domestic conditions. We analyze the effects of this alternative scenario in Section 6.

the residual in following regression:

$$r_t = \theta_0 + \theta_1 Z_t + u_t \tag{1}$$

where r_t is the FFR. The set of controls Z_t include contemporaneous and lagged inflation, log GDP, corporate spreads, log GDP of foreign economies, as well as lagged values of the FFR, and a quadratic time trend.[12] Since we include current macroeconomic variables as controls, our shock identification is analogous to a Cholesky identification in a VAR that orders the FFR last, as done by Christiano, Eichenbaum, and Evans (2005) and others.[13] We use quarterly data from 1965Q1 to 2016Q2, and replace the FFR with the Wu-Xia Shadow Fed Funds Rate from 2009 to 2015 to account for the zero-lower-bound and for the stimulus to the economy provided by the unconventional monetary policy actions that followed the Great Recession.[14]

Figure 3 plots the identified monetary shocks. The largest contractionary shocks are in the early 1980s during the Volcker tightening period, and in 2008 at the onset of the zero-lower-bound era. In recent years, the identified shocks point to a tightening of policy in 2013, around the period of the taper tantrum, as well as to an easing in 2014 and 2015

4.2 Estimation of the Foreign Effects

With the identified monetary shocks at hand, we compute the dynamic responses of foreign and U.S. GDP using the local projection method developed by Jorda (2005). This method allows us to compute the response of variables to shocks at different horizons without imposing many structural restrictions. This flexibility can be easily extended to estimate state-dependent responses, which eases comparison with the next section when computing responses as a function of the economy's exposure to interest rate shocks.[15]

For computing the response of U.S. GDP, we estimate the following equation:

$$y_{t+h} = \alpha_h + \beta_h u_t + A_h Z_t + \epsilon_{t+h} \qquad \text{for } h = 0, 1, 2, \ldots, H \tag{2}$$

where y_{t+h} is U.S. GDP in quarter $t+h$, u_t is the monetary shock, and Z_t are a set of controls. A plot of $\{\beta_h\}$ is the dynamic response of U.S. output to an innovation in u_t. We also estimate equation (2) using the FFR as y_{t+h} to compute its response to the identified shock. In both cases,

[12] We use four lags for all variables. Inflation is measured as the 4-quarter change in the GDP deflator. Corporate spreads correspond to the difference between the Moody's Seasoned Baa Corporate Bond Yield and the 10-Year Treasury Note Yield at Constant Maturity. We use PPP-weighted foreign economies GDP.

[13] Our results below are robust to using the Romer and Romer (2004) shock. See Section 6.

[14] See Wu and Xia (2016) for details.

[15] See, for instance, Auerbach and Gorodnichenko (2013) for a recent example of state-dependent multipliers estimation using Jorda (2005) method.

the set of controls Z_t includes four lags of y_t and a quadratic time trend.

We take advantage of the panel dimension when computing the foreign GDP response to the monetary shock. In particular, we estimate a version of (2) as follows:

$$y_{i,t+h} = \alpha_{i,h} + \beta_h u_t + A_{h,i} Z_{i,t} + \epsilon_{i,t+h} \qquad \text{for } h = 0, 1, 2, \ldots, H \tag{3}$$

where $y_{i,t+h}$ is the GDP of country i in quarter $t+h$, and $\alpha_{i,h}$ is a country-specific fixed effect. Notice that we project all countries on the same shock u_t. Accordingly, $\{\beta_h\}$ measures the average response of output across countries to an innovation in u_t. Controls $Z_{i,t}$ include four lags of country's i GDP, as well as a linear and a quadratic trend.[16]

We are interested in documenting how responses to higher U.S. rates may change for advanced and emerging economies. To this end, we estimate equation (4) separately for advanced foreign economies (AFE) and emerging market economies (EME).

4.3 Results: U.S. Monetary Policy Matters

Figure 4 shows the response of U.S. GDP, the FFR, and foreign GDP to a monetary shock. The shaded areas denote 68 percent confidence intervals and are based on robust standard errors that account for serial correlation (in the case of the U.S. responses) and for clusters by time and country (in the case of the foreign responses).[17] A shock that increases the FFR by one percentage point induces a lasting decline in U.S. GDP, which contracts output by 0.7 percent after two years and recovers thereafter. This magnitude and duration of the U.S. output response to a monetary shock is largely in line with previous findings in the literature (Ramey, 2016).

The dynamic response of GDP in advanced foreign economies (AFEs) follows a similar profile to the U.S. one, but is smaller and more delayed: at the trough, GDP drops by about 0.5 percent three years after the shock. The GDP response of emerging economies (EMEs) to the monetary shock is as delayed as the advanced economies (AFEs) response, but eventually as large as the one in the U.S., with GDP falling 0.7 percent four years after the shock. All told, the results highlight how emerging economies are more exposed than advanced economies are to higher U.S. interest rates.

[16] We let the coefficients on the controls $Z_{i,t}$ to be country-specific. Assuming common coefficients across countries makes foreign responses to U.S. monetary shocks marginally larger than in the specification presented here.

[17] We calculate the confidence bands using the Driscoll and Kraay (1998) standard errors that already allow arbitrary correlations of the error term across countries and time.

5 Foreign Effect of Higher U.S. Interest Rates: Disentangling the Channels of Transmission

We turn now to estimating how the dynamic response to a monetary shock depends on the country characteristics that determine the strength of trade, exchange rate, and financial channels.

5.1 Methodology

Consider a set of variables $v \in \mathcal{V}$ that measure the exposure of an economy to higher U.S. interest rates, and let higher values of v represent higher exposure. To estimate how exposure affects the economy's response to a monetary shock, we extend the specification in equation (3) so that the identified shock interacts with the measures of exposure. In particular, we estimate the following equation:

$$y_{i,t+h} = \alpha_{i,h} + \beta_h u_t + \sum_{v \in \mathcal{V}} \beta_h^v \left(e_{i,t-1}^v u_t\right)^{\perp} + A_{h,i} Z_{i,t} + \epsilon_{i,t+h} \qquad \text{for } h = 0, 1, 2, \ldots, H, \tag{4}$$

where $e_{i,t}^v$ is the exposure index for variable v. Above, the interaction term $\left(e_{i,t-1}^v u_t\right)^{\perp}$ is constructed so that β_h captures the response to a shock when the exposure measures are at their median values, and β_h^v represents the marginal response to the shock when exposure $e_{i,t-1}^v$ is high.

We construct the interaction term $\left(e_{i,t-1}^v u_t\right)^{\perp}$ in five steps. First, we standardize each exposure variable $v_{i,t}$ by subtracting its mean and dividing by its variance. [18] Second, we construct a logistic transformation of the standardized variable $(v_{i,t}^s)$ as $\ell_{i,t}^v = \frac{\exp\{v_{i,t}^s\}}{1+\exp\{v_{i,t}^s\}}$. Third, we re-center $\ell_{i,t}^v$ in terms of the distance between its 50^{th} and its 95^{th} percentile: $e_{i,t}^v = \frac{\ell_{i,t}^v - \ell_{50}^v}{\ell_{95}^v - \ell_{50}^v}$, where ℓ_p^v corresponds to the p^{th} percentile of $\ell_{i,t}^v$. Fourth, we construct the interaction term $\left(e_{i,t-1}^v u_t^r\right)$. Finally, we orthogonalize $\left(e_{i,t-1}^v u_t^r\right)$ using a recursive procedure: for the first exposure variable v_1, we regress $\left(e_{i,t-1}^{v_1} u_t^r\right)$ on $[u_t, \quad Z_{i,t}]$ and obtain the residual $\left(e_{i,t-1}^{v_1} u_t^r\right)^{\perp}$; for the second variable v_2, we regress $\left(e_{i,t-1}^{v_2} u_t^r\right)$ on $\left[u_t, \quad Z_{i,t}, \quad \left(e_{i,t-1}^{v_1} u_t^r\right)^{\perp}\right]$ and obtain the residual $\left(e_{i,t-1}^{v_2} u_t^r\right)^{\perp}$; and successively with the other exposure measures.[19]

The standardization step puts all exposure variables on a comparable scale. The logistic transformation maps variables to the unit interval which allows us to consider them in distri-

[18] The standardization is a simple device to put all variables on equal footing, and follows the lead of many, including Auerbach and Gorodnichenko (2013) and Herrera and Garcia (1999).

[19] More generally: for the n^{th} exposure variable v_n, we regress $\left(e_{i,t-1}^{v_n} u_t^r\right)$ on $\left[u_t, \quad Z_{i,t}, \quad \left(e_{i,t-1}^{v_1} u_t^r\right)^{\perp}, \quad \left(e_{i,t-1}^{v_2} u_t^r\right)^{\perp}, \ldots, \quad \left(e_{i,t-1}^{v_{n-1}} u_t^r\right)^{\perp}\right]$ and obtain the residual $\left(e_{i,t-1}^{v_n} u_t^r\right)^{\perp}$. This procedure is known as regression by successive (Gram-Schmidt) orthogonalization. See for instance Balli and Sørensen (2013) for an application to regressions with interaction effects.

butional/probabilistic terms.[20] The re-centering step allows us to interpret the coefficients as deviations from median levels of exposure. In particular, β_h is the response to the shock when all exposure indexes are at its median value, and $\beta_h + \beta_h^v$ is the response when the exposure index $e_{i,t}^v$ is at the 95^{th} percentile of its distribution.

The orthogonalization step eases interpretation and comparison with Section 4.3. In particular, since all the interaction terms are orthogonal to the shock u_t^r, the β_h estimated in equation (4) is identical to the one from equation (3). Thus, we keep on considering $\{\beta_h\}$ as the average response to the shock. Furthermore, because each additional exposure measure is orthogonal to the previous ones, we can interpret β_h^v as the marginal effect of variable v on the pass-through of the monetary shock to foreign GDP when v moves from the 50th to the 95th percentile of its distribution.

5.2 Exposure Variables

In practice, we consider three measures of exposure that capture the three channels discussed in Section 2.

1. Exchange Rate Channel: we construct a variable measuring the degree to which a country's currency is pegged to the dollar. The variable equals 0 when a country has a flexible exchange rate against the dollar, 0.5 if the country pegs against the dollar within a somewhat large band ($+/-5$ percent), and 1 if the country is closely pegged to the dollar (including a $+/-2$ percent band). We consider countries with a higher degree of anchoring to the dollar as more exposed to U.S. monetary shocks, since higher U.S. rates would induce an appreciation of the dollar –and thus, the domestic currency – which depresses their GDP by making imports cheaper and exports more expensive. The median observation in our sample for advanced economies is a flexible exchange regime, which applies to 80 percent of the country-quarter observations. Instead, the median for emerging economies is a system with a close anchor to the dollar, which applies to 55 percent of the observations.[21]

2. Trade Channel: we measure the amount of trade with the U.S. (exports plus imports) as a fraction of the country's GDP. Note that the median amount of trade with the U.S. is about 3.5 percent of GDP for advanced economies (such as the U.K. in the 2000s), and around 10 percent of GDP for emerging economies (such as Chile in the 2000s).

