

# THE PUZZLING CHANGE IN THE INTERNATIONAL TRANSMISSION OF U.S. MACROECONOMIC POLICY SHOCKS

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## Abstract

Using five separate identification methods, we demonstrate a dramatic change over time in the international transmission of US macroeconomic shocks. International spillovers from US monetary policy, government spending, and tax policy shocks take on a different nature the 21st century than they did in post-Bretton Woods period. Our analysis is based on the a panel of 17 high income and emerging market economies. Prior to the 1990s, the US dollar appreciated, and ex-US industrial production declined, in response to increases in the US Federal Funds rate, as predicted by textbook open economy models. Similarly, fiscal policies leading to interest rate increases appreciated the dollar and lead to output contractions. The past three decades have seen a shift, whereby increases in US interest rates depreciate the US dollar but stimulate the rest of the world economy. We sketch a simple theory of exchange rate determination in face of interest-elastic risk aversion that rationalizes these findings.

## 1 Introduction

The international transmission of macroeconomic policies a central topic in international macroeconomics, forming the basis for policy design and potential policy coordination. These spillovers take on increasing importance with freer movement of goods and capital, including to and from

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developing countries. When advanced-economy central banks flooded markets with liquidity following the 2007-8 global financial crisis, debates intensified on how these policies affected countries beyond their jurisdiction. Guido Mantega, the Brazilian Finance Minister, dubbed these policies a “currency war”.<sup>1</sup> Spillovers from the expected tightening of monetary policy in 2013, the proverbial “taper tantrum”, were of sufficient concern to have been raised in US Federal Open Committee meetings.<sup>2</sup>

A previous literature, discussed below, has studied spillovers from US monetary or fiscal policy to the rest of the world. In updating and expanding this earlier analysis, we find that spillovers from US macroeconomic policy—both monetary and fiscal—have seen a dramatic shift over time. In the period following the end of the Bretton-Woods system of fixed exchange rates, a contractionary monetary shock in the US appreciated the US dollar in both real and nominal terms and caused a decline in output in the rest of the world. This accords with conventional wisdom and textbook macroeconomic models. However, in the past three decades, a US monetary tightening now *depreciates* the US dollar and *stimulates* output overseas.

The analysis is based on data at monthly frequency for the 8 largest high income countries, excluding the US, and the 9 largest emerging markets for which data is available at monthly frequency. Our results are robust to several methods used in the literature to identify monetary shocks: Vector Auto-Regressions (VARs, as in Sims 1992, Eichenbaum & Evans 1995, Christiano *et al.* 1999), historical studies that control for the Fed’s real-time information set (Romer & Romer 2004) and high frequency shocks (Gertler & Karadi 2015). The results hold separately in the high income and emerging market samples (the latter including data primarily from the later period).

Interestingly, a similar shift is evident in the transmission of fiscal policy shocks. While fiscal expansions appreciated the dollar in both nominal and real terms in the earlier period, they caused the dollar to depreciate in the past three decades. This is true both of government spending shocks, identified by the Ramey’s (2011) military buildup narrative, and tax shocks, identified by the historical narrative in Romer & Romer (2010). Once again, the responses in the first decades following Bretton Woods are consistent with textbook open economy macroeconomic theory. The shift in the international transmission of fiscal policy is coherent with the results for monetary policy described above in that policies leading to higher US interest rates led to dollar appreciations in the 1970s and ‘80s, but to dollar depreciation more recently.

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<sup>1</sup><https://www.ft.com/content/33ff9624-ca48-11df-a860-00144feab49a>

<sup>2</sup><https://www.nytimes.com/2019/01/11/us/politics/federal-reserve-jerome-powell.html>

It is difficult to reconcile the exchange rate response in recent decades—particularly to monetary shocks—with standard macroeconomic theories of the open economy. The textbook Mundell-Flemming-Dornbusch model and its modern new-Keynesian variants (Svensson & van Wijnbergen 1989, Obstfeld & Rogoff 1995, Betts & Devereux 2000, Devereux & Engel 2003, Corsetti & Pesenti 2005) predict a US dollar appreciation in response to a Fed interest rate hike. In such models, exchange rate reactions to monetary policy shocks are governed by an uncovered interest parity (UIP) condition, a no-arbitrage condition that requires expected exchange rate movements to compensate investors for differential interest rates of assets denominated in different currencies. Under UIP, a monetary tightening is associated with an immediate appreciation. Recent theoretical advances in exchange rate determination (cf. Gabaix & Maggiori 2015) allow for UIP deviations. A key departure of the Gabaix & Maggiori (2015) framework (GAMA model) is to give prominence to financial flows in determining exchange rate dynamics. But this and other existing models would still predict an exchange rate appreciation following a tightening of monetary policy.

We find a plausible rationalisation of our empirical results in an expanded version of the GAMA model. In the GAMA model, financial intermediaries absorb imbalances in the supply and demand for currencies, while take on currency risk exposure. Limited risk taking capacities stemming from financial frictions imply that currencies will provide excess returns to compensate the financiers for their risk exposure. Although a core result of the GAMA model is that UIP no longer holds, the reaction of exchange rates to an interest rate change is still in the same direction as in the standard model. We introduce a new force in the model: the risk capacity of the financiers depends on a general level of risk appetite in the financial sector, and we allow risk appetite to vary with US interest rates.<sup>3</sup> When US interest rates rises, risk appetite decreases, and the risk bearing capacity of financiers declines. This limits their demand for FX exposure. If the financial sector is long on US dollars—a plausible assumption in recent decades—this decreases their demand for US dollars and causes a dollar depreciation. The US dollar will then depreciate in response to a tightening of monetary policy if the risk-taking channel dominates the standard forces implied by UIP. The assumption of interest rate dependent risk-taking behavior is plausible and supported by existing evidence (Borio & Zhu 2012, Bekaert *et al.* 2013, Bruno & Shin 2015, Lian *et al.* 2018, Miranda-Agrippino & Rey 2020).

The response of non-US output to monetary policy shocks is equally puzzling. International

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<sup>3</sup>For simplicity, we make the constraint dependent on the US interest rate, but results would go through if it depended on the world average interest rate, which is highly dependent on US monetary policy.

spillovers in standard open economy models come from two main channels: demand and expenditure switching. In the standard model a tightening of US monetary policy could be expansionary or contractionary for the rest of the world. On one hand, tighter monetary policy reduces US import demand; on the other hand, it leads to an appreciation of the US dollar, leading consumers to substitute away from US goods. However, given our finding that the US dollar *depreciates* in response to US interest rate hikes, the expenditure switching effect now is unfavorable for the rest of the world; and both forces would tend to depress output outside the US. In stark contrast, we find that non-US output increases following a Fed tightening. While our model doesn't contain a productive sector, we describe a growing literature that focuses on balance sheet effects that allow for output expansions in face of an appreciating local currency.

It is difficult to date the change in the international transmission of US macroeconomic policy with any precision. Formal break point analyses (Bai & Perron 1998) point to different dates for high income and emerging markets. The best fit for the former is circa 1985, while the transition appears to occur at the turn of the millennium for the latter. This is partially explained by the limited data availability for emerging markets before the late 1990s (high inflation episodes in the 1990s make exchange rate analysis difficult) and the highly managed exchange rates for most countries in this group prior to 2000. We conduct our analysis pre- and post- 1990 as a compromise of sorts between the two income categories and to ensure a sufficient sample size in both subsamples. Results are similar using any date between 1985 and 2000 as the break point.

The challenge in identifying the break point also makes it difficult to disentangle empirically the exact reasons for the shift. Multiple changes occurred in global economy in this period and several of them may have contributed to the changing nature of international macroeconomic spillovers. First, the increased financialization of the world economy may have made macro-finance theories of the sort explored in this paper more central in exchange rate determination. The increasing role of finance may have also made the financial sector more sensitive to interest changes, a factor that is central to our theory. Second, the US dollar has become increasingly central in the international monetary system in recent decades (Rey 2013, Ilzetzi *et al.* 2019). This may have increased demand for US dollar liquidity and may have stretched the financial system's currency exposure. We use our theoretical framework to study conditions under which increased dollarization of the world economy leads to a reversal in the exchange rate response to interest rate shocks. Finally, the change in regime in our empirical findings corresponds roughly to the period when the US began running a persistent current account deficit (a period beginning in the

mid-1980s or early 1990s). As will become apparent in Section 4, our theoretical results hold with greater force when the US is running a current account deficit.

An extant empirical literature studies the the international propagation of US monetary and fiscal policy shocks. Our findings for monetary shocks in the post-Bretton Woods period are in line with those in Eichenbaum & Evans (1995), Cushman & Zha (1997), and Kim & Roubini (2000), whose sample periods range from the 1970s to about 1990. Our contrasting empirical results for the period beginning in the 1990s are new and robust to alternative identification schemes standard in the literature. We further extend this analysis to the largest emerging market economies and find that they respond similarly to high income economies to US policy shocks in the later sample, where data is available for both income categories. Our findings resonate with evidence on Latin American economies, where Canova (2005) finds that the local currency appreciates relative to the US dollar in response to US monetary tightening. We find that exchange rates of high income economies responded similarly in the same time sample, rather than this being a peculiarity limited to Latin America or developing countries more generally. Our analysis synthesizes existing disparate results and we are the first to point to the change in the monetary policy transmission over time.<sup>4</sup>

Monacelli & Perotti (2010) and Ravn *et al.* (2012) previously pointed to the puzzle of currency depreciation following increases in government spending. The two studies provide theories to rationalize these results. Our analysis shows that the puzzle is a recent phenomenon and holds for tax policy as well. Further, we find a systemic change in the international transmission mechanism that spans both fiscal and monetary policies. Occam's razor demands a unified theory that resolves both the monetary and fiscal exchange rate puzzles. While our theory is formulated in terms of monetary policy, it achieves this aim in that it describes how domestic interest rate increases may lead to a depreciation, regardless of the reason for the interest rate change.