3. Financial Channel: we construct a *vulnerability index* as an equally-weighted average of the

[20] The logistic transformation is a simple manner to estimate the state-dependent effect of shocks that has been extensively used in recent work. See Auerbach and Gorodnichenko (2017) and Ramey (2016) and citations therein.

[21] Ilzetzki et al. (2017) also note that, by their classification, the U.S. dollar scores by a wide margin as the world's dominant anchor currency.

following four variables: current account deficit, reserves (entering with a negative sign), inflation, external debt.[22]

A large current account deficit may limit the willingness of foreign lenders to extend credit, or may even trigger sharp capital outflows, especially in the presence of high interest rates abroad. Additionally, evidence from Claessens, Dell'Ariccia, Igan, and Laeven (2010) indicates that large current account deficits raise the incidence and severity of a crisis.

Both reserves and external debt are popular among credit risk agencies and international organizations to assess the external vulnerability of a country. See for instance Santacreu (2015). Additional, there is evidence that both variables are important in capturing the sensitivity of an economy to adverse shocks. For instance, Frankel and Saravelos (2012) suggest that central bank reserves are one of leading indicators in explaining crisis incidence across different countries. Lane and Milesi-Ferretti (2017) indicate that excessive reliance on debt finance may increase a country's actual and perceived vulnerability.

Although not a direct measure of financial channels, we also include inflation—measured by the annual change in the consumer price index—in our vulnerability index. High inflation may indicate structural problems in a government's finances, or could generate political instability which in turn acts as an amplifier of higher U.S. interest rate effects. High inflation may also increase the sensitivity of a country's borrowing costs to changing interest rates: for instance, Cantor and Packer (1996) find that inflation is a significant determinant of sovereign ratings.

For each variable, we take a 3-year moving average and truncate observations on both sides at a 5% threshold in order to remove outliers and to guard against extreme measurement error—to us, it seems immaterial whether a country has a 100 or a 1,000 percent inflation rate. The three exposure measures are constructed separately for advanced and emerging economies.

Table 2 presents summary statistics for the exposure variables in our analysis. The vulnerability index is constructed so that it takes on high values when inflation, external debt and the current account deficit are high, and when reserves are low.

To give a visual impression of the evolution of these indicators, Figure 5 plots the recent evolution of the three exposure measures for a selected sample of countries.[23] The figure showcases the evolution over time and across countries of our exposure measure, which allows us to measure the heterogeneous effects of U.S. interest rates. The top left panel shows how Canada, Japan,

[22] As an alternative to an equally-weighted average, we also considered the first principal component. The results were qualitatively and quantitatively similar to those presented here.

[23] In particular, we plot the logistic transformation of the original exposure variables after the second step, that is after truncation and before re-centering.

and the U.K. have at some point in the past abandoned their peg to the dollar.[24] Canada, for instance, was closely pegged to the dollar until 2002, kept a managed floating regime between 2002 and 2010, and moved to a floating exchange regime thereafter.

The orthogonalization procedure merits some discussion. This procedure is a convenient method to illustrate the marginal effect of each exposure variable after controlling for the others. However, it also implies that the particular ordering of the exposure measures matters. We choose the ordering in a way that conforms closely to the historical evolution of the channels. The exchange rate channel is perhaps the most intuitive and natural, and we order it first. The trade channel matters over and above the exchange rate channel, and we order it second. Finally, the financial channel is a residual channel that captures forces that operate beyond the standard channels, and we order it last. That said, there is little correlation in the data across our exposure measures. Therefore, we experimented with different orderings and found very similar quantitative results.

5.3 Results: Exposure Matters

Figure 6 shows the foreign GDP response to a monetary shock, as well as the marginal effects of varying each exposure measure from its median value to the 95th percentile.

The left column shows how the exchange rate channel affects the responses of foreign economies. For advanced economies, moving from the median—corresponding to a flexible exchange rate regime vis-a-vis the dollar— to the high end of the distribution—corresponding to a dollar peg—more than doubles the drop in GDP following an adverse U.S. monetary shock. The response among the "high-peg" countries is mostly representative of the early part of the sample, when a large fraction of advanced economies were de facto pegged to the dollar. By contrast, the response of emerging economies is less sensitive to whether they peg to the dollar or not. We illustrate this point in the bottom left panel of Figure 6. One twist in the figure is that, for emerging economies, "median" and "high" response both identify countries that are anchored to the dollar: nevertheless, the response of countries that are not pegged (shown by the black "low exposure" line) exhibits a similar pattern, with a delayed decline in GDP which bottoms out three years after the monetary shock.

The middle column shows the role of the trade channel. For advanced economies, trade intensity with the United States is an important determinant of the spillovers of U.S. monetary shocks. For instance, moving from the U.K.'s (median) to Canada's (high) trade openness with the U.S. (see Figure 5) doubles the negative response. For emerging economies however, trade intensity with the U.S. matters little. Moving from Korea's current trade exposure with the U.S. –a value close to the

[24] See Ilzetzki et al. (2017), which we draw on for our classification.

median—to Mexico's trade exposure with the U.S.—a value of the upper end of the distribution—increases the GDP decline only marginally.

The right column shows the importance of the financial channels. In both advanced and emerging economies, a high degree of the vulnerability index increases the spillovers. This effect is particularly pronounced for emerging economies. Here, moving from a median to a high level of vulnerability more than doubles the GDP response.

Taken at face value, the traditional Mundell-Fleming-Dornbusch view of foreign spillovers is consistent with the response of advanced economies. However, such a view appears at odds with the response of emerging economies, where trade and exchange rate exposure to the United States matter only little. By contrast, the financial channels seem very important for emerging economies, much more so than for advanced ones.

To shed further light into the contribution to foreign spillovers of the subcomponents of the index, Figure 7 illustrates the individual contribution of the four indicators entering the vulnerability index, when they are increased from their median value to their 95th percentile of the distribution. The four indicators have little explanatory power for the responses of advanced foreign economies, although a higher current account deficit and higher inflation are associated with a slightly larger GDP decline following a contractionary U.S. monetary policy shock. By contrast, in emerging economies all four indicators—inflation in particular—have explanatory power in enhancing the response of GDP to a U.S. shock.

We next provide additional evidence for the channels by investigating how other foreign variables respond to a U.S. monetary shock. These exercises are shown in Figures 8 and 9 for foreign real exchange rate indexes and foreign short-term interest rates, respectively.[25]

In Advanced Economies (top panels of Figures 8 and 9), the exchange rate and the interest rate responses follow textbook predictions. The exchange rate appreciates for countries that peg to the dollar, while it depreciates for the (majority of) countries that maintain a flexible exchange rate regime. Peggers increase their interest rate almost one-for-one with the U.S. rate, which leads to an overall appreciation of their currencies. For peggers, the large increase in interest rates causes a large decline in GDP. In experiments not reported here, we have also found that real exports drop more in countries that peg against the dollar and in countries that trade more with the United States.

In Emerging Economies (bottom panels of Figures 8 and 9), the real exchange rate appreciates, and policy rates increase: although the peak increase of policy rates is about 50 basis points, policy rates increase much more persistently than even the United States. These effects occur regardless of the exchange rate regime. It is perhaps puzzling that the results for emerging economies suggest

[25]Note that here we plot trade-weighted real exchange rates (with higher values meaning appreciation), which can move even if a country pegs against the dollar.

a significant appreciation of their real exchange rate in response to a U.S. monetary tightening. To us, this puzzling result follows from the persistent increase in domestic interest rates in emerging economies.

6 Robustness

This section focuses on studying how the results regarding the foreign effects of an interest rate increase vary as we consider alternative sources of interest rate increases, alternative samples, or alternative monetary shocks.

6.1 Demand Shocks

Figure 10 shows the impulse responses when the source of higher interest rates is a U.S. demand rather than a U.S. monetary shock. We compute the aggregate demand shock as the residual of a U.S. log GDP equation using the same set of controls as with a monetary shock, but including only lags of the variables. The demand shock is better understood as any combination of supply and demand factors that increases U.S. GDP within the quarter after controlling for past domestic and foreign activity. U.S. GDP and U.S. interest rates (not plotted) increase respectively by 1 percent and by 0.8 percentage points, before gradually returning to the baseline. The increase in the U.S. interest rate is in line with what one could expect from an endogenous response in monetary policy (as would be implied, for instance, by a Taylor rule).

When the source of higher interest rates is a U.S. demand shock, the initial foreign response is positive, although the "foreign multiplier" is smaller for emerging than for advanced economies. In emerging economies, the positive spillovers of a positive demand shock are quickly offset by higher U.S. interest rates, and GDP falls below baseline after about one year.

6.2 Alternative Samples and Alternative Monetary Shocks

We now explore the robustness of the foreign effects of monetary policy shocks around our benchmark specification, which we use as a reference point.

Figure 11 shows the results when we allow the foreign effects of U.S. monetary shocks to differ between the pre-1985 and post-1985 period.[26] We choose the breakpoint following a large literature dating the mid-1980s as the beginning of the Great Moderation in the United States.[27] We find more uncertain effects of monetary shocks for the United States in the post-1985 period,

[26] Note that we re-estimate the monetary policy rule that we use to extract the monetary shocks across the two different subsamples.

[27] See for instance McConnell and Perez-Quiros (2000) and Iacoviello, Schiantarelli, and Schuh (2011).

as shown by the larger confidence intervals around the point estimates. The results for advanced and emerging economies portray a similar picture: GDP initially increases in both blocs, before falling substantially below baseline after two to three years. Importantly, in both subsamples the maximum GDP decline is larger in emerging than advanced economies, in line with the evidence for the full sample. Additionally, the larger uncertainty around the estimates in the later sample echoes several studies that find that after the 1980s the effects of monetary policy shocks have become more uncertain and harder to interpret (see e.g. Ramey (2016)).