Before turning to our main empirical results in Section 3, we describe the data, our empirical methodology, and the various identification methods used in this paper in Section 2. Section 4 then presents our theory of exchange rates and monetary policy in face of interest-elastic risk aversion in the financial sector. Finally, Section 5 concludes.

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<sup>4</sup>Stavrakeva & Tang 2018 show a change in monetary policy transmission as the Fed transitioned to quantitative easing during the 2007-9 global financial crisis. They attribute this change to a greater importance of the signalling effect of monetary policy, whereby a loosening of US monetary policy signals bad news in the Fed's information set, leading to a dollar appreciation through flight to safety. In our larger sample we find that the shift in monetary policy transmission may have occurred earlier. Further, we find that the shift occurs not only for monetary, but also for fiscal policy, suggesting a phenomenon that may go beyond the signalling effect of monetary policy.

## 2 Data and Methodology

In this section, we describe the data and methods used to estimate spillovers from US monetary and fiscal policy to the rest of the world.

### 2.1 Data

We analyze the transmission of US fiscal and monetary shocks to the rest of the world in an unbalanced panel of the largest 18 countries and areas outside the US for which exchange rate and industrial production data are available at monthly frequency. This includes the 8 largest high income countries, the euro, and 9 of the 15 largest developing countries, chosen based on data availability. The full list of countries and their sample dates is found in Table ?? in the appendix. While data is available prior to 1973 for some countries, our sample begins the end of the Breton Woods system of fixed exchange rates at 1973 and ends at the end of 2007, after which US monetary policy was constrained by the zero lower bound on the nominal interest rate and the international transmission of monetary policy may have changed further (cf. Stavrakeva & Tang 2018).

The panel is unbalanced primarily because of limited monthly data for developing countries before 1990. Our hypothesis that the transmission of macroeconomic shocks changed after this date may be confounded by the sample change and instead reflect differences between high income and developing countries. However, results aren't driven by changes in sample composition and results are in fact slightly stronger when restricting the sample to a balanced panel of high income countries alone.<sup>5</sup>

The euro replaced a number of the national currencies in our sample (German Deutschemark, French franc, and Italian lira) in 1999. We continue treating these countries as separate entities when considering production and real exchange rate spillovers after 1999. These countries are dropped from the analysis of nominal exchange rate after 1999 to avoid over-weighting the euro in our sample. The euro is treated as a separate cross-sectional territory from 1999 to 2007 when analyzing nominal exchange rate responses.

We analyze the response of four main non-US variables to US macroeconomic shocks. These are the nominal and real exchange rates, industrial production, and the nominal policy interest rate in each country in our panel. The main data source is the International Monetary Fund's International Finance Statistics (IFS), which completed from national sources. The nominal exchange rate is

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<sup>5</sup>Results for this restricted sample are available in working drafts of the paper, available on request from the authors.

taken as the monthly average of the nominal bilateral exchange rate in local currency to US dollars, so that an increase in this variable reflects a US dollar appreciation. Industrial production is given as an index. The real exchange rate is calculated from the nominal exchange rate and the US and local price level. These variables are seasonally adjusted and in natural logarithms. The policy interest rate is in percentage points.

## 2.2 Monetary Policy Shocks

We use three separate identification methods common in the literature to ensure the robustness of our results. This includes VAR methods following Christiano *et al.* (1999), Romer & Romer's (2004) historical analysis, and Gertler & Karadi's (2015) shocks derived from high frequency data. While each individual method has distinct disadvantages, the fact that three give almost identical results provides a preponderance of evidence that the transmission of US monetary policy shock changed circa 1990.

Romer & Romer (2004) (RR) shocks to the Federal Funds Rate (FFR) are deviations from the Federal Reserve's historical response function to its information set. The latter is compiled from the Fed's Greenbook forecasts. Specifically, RR regress the change in the FFR—or the intended change, before the FFR was publicly announced as the Federal Reserve's policy instrument—on its previous level; forecasts of the current, last quarters, and following two quarters of inflation and GDP; the change in these forecasts since the previous meeting of the Federal Open Market Committee; and its estimates of current unemployment. Residuals from this regression are treated as monetary policy shocks, reflecting changes in the policy rate beyond the systemic response to economic conditions based on the Fed's real-time information set.

The original RR series end in 1996. We replicate the RR series up to 1996 and extend it to 2005, using the same methodology. Figure A.1 in the appendix compares the original RR series with our replication and extension of their methodology. The difference between the two is barely discernible for the overlapping period.

Our second shock series derives from Eichenbaum & Evans's (1995) (EE) recursive identification. This involves running a Vector Autoregression (VAR) that includes the following US variables: GDP, CPI, the Federal Funds Rate (FFR), and non-borrowed reserves (NBR). Inclusion of an index of commodity prices and of M2 as in Christiano *et al.* (1999) does not alter our results. Shocks to the FFR are identified through a Cholesky decomposition of the VAR's residuals when the variables are ordered as listed above. In contrast to the cited literature, we measure output as

US industrial production rather than GDP, to allow analysis at a monthly frequency.<sup>6</sup>

Finally, the third shocks series is taken from Gertler & Karadi (2015) (GK), who measure policy shocks as changes in one-month Fed Funds Rate futures on the day of Fed policy announcements. They then sum the daily shocks to arrive at the cumulative monetary policy surprise on a given month. (For most months this is simply the shock on the day of the Federal Reserve’s Open Market Committee meeting in that month.)

Figure A.2 in the appendix plots the three shock measures. The top panel compares the RR and EE shocks. The bottom panel shows the RR and GK shocks (the latter on the right hand scale). The Fed Funds futures market is a relatively modern construct, explaining the shorter span of the GK series. GK shocks are measured by small changes in the private sector’s expectations in a short window around FOMC announcements and are consequently smaller in amplitude than the other two shocks. There is some overlap between the measures, but the correlation between the three is very small. The correlation between the RR and CEE series is merely 0.14 and is driven mainly by the Volker shocks in the early 1980, captured in both measures. The GK shocks are actually *negatively* correlated with both other measures. Similar responses all three measures are a indication of our results’ robustness, rather than a mere redundancy.<sup>7</sup> The largest monetary shocks by far is the Volker shock of the early 1980s and the loosening of policy that follows. The largest high frequency FOMC surprises occurred in the past decade, but these are far smaller in magnitude.

### 2.3 Fiscal Policy Shocks

We investigate foreign responses to US fiscal shocks looking at both government spending and tax shocks. In both cases, we follow narrative approaches to identify fiscal shocks. For public spending, We follow Ramey’s (2011) narrative of large military buildups. This time series of news shocks is derived from Business Week reporting of expected public spending increases due wars and geopolitical threats. On the tax side, we use the tax shocks identified by Romer & Romer

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<sup>6</sup>Using a monthly interpolation of quarterly GDP data yields similar results.

<sup>7</sup>The lack of correlation could, but doesn’t necessarily, indicate the superiority of one measure over another. The three are different ways to measure monetary policy shocks and could in principle capture different aspects of monetary surprises. The Romer & Romer (2004) series gives interest rate deviations from the Fed’s average response to its own real time information set. Gertler & Karadi (2015) measure monetary policy surprises identified at very high frequency, reflecting (relatively small) updates to the private sector’s information set at FOMC announcements. Christiano *et al.* (1999) capture interest rate deviations from the average monetary reaction to US macroeconomic variables, where the reaction function incorporates future information that may not have been available to either the private or the public sector.



(2010). We separate tax changes that were due to cyclical conditions and those that were exogenous to business cycle conditions. Our measure of US tax shocks uses the tax changes that Romer & Romer (2010) classify as having been motivated by long run considerations.

Figure A.3 in the appendix displays the measures of public spending shocks and tax shocks. We wouldn't necessarily expect the two measures to be correlated. In fact, a high correlation might raise concerns that tax changes in the Romer & Romer (2010) series were endogenously driven by military financing needs. In practice, the correlation is essentially zero (-0.10). The largest military spending shocks in the post-Bretton Woods period are the Reagan cold-war expansion of the early 1980s, the decline in military spending following the fall of the Berlin wall, and the wars in Afghanistan and Iraq in the early 2000s. The largest tax shocks are the Reagan and George W. Bush tax cuts.

We analyze responses to fiscal policy in quarterly data, corresponding to the frequency of the US fiscal narratives.

## 2.4 Empirical Specification

The results reported in the following section are impulse responses estimated directly using local projections (Jorda 2005). We project the five shock series described above directly on the outcome variable in question (exchange rate, industrial production, discount rate) in bilateral regressions described as follows:

$$y_{c,t+h} = \beta_h x_t + \sum_{i=1}^I (\delta_i^y y_{c,t-i} + \delta_i^x x_{t-i}) + \alpha_c + \gamma_t + \varepsilon_{c,t,r}. \quad (1)$$

where  $y_{c,t+h}$  is the outcome variable for country  $c$  at a horizon of  $h$  months/quarters from date  $t$ .  $\beta_h$  gives the impulse response of outcome variable  $y$  at horizon  $h$  to the US macroeconomic shock given by  $x_t$ . The local projection regression includes  $I$  lags of both the dependent and shock variables.<sup>8</sup> We include  $I = 24$  monthly lags or  $I = 4$  quarterly lags.<sup>9</sup> The regressions include country fixed effects, represented by the vector  $\alpha_c$ , and quadratic time trends represented by  $\gamma_t$ .<sup>10</sup>

<sup>8</sup>The shock variables have little serial correlation, so excluding their lags from the regression has little impact on the results.