It is interesting to compare the subsample results with the implications of our full-sample estimates that allow for time-varying exposure measures. Specifically, we compute the impulse responses for each subsample by setting AFE and EME exposure indexes to their average values in the two subsamples. The results using the median "exposure by period" are shown by the brown lines in Figure 11. According to this alternative set of estimates, the effects of monetary shocks on advanced and emerging economies should have become slightly smaller in the second half of the sample, mostly because advanced economies have moved on average towards a "more flexible" exchange rate regime, and because emerging economies have become "less vulnerable" in the second part of the sample. However, caution must be used in comparing the two sets of estimates. When we split our sample, we are allowing for changes both in the monetary policy rule and in the effects of deviations from that rule. By contrast, the results that only vary the exposure by period implicitly keep the systematic component of U.S. monetary policy unchanged, thus ignoring the effects of a change in the monetary policy rule itself.

Additional robustness exercises are shown in Figure 12. In the top panel, we show the results when we replace the monetary shocks identified using the benchmark specification with the updated Romer and Romer (2004) shocks as constructed by Ramey (2016) for the period 1969-2007 (we use quarterly averages of the original monthly values).[28] The results are very similar across exercises, showing that the our baseline findings are robust to alternative methods of identifying monetary policy surprises.

In the middle panel, we return to our benchmark specification but truncate the sample in 2007Q4, in order to limit ourselves to the pre-zero lower bound period. The results excluding the zero lower bound period are similar to the benchmark results.

In the lower panel, we change the quarterly interpolation method for the observations on GDP that are available at annual frequency only. In particular, we retain Denton's interpolation method, but assume that log GDP follows a linear trend within the quarters of the year (subject to the constraint that the sum of quarterly GDP equals annual GDP). As the panel shows, the

[28] Rudebusch (1998) argues that VAR-based measures of monetary shocks make little sense, since they appear at odds with narrative evidence on the nature of the Fed's reaction function and since they show little correlation across specifications.

results barely change.

7 The Historical Contribution of U.S. Interest Rates to Foreign Activity

Up to now, we have focused on the question of understanding the nature of foreign spillovers of U.S. monetary shocks. A related question is: how have U.S. monetary policy shocks contributed, historically, to fluctuations in activity in foreign economies?

Figure 13 presents the historical contribution of the estimated U.S. monetary shocks to GDP in some selected economies, based on the coefficient estimates of equation (4), and starting in 1975 (to avoid cluttering). The bars measuring the median contribution are common across all economies in the advanced bloc, and across all economies in the emerging bloc, and illustrate the contribution of U.S. monetary surprises to GDP growth in these economies over the sample. The marginal contribution of exchange rate, trade and financial channels varies across economies and over time, reflecting changes in exposure. For instance, a comparison in the top row between Canada and Japan illustrates the somewhat larger role of U.S. monetary shocks to business cycles in Canada because of Canada's large trade exposure with the United States. By contrast, in the bottom panel, much of the disparity between Mexico and Korea reflects differences in their vulnerability index. For instance, the positive contribution of expansionary monetary policy shocks around 2014, in the aftermath of the taper tantrum, benefits Mexico more than it benefits Korea, reflecting Mexico's larger values of the vulnerability index.

8 Conclusions

Our results shed light on the relative importance of financial, trade, and exchange rate channels in propagating the effects of U.S. interest rate shocks around the world. The traditional Mundell-Fleming-Dornbusch view of foreign spillovers is consistent with the response of advanced economies. However, such a view appears at odds with the response of emerging economies, where trade and exchange rate exposure to the United States do not seem to matter. By contrast, the financial channels are very important for emerging economies, in addition to having a non-negligible effect on advanced ones.

Our findings also highlight the bright and the dark side of foreign responses to U.S. interest rate increases. On the dark side, these responses seem to be large, to the point that they suggest that foreign economies—especially vulnerable, emerging economies—may react to U.S. monetary shocks more so than the U.S. economy itself. On the bright side, they illustrate how countries

that succeed in keeping their financial house in order can weather foreign shocks relatively better than their vulnerable counterparts.

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Table 1: Data Availability

	GDP			Dollar Peg		Trade U.S.		Curr.Acct.		Reserves		Inflation		Ext.Debt	
Country	**first**	**firstQ**	**last**	**first**	**last**	**first**	**last**	**first**	**last**	**first**	**last**	**first**	**last**	**first**	**last**
Argentina	1965	1993	2016	1965	2016	1971	2016	1970	2016	1970	2016	1965	2016	1970	2016
Australia	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Austria	1965	1970	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Belgium	1965	1970	2016	1965	2016	1965	2016	1994	2016	1970	2016	1965	2016	1970	2016
Botswana	1965	1994	2016	1965	2016	1974	2016	1974	2016	1975	2016	1965	2016	1975	2016
Brazil	1965	1990	2016	1965	2016	1982	2016	1970	2016	1970	2016	1965	2016	1970	2016
Canada	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Chile	1965	1996	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
China	1965	1992	2016	1965	2016	1972	2016	1981	2016	1976	2016	1965	2016	1980	2016
Colombia	1965	2000	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Czech Republic	1990	1996	2016	1965	2016	1993	2016	1992	2016	1992	2016	1971	2016	1992	2016
Denmark	1965	1966	2016	1965	2016	1965	2016	1970	2016	1970	2016	1967	2016	1970	2016
Ecuador	1965	1990	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
El Salvador	1965	1990	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Finland	1965	1970	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
France	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Germany	1970	1970	2016	1965	2016	1970	2016	1970	2016	1970	2016	1965	2016	1970	2016
Greece	1965	1970	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Hong Kong	1965	1990	2016	1965	2016	1965	2016	1997	2016	1970	2016	1965	2016	1978	2016
Hungary	1991	1995	2016	1965	2016	1991	2016	1991	2016	1991	2016	1967	2016	1991	2016
Iceland	1965	1997	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
India	1965	1996	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Indonesia	1965	1984	2016	1965	2016	1967	2016	1970	2016	1970	2016	1965	2016	1970	2016
Ireland	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Israel	1965	1995	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Italy	1965	1970	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Japan	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Jordan	1975	1992	2016	1965	2016	1975	2016	1975	2016	1975	2016	1970	2016	1975	2016
Korea	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Luxembourg	1965	1965	2016	1965	2016	1997	2016	1970	2016	1983	2016	1965	2016	1989	2016
Malaysia	1965	1991	2016	1965	2016	1966	2016	1970	2016	1970	2016	1965	2016	1970	2016
Mexico	1965	1980	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Netherlands	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
New Zealand	1965	1965	2016	1965	2016	1965	2016	1977	2016	1977	2016	1965	2016	1977	2016
Norway	1965	1970	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Peru	1965	1980	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Philippines	1965	1981	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Poland	1990	1995	2016	1965	2016	1990	2016	1990	2016	1990	2016	1971	2016	1990	2016
Portugal	1965	1965	2016	1965	2016	1965	2016	1971	2016	1970	2016	1965	2016	1971	2016
Singapore	1965	1975	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
South Africa	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Spain	1965	1970	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Sweden	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Switzerland	1965	1965	2016	1965	2016	1965	2016	1980	2016	1980	2016	1965	2016	1980	2016
Taiwan	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1976	2016
Thailand	1965	1993	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
Turkey	1965	1987	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
United Kingdom	1965	1965	2016	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016
United States	1965	1965	2016	1965	2016			1970	2016	1970	2016	1965	2016	1970	2016
Venezuela	1965	1997	2015	1965	2016	1965	2016	1970	2016	1970	2016	1965	2016	1970	2016

Data coverage for each of the variables included in the panel.

Table 2: Summary Statistics for the Exposure Measures

	Advanced Economies			**Emerging Economies**		
Exposure Variables	*5%*	*Median*	*95%*	*5%*	*Median*	*95%*
Exchange Rate Regime vs Dollar	0	0	1	0	0.85	1
Trade Openness with U.S., %	1.3	3.5	17.8	1.9	9.8	34.4
Inflation Rate	0.6	3.4	18.3	0.6	7.5	88.2
Current Account Deficit, % of GDP	-6.9	0.3	4.9	-8.5	0.5	4.4
Reserves, % GDP	0.4	2.3	16.5	0.4	5.1	66.1
External Debt minus Reserves, % of GDP	2.1	29.9	361.6	-31.4	11.4	75.0

All variables computed as 12-quarters moving averages. The exchange rate regime ranges from zero (flexible exchange rate vis-à-vis the dollar) to one (fixed regime). Trade openness is the sum of nominal merchandise imports and nominal merchandise exports, divided by nominal GDP. The vulnerability index is an equally-weighted average of a logistic transformation of inflation, current account deficit, reserves (with a negative sign), and external debt.