<sup>9</sup>Formal lag inclusion criteria give slightly different results in each regression, but the chosen values are close to the optimum according to the Schwartz criterion in all specifications.

<sup>10</sup>We control for trends rather than including time fixed effects, because the latter reduces statistical power substantially. This leads to very wide error bands, but results are qualitatively similar to the ones reported in the following section.  $\alpha$  and  $\gamma$  coefficients and the residuals  $\varepsilon_{c,t}$  take on different estimated values in each regression of horizon  $h$ , but we suppress  $h$  subscripts for ease of notation.

## 3 The International Transmission of US Macroeconomic Shocks

### 3.1 Monetary Policy Shocks

We now describe the response of the international macro-economy to monetary policy shocks. Figure 1 displays the response of a number of variables to a Romer & Romer (2010) shock in horizon up to 4 years (48 months). In this and all subsequent figures, the left-hand column presents responses in the period 1973-1990 and the right-hand column in the period 1991-2007. Shaded areas give 95% confidence intervals.

The first row shows the average response of (log) bilateral nominal exchange rates to a one percentage point increase in the FFR. Exchange rates are given in local currency units per US dollar, so that a rising exchange rate represents a US dollar appreciation. In the earlier period, the dollar steadily appreciated, ultimately leading to an 8% appreciation, following a Fed tightening. This is precisely the prediction of standard macroeconomic models. The exchange rate response should be immediate in open economy models, rather than delayed as seen in the figure. This is a violation of uncovered interest parity, which would require a dollar appreciation to compensate investors in foreign bonds for higher US yields. This is a known phenomenon, is the basis of “carry trade” investment strategies, and was previously noted in a large literature following Froot & Thaler (1990) and Eichenbaum & Evans (1995). The exchange rate response in the 1991-2007 period is in stark contrast and is the main result of the paper. In this period the US dollar sees a large *depreciation* following a Fed tightening, peaking at 5% roughly a year a half after the shock.

The second row of Figure 1 shows the average response of foreign industrial production to a Fed tightening. In the earlier period, foreign output declines steadily, dropping by as much as 2% in response to the 100 basis point tightening of monetary policy. This response is consistent with earlier findings (Eichenbaum & Evans 1995) and is theoretically coherent. The US tightening has demand effect and expenditure switching effects. Lower US/world demand due to the Fed tightening leads to lower foreign production. On the other hand, consumers may substitute towards now cheaper foreign goods due to the stronger dollar. If the demand effect dominates expenditure switching, the foreign industrial production decline shown in the figure is to be expected.

In contrast, foreign industrial production increases following a Fed tightening in the more recent period. The response peaks at 2% in the year following the monetary policy shock. This response is particularly puzzling because in this case both the demand and expenditure switching effects would call for a decline in foreign output. As before, lower world demand would tend

to lower production. But now with the US dollar depreciating, the expenditure switching effect would also lead to lower foreign production as US goods are now relatively cheaper. We note that we do not see a similar increase in US industrial production in this period, so the phenomenon documented here is a change in the international rather than the domestic transmission of monetary policy.

The third row of the figure shows the response of the real exchange rate to US monetary policy shocks. Mussa (1986) highlighted that real exchange rate movements are dominated by nominal exchange rates, not relative prices. It is hardly surprising that the real exchange response is almost identical to those of the nominal exchange rate in the first row of the figure.

The fourth row of Figure 1 shows the average response of the non-US policy rate (in percentage points) to a one pp increase in the FFR. Changes in policy responses to US policy could potentially explain differences in the effect of US shocks on the rest of the world. Prior to 1990, foreign central banks followed the Fed and increased interest rates by half a percentage point for each percentage point tightening in the US. Impulse responses in the later period are slightly larger and suggest the possibility that foreign central banks responded more than one-to-one to US interest rate hikes. This could provide an explanation for the US dollar depreciation. However, standard errors of these estimates are large, we cannot reject the hypothesis that foreign monetary responses remained the same, and this result isn't robust to other monetary policy shocks, as we shall see below.

Turning to Christiano *et al.* (1999) shocks, Figure 2 shows the response of the same four variables to monetary policy shocks identified through VAR residuals. These results are based on direct projection of the VAR residuals of a US-only VAR on the foreign variables, for consistency with other specifications. However, impulse responses are similar when merging the foreign variables into the US VAR used to identify policy shocks and estimating their response from this single VAR.<sup>11</sup> The figure shows the responses of the nominal exchange rate, non-US industrial production, the real exchange rate, and the policy interest rate (from top to bottom) to a 1% increase in the FFR, in the period 1973-1990 (left column) and 1991-2007 (right column). Despite the low correlation between the RR and EE shocks, results are nearly identical. The nominal and real interest rates both increase, peaking at around 5%, in response to a Fed tightening before 1990. The dollar instead depreciates by a similar magnitude in the 90s and beyond. Non-US industrial production

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<sup>11</sup>Identified monetary policy shocks are very similar in this specification regardless of how the foreign variable is ordered in the Cholesky decomposition. Results are robust to measuring EE shocks as deviations from separate VARs in the two sub-samples.

decreases in the early period but increases in later years. As noted earlier, there is no sign that foreign central banks responded more aggressively to US monetary policy in the past three decades when identifying monetary policy shocks through VAR residuals. If anything, the the monetary policy response in the 70s and 80s appears larger in this specification.