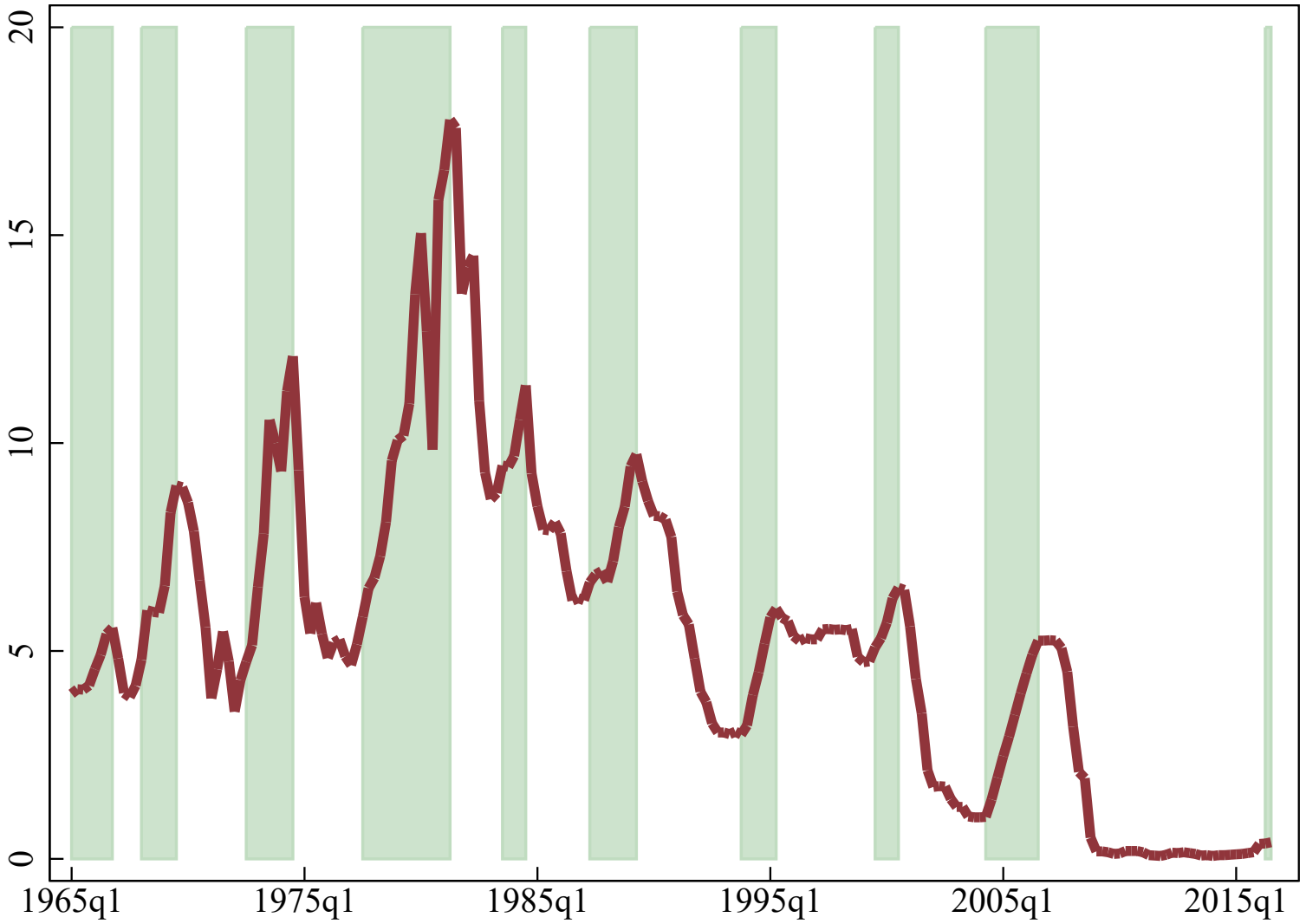

Figure 1: The Federal Funds Rate (FFR) from 1965Q1 through 2016Q2

Note: The shaded areas denotes periods of interest rate tightenings. A quarter t contains a tightening if it satisfies any of the following criteria: (1) the FFR does not fall in t and must have risen by at least 20 and 40 basis points in quarters $t-1$ and $t-2$; (2) the FFR does not fall by more than 30, 20 and 10 basis points in t, $t-1$, and $t-2$, does not fall in $t+1$, and rises by at least 20 and 30 basis points in $t+2$ and $t+3$; (3) the FFR rises by at least 100 and 200 basis points in $t-3$ and $t-2$, and rises by at least 100 basis points in $t+2$.

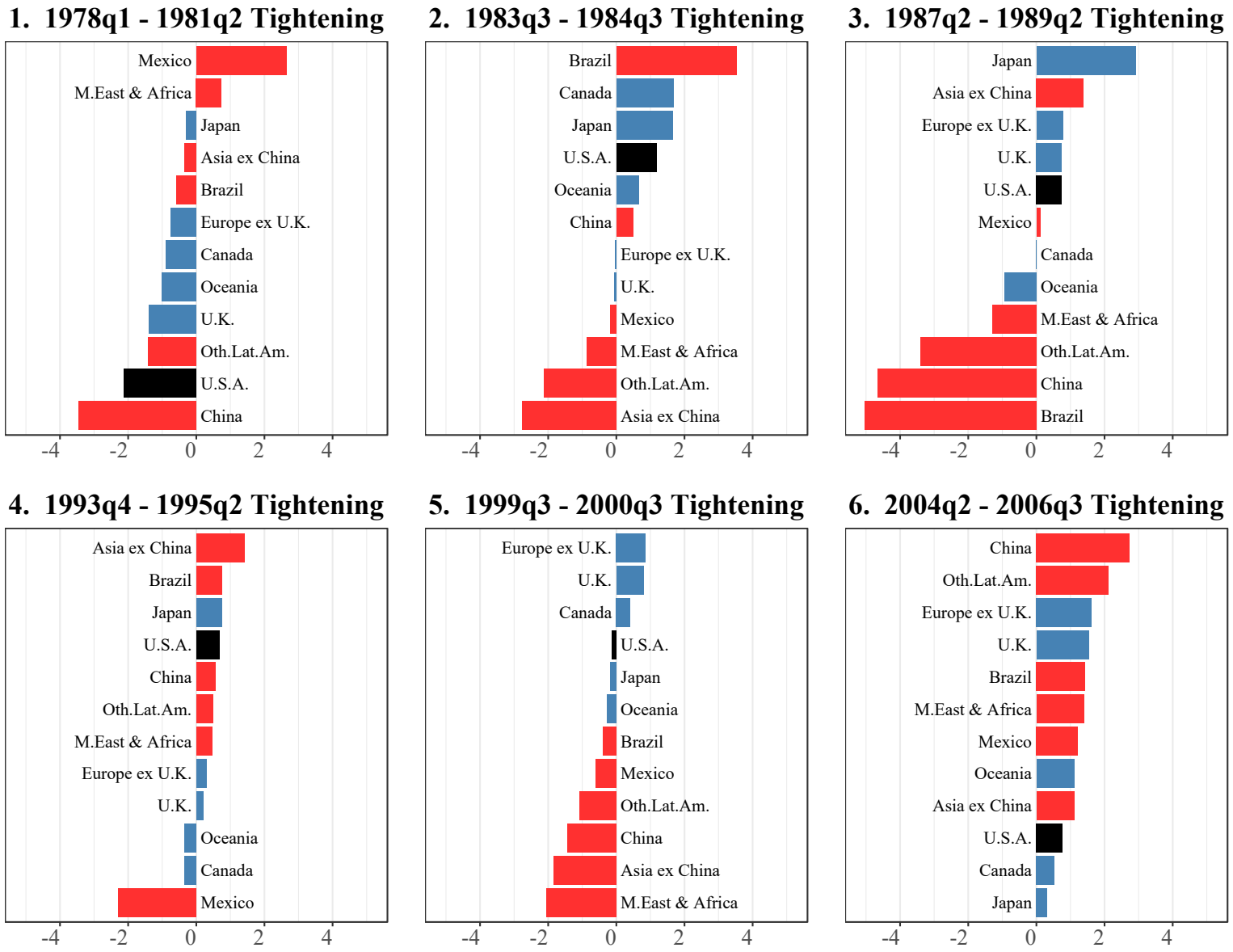

Figure 2: Foreign GDP Growth Relative to Forecast After U.S. Interest Rate Increases

Note: Annual GDP growth surprises (actual minus forecast) in each region relative to ARIMA model in the aftermath of selected U.S. monetary policy tightenings.

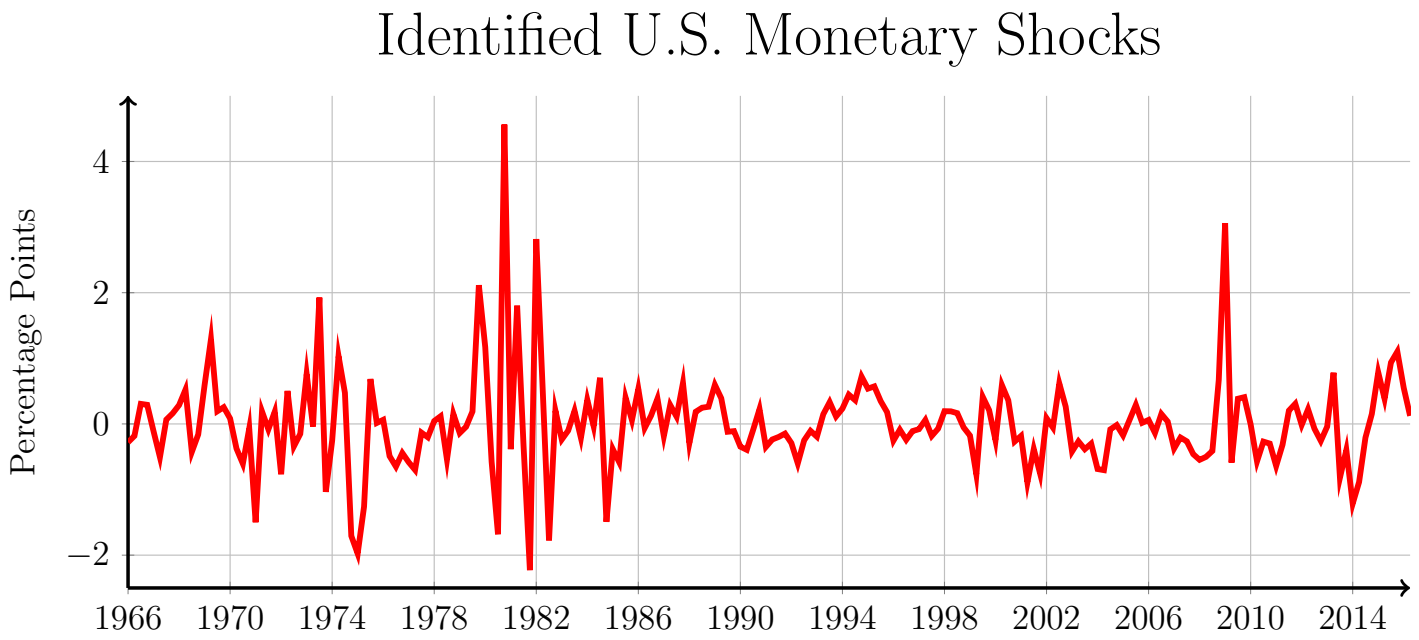

Figure 3: Identified Monetary Shocks

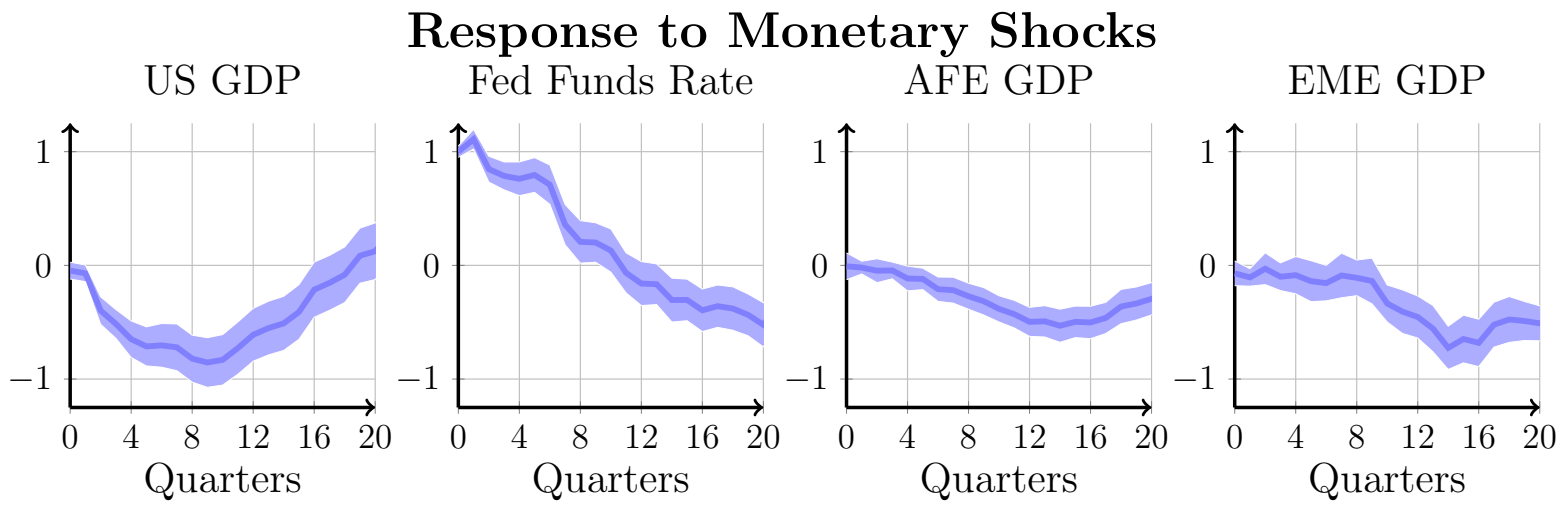

Figure 4: IRF Response to Monetary Shocks

Note: Impulse Response to a U.S. Monetary Shock in the Benchmark Specification. AFE denotes Advanced Foreign Economies, EME denotes Emerging Economies. GDP in percent deviation from baseline. Fed Funds Rate in percentage points. The shaded areas denote 68 percent confidence intervals.

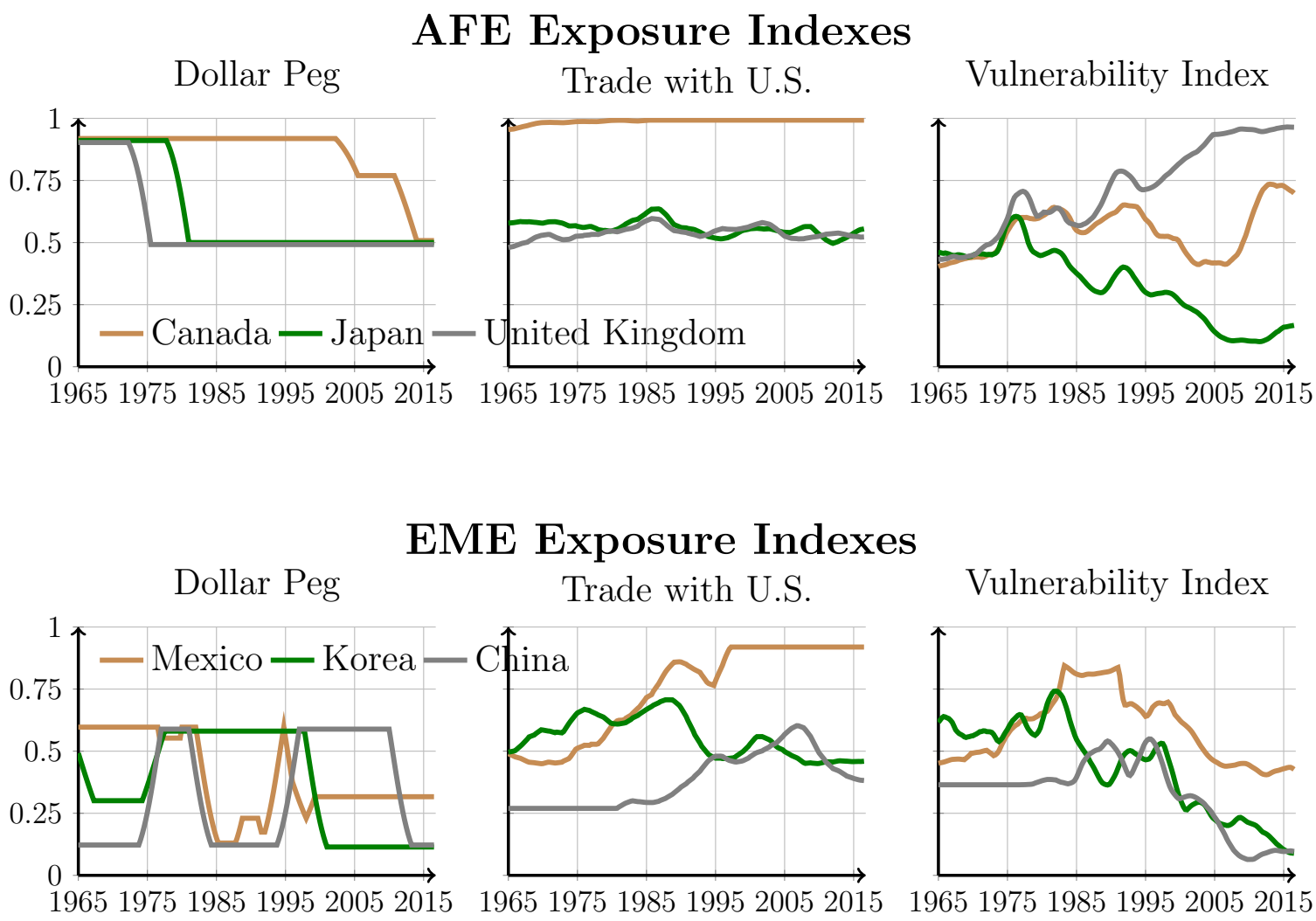

Figure 5: Evolution of the Exposure Indexes for six countries

Note: The indexes are constructed separately for Advanced and for Emerging Economies. The Vulnerability Index is the first principal component of Inflation, minus GDP growth, and current account deficit. (Loadings are shown in Table 2.)

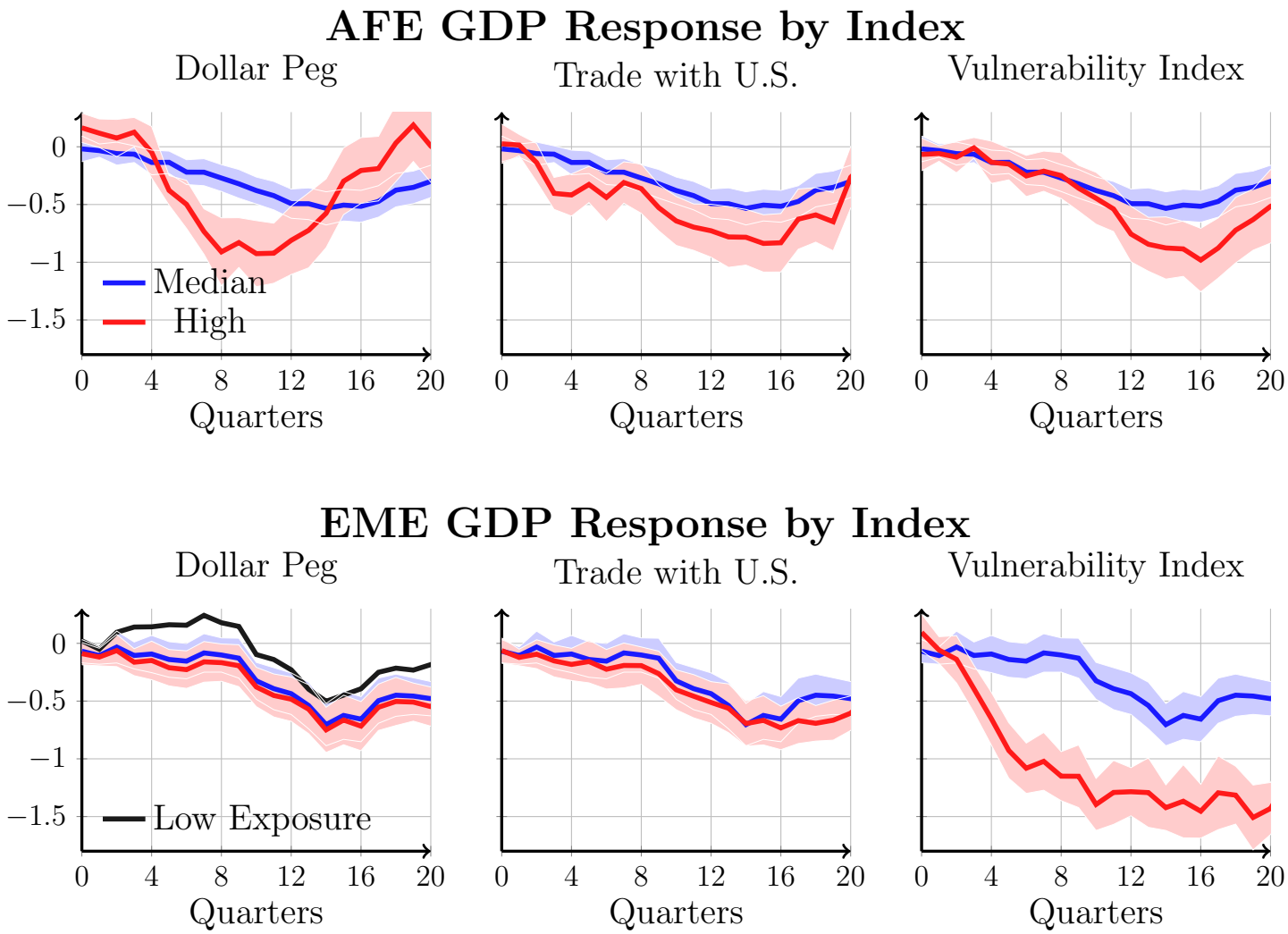

Figure 6: GDP Response (in percent) to a Monetary Shock by Index

Note: The "Median" response is the GDP response of an economy with values for each index equal to the median value, as reported in Table 2. The "High" response is the response of an economy with values for each index equal to the 95th percentile, as reported in Table 2. The shaded areas denote 68 percent confidence intervals.