Finally, Figure 3 shows the response of the same variables to a monetary policy shock identified through high frequency changes in Fed funds futures in narrow windows around Fed announcements (Gertler & Karadi 2015). Data on Fed funds futures is only available starting in 1986, so that the early period sample is substantially curtailed to the five years from 1986 to 1991. This may explain the noisy and unstable responses in the early period in the left hand column of the figure. However, the results for 1991-2007 on the right are strikingly similar to those shown using the two previous identification methods. Again, the US dollar depreciates substantially in real and nominal terms following a Fed tightening and foreign industrial production increases. As in the case of the EE shocks, there is no discernible tightening of foreign monetary policy following a US monetary policy shock.

### 3.2 Fiscal Shocks

How does the the economy of the rest of the world respond to fiscal shocks? We begin the analysis looking at government spending shocks, using Ramey's (2011) military spending news shocks. Figure 4 shows the response of the nominal exchange rate, industrial production, and the real exchange rate to news of an impending military expansion, leading to one percent increase in US government spending. The first row shows the response of the nominal exchange rate. In the period 1973-1990, the US dollar appreciates by up to 3% following a fiscal expansion. This is consistent with the textbook Mundell-Flemming-Dornbush model, although more modern models could lead to an exchange rate response of either sign. In stark contrast, the dollar depreciated substantially in the two years following a government spending expansion in the later period. Given that increases in public spending tend to increase interest rates, these results are consistent with the responses to US monetary policy shown earlier. Shocks that lead to an interest rate increase are followed by a dollar appreciation in the early period, but a dollar depreciation in the past thirty years.

Industrial production responses shown in the second row of Figure 4 show a similar reversal. Foreign industrial production declines in response to a US fiscal expansion in the period 1973-1990, but increases in 1991-2007. Finally, the real exchange rate, shown in the third row of the

figure, follows a similar pattern to the nominal exchange rate, although the response in the past three decades is somewhat noisy.

Turning to tax policy, Figure 5 shows the world economy's response to a 1 percentage point of GDP increase in US tax revenues, identified as exogenous to the state of the business cycle in Romer & Romer's (2010) historical narrative. The US dollar depreciates in nominal terms (first row) in the early period, but appreciates afterwards. This result coheres with the results in Figure 4 in that US deficit-increasing fiscal shocks lead to a US dollar appreciation in 1973-1990, but lead to a depreciation in later years. The ex-US industrial production response is less accurately estimated and there is no clear difference between the two sub-samples. Finally, the real exchange rate response (in the third row of the figure) is very similar to that of the nominal response.

## 4 Theory: Exchange Rates and Interest-Elastic Risk Taking

The model we outline here builds on the GAMA model. There are two countries, the US and Japan (representing the rest of the world), each populated by a unit measure of households. Each household inelastically supplies one unit of labor in each of the two periods and consumes three types of goods: a domestic and a foreign tradable good, and a nontradable good. Labor is internationally immobile. US households derive utility from the consumption of the three goods according to

$$\theta_0 \ln C_0 + \beta \mathbb{E} [\theta_1 \ln C_1],$$

where the consumption basket takes the form

$$C_t = [(C_{N,t})^{\chi_t} (C_{H,t})^{a_t} (C_{F,t})^{t_t}]^{\frac{1}{\chi_t + a_t + t_t}}.$$

$C_{N,t}$  denotes the consumption of nontradable goods,  $C_{H,t}$  the consumption of domestic tradable goods, and  $C_{F,t}$  the consumption of foreign tradable goods. The nontradable good is the numeraire with a price of one unit of domestic currency.

Consumers in each country trade in a risk-free domestic currency bond solely with the financial intermediary. Their intertemporal budget constraint is

$$\sum_{t=0}^1 R^{-t} (C_{N,t} + P_{H,t} C_{H,t} + P_{F,t} C_{F,t}) = \sum_{t=0}^1 R^{-t} (Y_{N,t} + P_{H,t} Y_{H,t}),$$

where  $P_{H,t}$  is the US dollar price of domestic tradable goods,  $P_{F,t}$  the dollar price of foreign tradable

goods;  $Y_{H,t}$  is domestic tradable output and  $Y_{NT,t}$  nontradable output. The domestic interest rate is denoted as  $R$ .

The Japanese household faces a symmetrical problem, with preferences of the form

$$\theta_0^* \ln C_0^* + \beta^* \mathbb{E} [\theta_1^* \ln C_1^*],$$

where

$$C_t^* = \left[ (C_{N,t}^*)^{\chi_t^*} (C_{H,t}^*)^{\xi_t} (C_{F,t}^*)^{a_t^*} \right]^{\frac{1}{\chi_t^* + \xi_t + a_t^*}}, \quad t = 0, 1.$$

All '\*' variables denote those of Japanese households.

Households in each country maximise the expected utility of consumption while choosing the intratemporal allocation of domestic and foreign tradable goods, as well as nontradable goods. The US household's optimal intratemporal allocation of consumption satisfies

$$\chi_t / C_{N,t} = \lambda_t,$$

$$a_t / C_{H,t} = P_{H,t} \lambda_t,$$

$$\iota_t / C_{F,t} = P_{F,t} \lambda_t,$$

where  $\lambda_t$  is the multiplier associated with the budget constraint. As in the original GAMA model, we make the simplifying assumption that  $Y_{N,t} = \chi_t$ , which, combined with the market clearing condition  $C_{NT,t} = Y_{NT,t}$ , implies that  $\lambda = 1$  in all states. This assumption, which neutralises variations in household marginal utility, is made following for analytical convenience. First order conditions lead to a convenient expression for the dollar value of US imports from Japan (in units of domestic nontradable goods):  $P_{F,t} C_{F,t} = \iota_t$ ; and similarly, the yen value (in units of Japanese nontradable goods) of US exports to Japan:  $P_{H,t}^* C_{H,t}^* = \xi_t$ . Let  $e_t$  denote the exchange rate, defined as the price of a dollar in yen (the units of Japanese nontradable goods that can be exchanged for one unit of US nontradable goods).<sup>12</sup> US net exports amount to:

$$NX_t = \frac{\xi_t}{e_t} - \iota_t.$$

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<sup>12</sup>The notation is consistent with the notation in the previous section in that an increase in the exchange rate reflects a dollar appreciation.

The last optimality condition is the Euler equation:

$$1 = \mathbb{E} \left[ \beta R \frac{U'_{1,C_{N,1}}}{U'_{0,C_{N,0}}} \right] = \mathbb{E} \left[ \beta R \frac{\chi_1/C_{N,1}}{\chi_0/C_{N,0}} \right] = \beta R.$$

The simplifying assumption that  $C_{NT,t} = \chi_t$  implies the equation reduces to  $R = 1/\beta$ . Constant marginal utility owing to this assumption implies that there is no precautionary or intertemporal motive for consumption smoothing. This result does not affect the core mechanism at hand and we focus on exogenous changes to  $R$  in our subsequent analysis.

Central to the modelling framework is a group of financiers who intermediate the trade in bonds between the two countries. When there are trade imbalances between the two countries, the financiers absorb the gap between the relative demand and supply of dollars and yen. For instance, if the US runs a trade deficit there is an excess demand for dollar borrowings from American households and financiers fill in this gap by being long in dollars and short in yen. Their motivation for taking on currency risk is the excess returns earned from these holdings. The expected dollar returns that financiers maximize is

$$V_0 = \mathbb{E} \left[ \beta \left( R - R^* \frac{e_0}{e_1} \right) \right] q_0,$$

where  $q_0$  is the financiers' dollar holdings equal to the dollar value of the financiers' short position in yen,  $-e_0 q_0$ .

Financiers may divert funds after taking a position but before uncertainty is realized. If financiers divert, creditors recover  $(1 - \Gamma|e_0 q_0|)$  of their claims  $|e_0 q_0|$ . Anticipating the financiers' incentives to divert funds, creditors subject financiers to a constraint

$$e_0 V_0 \geq |e_0 q_0| \Gamma |e_0 q_0| = \Gamma (e_0 q_0)^2$$

Our departure from the GAMA model lies in the assumption about  $\Gamma$ , which determines the financiers' risk bearing capacity and is a key variable of interest. In the original model, the functional assumption that  $\Gamma = \gamma \text{var}(e_1)^\varphi$  is made for analytical convenience and captures the idea that risk taking is not only limited by the overall size of financial institutions' positions  $e_0 q_0$ , but also by their expected riskiness, which is proxied by the variance of future exchange rates. The notion of risk-bearing capacity is broad by design. We make the assumption that the tightness of the credit constraint also depends on a general level of risk aversion. When creditors' risk aversion

risks, the amount of risky positions financiers can take shrinks. And risk aversion in turn depends on US interest rates, following established empirical evidence on this linkage mentioned in the introduction. Thus, we augment the  $\Gamma$  function as follows:

$$\Gamma = \gamma (\text{var}(e_1))^\varphi, \quad \gamma = \psi R^\eta, \quad (2)$$

where  $\psi > 0, \eta > 0, \varphi \geq 0$ . A rise in US interest rate reduces creditors' risk appetite which subsequently tightens the credit constraint. This assumption conforms with the conventional wisdom of "risk-on, risk-off" cycles that may be affected by monetary policy changes. This view garners empirical support in numerous empirical studies over the past decade (Borio & Zhu 2012, Bekaert *et al.* 2013, Bruno & Shin 2015, Lian *et al.* 2018, Miranda-Agrippino & Rey 2020).