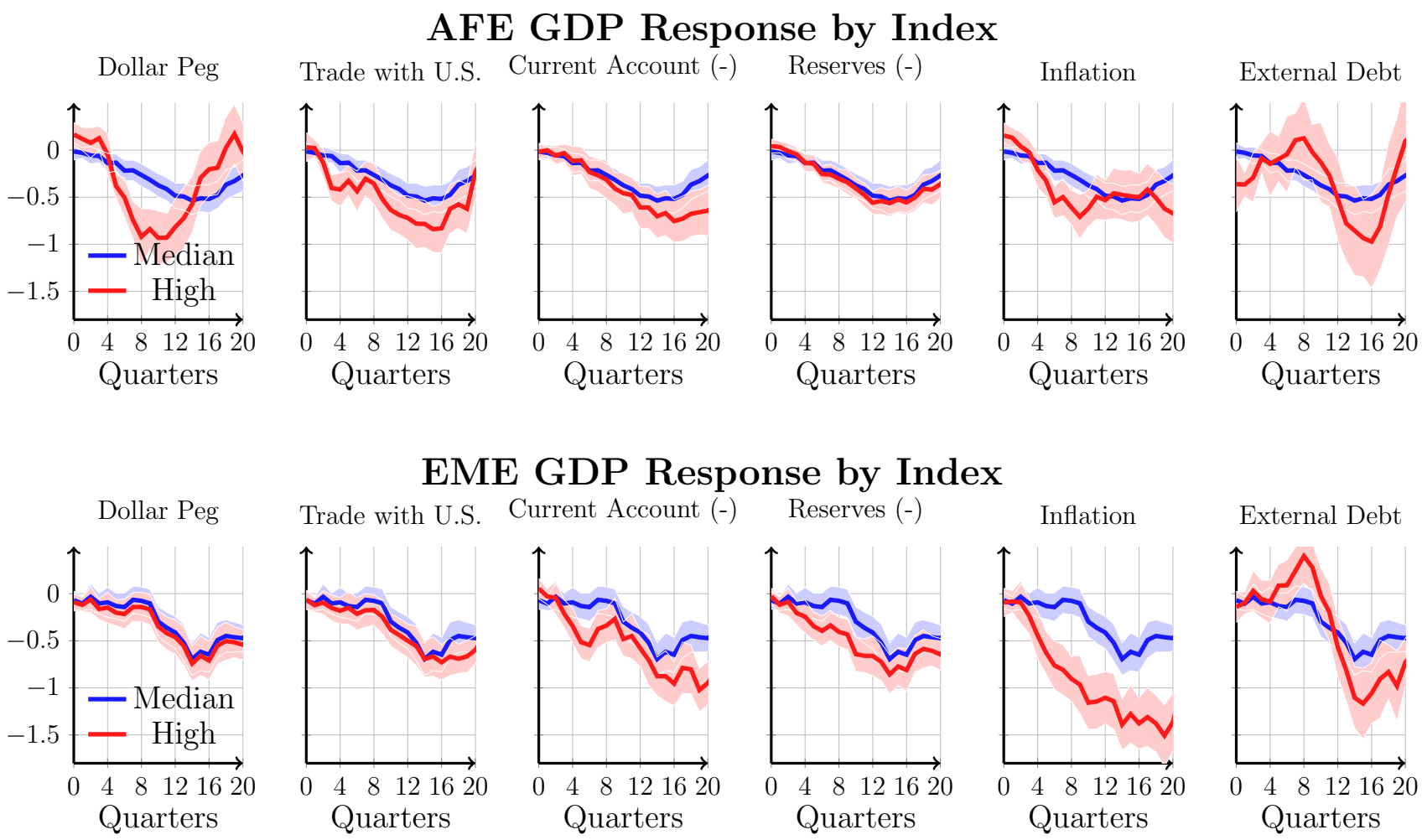

Figure 7: GDP Response (in percent) to a Monetary Shock for each component of the index.

Note: The shaded areas denote 68 percent confidence intervals.

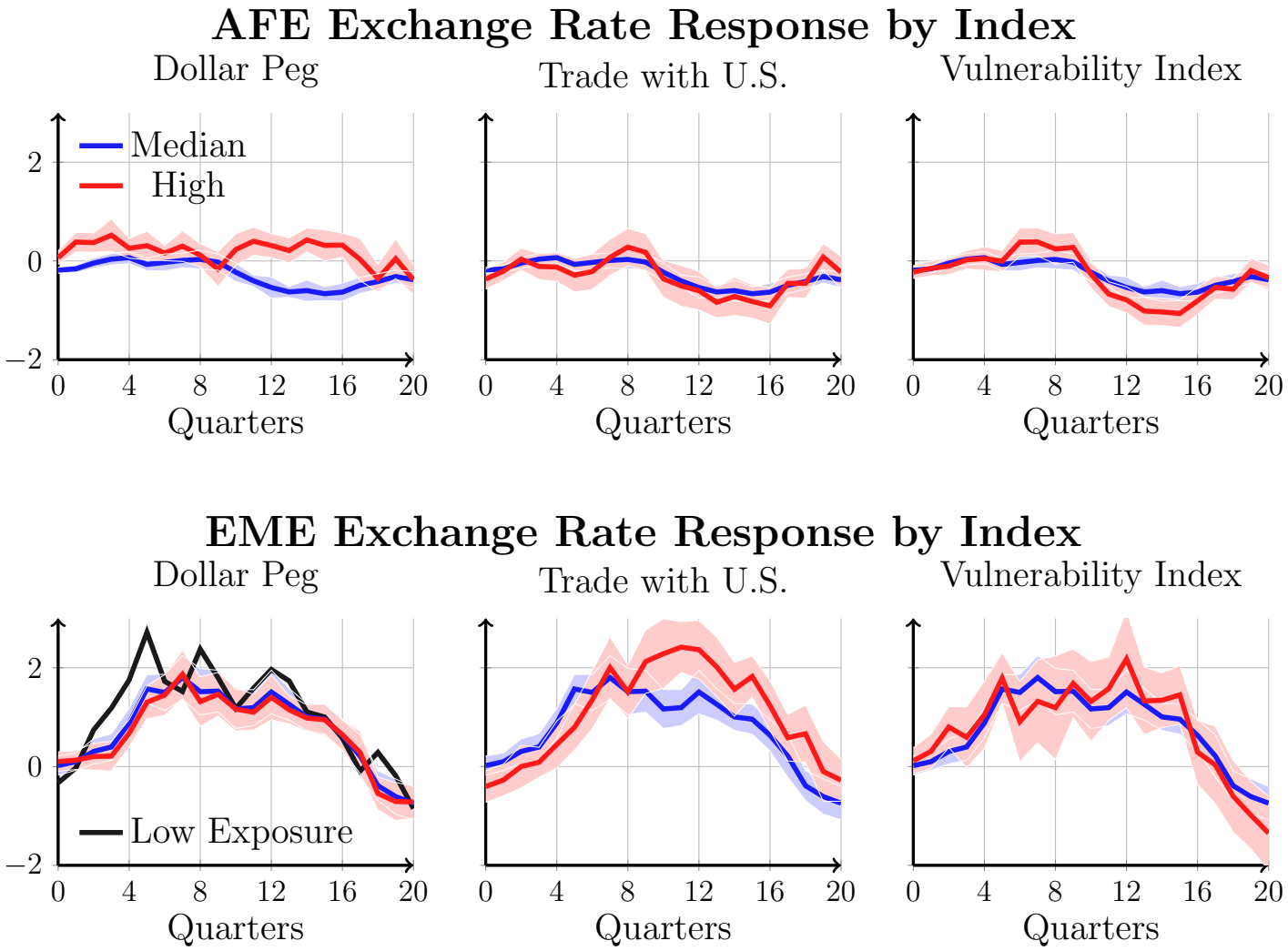

Figure 8: Exchange Rate Response (Percent) to a Monetary Shocks by Index

Note: The "Median" response is the response of the real exchange rate for an economy with values for each index equal to the median value, as reported in Table 2. The "High" response is the response of an economy with values for each index equal to the 95th percentile, as reported in Table 2. Higher values indicate an appreciation. The shaded areas denote 68 percent confidence intervals.

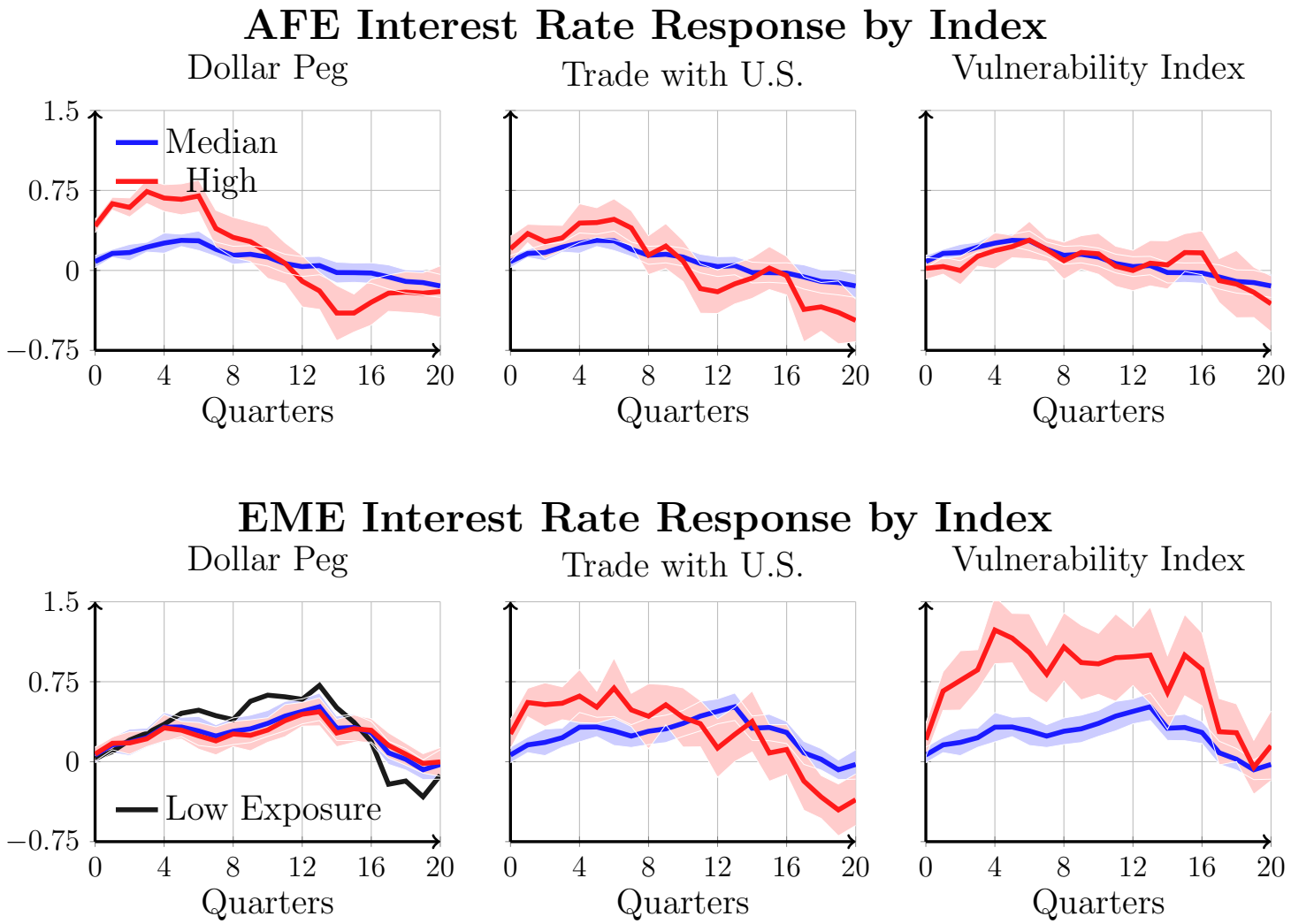

Figure 9: Interest Rate Response (Percentage Points) to a Monetary Shocks by Index

Note: The "Median" response is the short-term interest rate response of an economy with values for each index equal to the median value, as reported in Table 2. The "High" response is the response of an economy with values for each index equal to the 95th percentile, as reported in Table 2. The shaded areas denote 68 percent confidence intervals and are based on Newey-West standard errors that account for serial correlation.

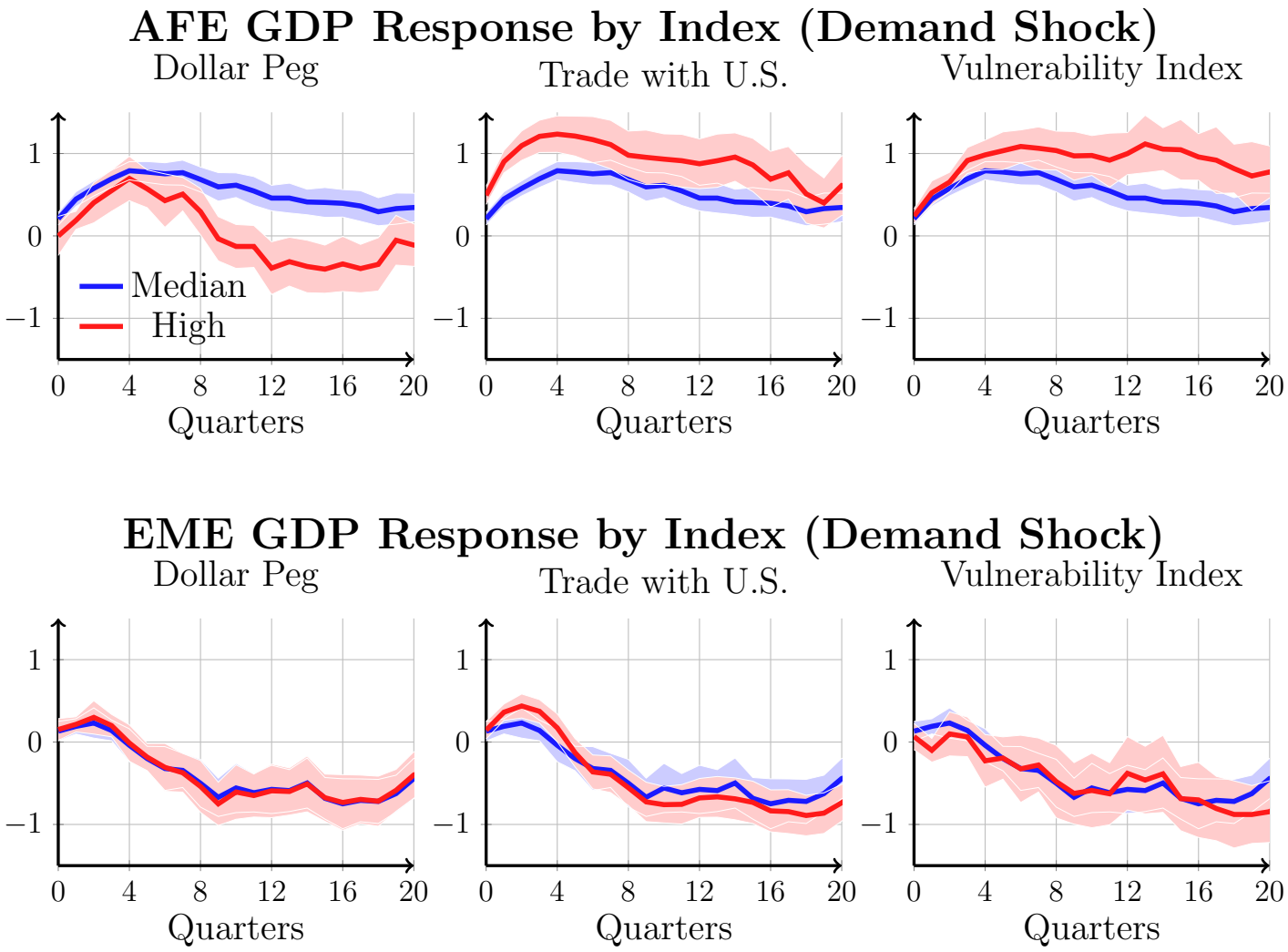

Figure 10: GDP Response % to a Demand Shock by Index

Note: The "Median" response is the GDP response of an economy with values for each index equal to the median value, as reported in Table 2. The "High" response is the response of an economy with values for each index equal to the 95th percentile, as reported in Table 2. The shaded areas denote 68 percent confidence intervals and are based on Newey-West standard errors that account for serial correlation.

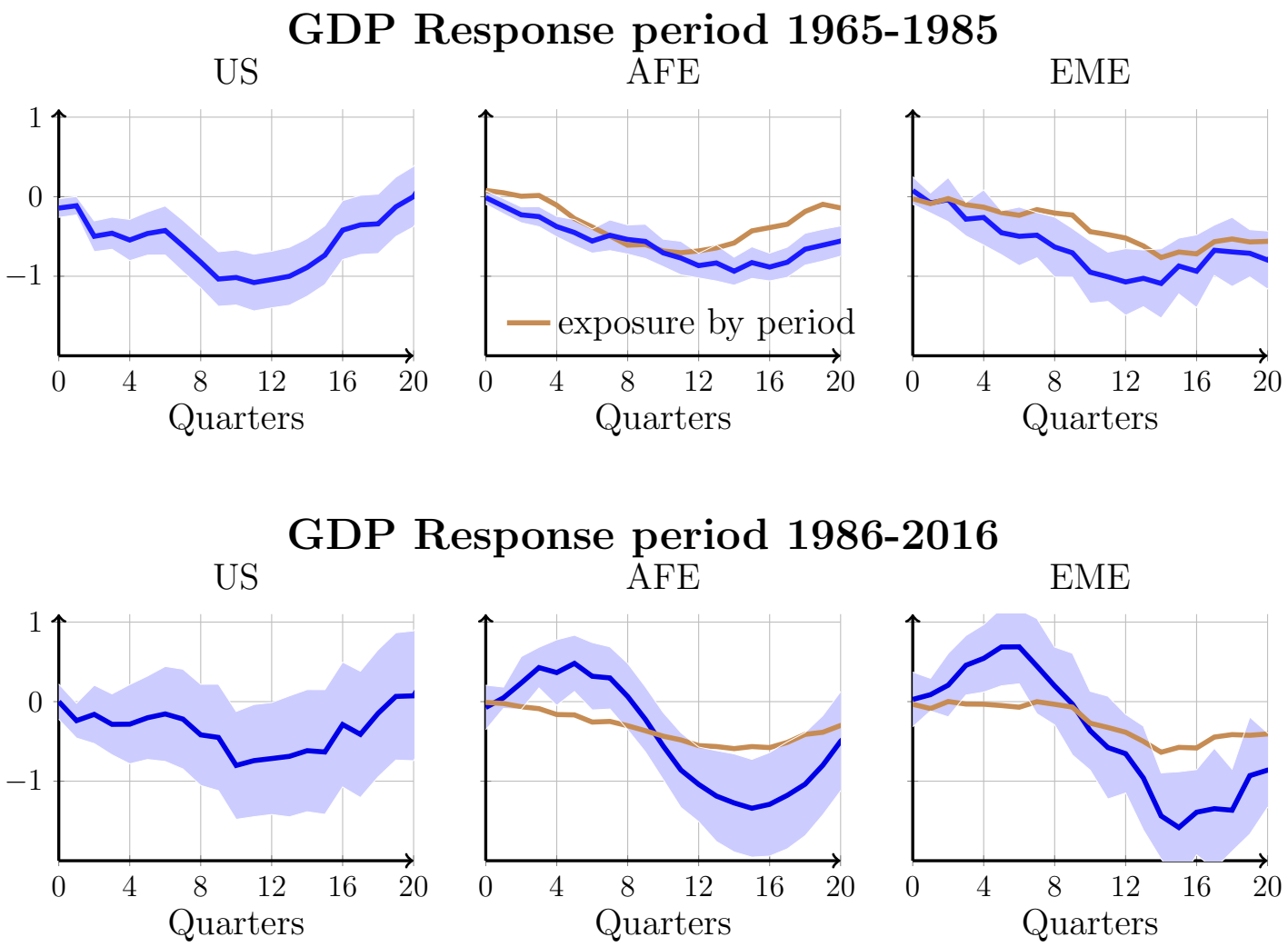

Figure 11: GDP Response (in percent) to a Monetary Shock across Subsamples

Note: The samples cover the periods 1965Q1–1985Q4 and 1986Q1-2016Q2 respectively. The shaded areas denote 68 percent confidence intervals.

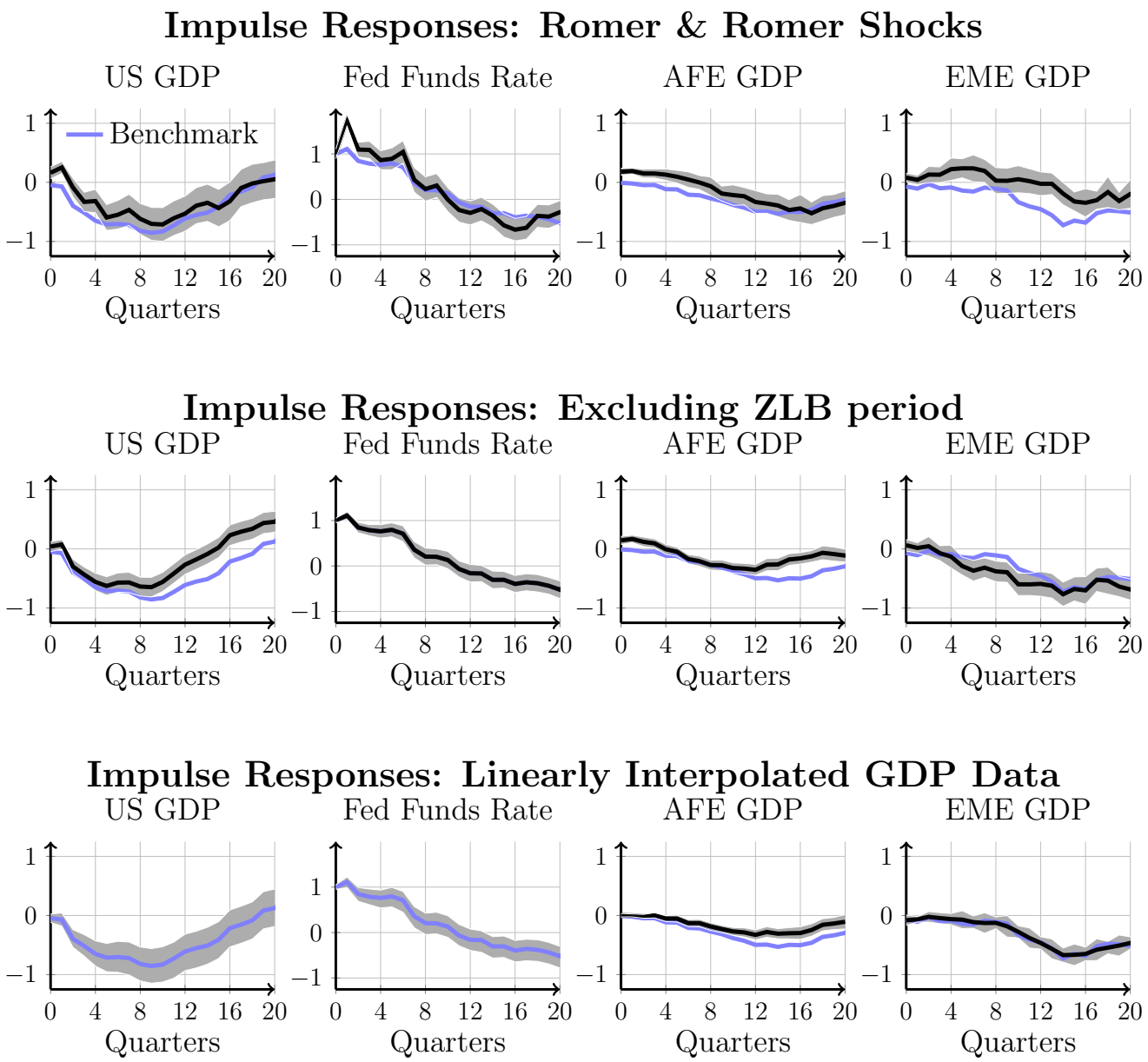

Figure 12: Impulse Responses to Monetary Shocks: Robustness

Note: GDP responses in percent from baseline. Fed Funds Rate response in percentage points. The shaded areas denote 68 percent confidence intervals.

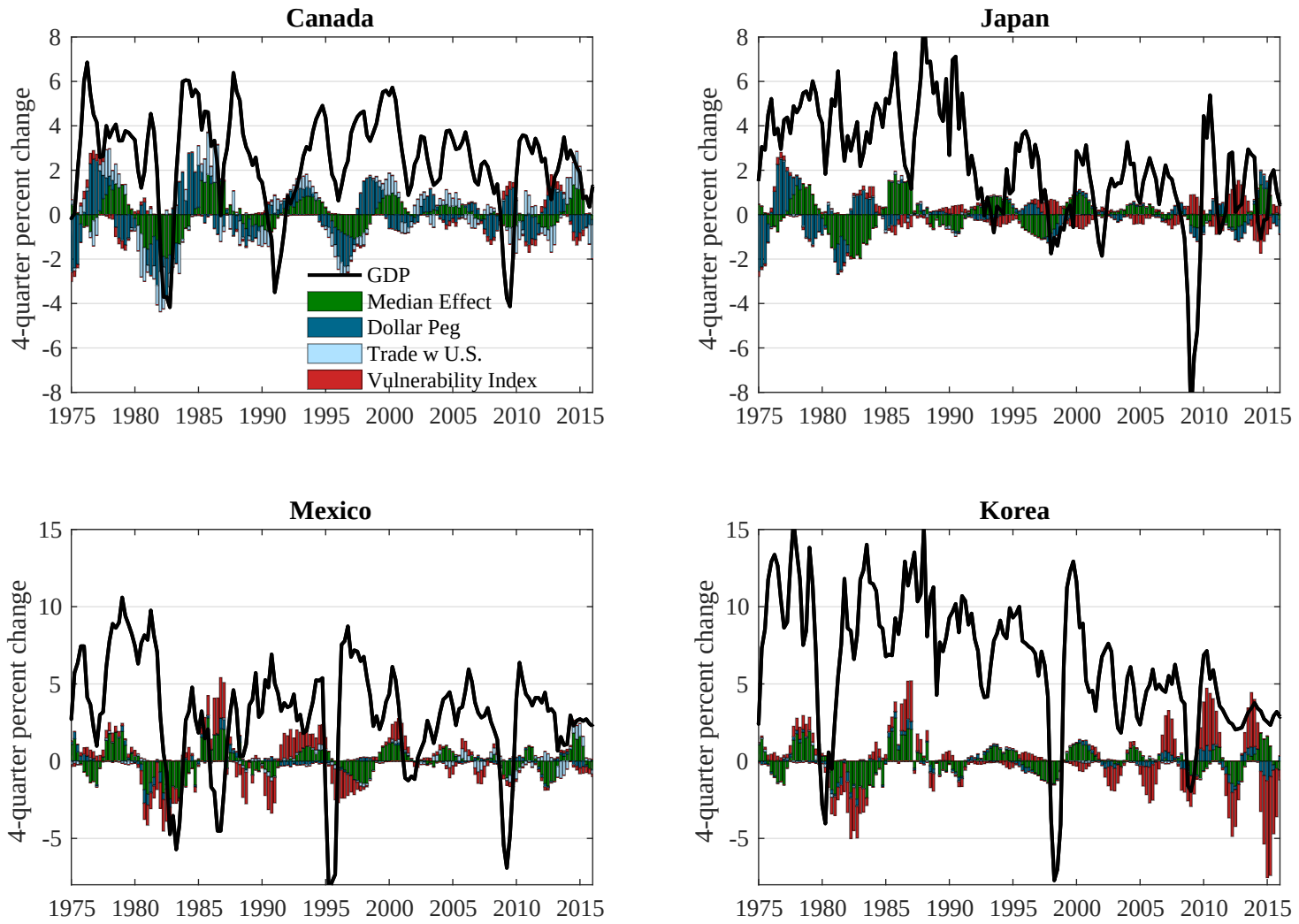

Figure 13: Historical Contribution of U.S. Monetary Policy shocks

Note: The green bar is the "median" effect that is common to all advanced economies or emerging economies. The blue/cyan/red bars are the marginal effects of the exchange rate/trade/vulnerability exposure channels.

A Related Empirical Literature

Several papers have looked at global implications of changes in U.S. interest rates. Examples include:

1. Kim (2001) uses structural VARs to measure the effects of U.S. monetary shocks for 6 advanced economies. He finds that U.S. monetary tightenings lead to a decrease in activity abroad, which appears mostly driven by an increase in the world real interest rate rather than by trade channels.

2. Canova (2005), using few years of data and multiple VARS, estimates the effects of U.S. monetary policy shocks on emerging markets in Latin America. He finds that a U.S. monetary policy shock affects the interest rates in Latin America quickly and strongly.

3. Dedola et al. (2017) find countries with lower capital mobility and a floating exchange rate regime are better insulated from the financial repercussions of U.S. monetary policy.

4. Ehrmann and Fratzscher (2005) study the transmission of U.S. monetary policy abroad but focus on financial variables.

5. Maćkowiak (2007) uses estimated structural VARs to find that output in a typical emerging market respond to U.S. monetary policy shocks by more than the output in the U.S. itself.

6. Di Giovanni and Shambaugh (2008) find that high foreign interest rates have a contractionary effect on real GDP in the domestic economy, but that this effect is centered on countries with fixed exchange rates.

7. Georgiadis (2016) is a recent study that is closely related to ours. He first projects estimated U.S. monetary policy shocks from a global VAR model against GDP in a large number of countries. He then estimates the determinants of spillovers using indicators that are assumed to be fixed in a given country over time. This assumption may lead to spurious results as a countries' position might change over time. He finds that the magnitude of spillovers depends on the receiving country's trade and financial integration, de jure financial openness, exchange rate regime, financial market development, labor market rigidities, industry structure, and participation in global value chains.

B Data Sources and Definitions

- **GDP**. We collect data from the country's national statistical offices or the central bank through Haver (databases G10+ and EMERGE). GDP in each country is real GDP, constructed using either chain-weighting or dividing nominal GDP by its deflator.

- **Inflation**. Source: national statistical offices via Haver.

- **Current Account, External Debt ("Debt Liabilities, stock"), and International Reserves ("FX Reserves minus gold")**. The source is the External Wealth of Nations Mark II database (Lane and Milesi-Ferretti, 2017). All variables are in current U.S. dollars and are divided by GDP in current dollars.

- **Interest Rates**. Figure 9 shows the response of foreign short-term nominal interest rates to a U.S. monetary shock. We obtain foreign interest rates via either Haver or the OECD. Our interest rate measure is one of the following: (1) the Central Bank Policy Rate from the IMF International Financial Statistics (IFS); (2) The Treasury Bill Rate (IFS); (3) The Discount Rate (IFS); (4) The Short-term interest rate (OECD); (5) The Overnight interest rate (OECD); (6) The Lending Rate (IFS). We use measure (1), and move to measure (2) if (1) is not available, to (3) if (1) and (2) are not available, and so on. This procedure allows us to assemble data for 48 of the 50 countries in our panel. We drop observations where the interest rate exceeds 50 percent. The procedure yields a panel of 9,018 country-quarter observations.

- **Exchange Rates**. Real effective exchange rates from Darvas (2012). We drop the observations where the year-on-year change in the real exchange rate is larger than 50 percent in absolute value. Most of the data begin in 1970. The sample contains 8,116 country-quarter observations.

- **Trade with the U.S.**. The data on trade are the merchandise trade data from the IMF Direction of Trade Statistics.