The non-diversion constraint is always binding in equilibrium, so that financiers' demand for dollars is:

$$q_0 = \frac{1}{\Gamma(R)} \mathbb{E} \left[ \frac{1}{e_0} - \frac{R^*}{e_1 R} \right]. \quad (3)$$

There are two competing effects of the US interest rate  $R$  on  $q_0$ . On the one hand, expected excess returns (in the square brackets) rise as  $R$  increases, and financiers have a higher demand for  $q_0$ . On the other hand, risk capacity falls ( $\Gamma(R)$  increases) when US interest rates rise, forcing financiers to take on smaller positions ( $q_0$  falls). The financiers could either increase or decrease their long dollar position—depending on which effect dominates.

The balance of payments equation requires that the household's supply of dollars bonds is equal to the financiers' demand for them in each period. That is, the net demand is 0:

$$\frac{\tilde{\xi}_0}{e_0} - \iota_0 + Q_0 = 0 \quad (4)$$

$$\frac{\tilde{\xi}_1}{e_1} - \iota_1 - RQ_0 = 0, \quad (5)$$

where  $Q_0$  is financiers' aggregate dollar holdings. In equilibrium,  $q_0 = Q_0$ . Henceforward, we consider the case in which the US runs a trade deficit, by setting preferences such that  $\iota_0 > \frac{R^*}{R} \mathbb{E}[\iota_1]$ .<sup>13</sup> This implies that excess returns  $\left(R - R^* \frac{e_1}{e_0}\right)$  is always positive, and  $Q_0 > 0$  in equilibrium.

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<sup>13</sup>This is the empirically relevant case in recent decades. We explore the possibility that this relationship has changed over time in the numerical results below.



The balance of payments equation, (4) gives the second equation linking  $e_0$  and  $q_0$ . For simplicity assume that  $\xi_t = 1$  in both periods  $t = 1, 2$ . Combining (3), (4), and (5) yields the equilibrium dollar position of the financiers and the exchange rates in both periods:

$$Q_0 = \frac{\iota_0 - \frac{R^*}{R} \mathbb{E}[\iota_1]}{\Gamma + 1 + R^*}, \quad (6)$$

$$e_0 = \frac{\Gamma + 1 + R^*}{(\Gamma + R^*) \iota_0 + \frac{R^*}{R} \mathbb{E}[\iota_1]}, \quad (7)$$

$$e_1 = \frac{\Gamma + 1 + R^*}{(\Gamma + 1 + R^*) \iota_1 + R \iota_0 - R^* \mathbb{E}[\iota_1]}. \quad (8)$$

The equilibrium response of  $Q_0$  to changes in  $R$  is:

$$\frac{\partial Q_0}{\partial R} = \frac{1}{R} \frac{\mathbb{E}[\iota_1] \frac{R^*}{R} (\Gamma + 1 + R^*) - \eta \Gamma \mathbb{E} \left[ \iota_0 - \iota_1 \frac{R^*}{R} \right]}{(\Gamma + 1 + R^*)^2}.$$

Thus,  $\frac{\partial Q_0}{\partial R} < 0$  if

$$\eta > \frac{\Gamma + 1 + R^*}{\Gamma} \frac{\mathbb{E}[\iota_1 R^*]}{\mathbb{E}[\iota_0 R - \iota_1 R^*]}. \quad (9)$$

This gives the conditions under which the risk-bearing capacity effect dominates—that is,  $Q_0$  falls when US rates rises. The parameter  $\eta$  governs the responsiveness of risk aversion to interest rates. The right hand side of the inequality is a decreasing function of  $\eta$  (as  $\Gamma$  is increasing in  $\eta$ ), and thus, there is a threshold level of  $\eta$  above which financiers' dollar demand falls. Intuitively, the more sensitive risk aversion  $\gamma$  is to interest rates, the more risk capacity falls when interest rates rise, and the small the dollar position financiers can take on. It is evidence from (4) that a fall in  $Q_0$  is associated with an immediate depreciation of the exchange rate ( $e_0$  falls).

The equilibrium exchange rates (7) and (8) range between the one that prevails under financial autarky ( $\Gamma$  goes to infinity) and the one when UIP holds ( $\Gamma = 0$ ). An increase in the US preference for Japanese imports ( $\iota_0$ ) which increases the trade deficit depreciates the exchange rate. An increase in US interest rates has an ambiguous impact on dollar exchange rates. To understand the intuition behind these results we can turn to a graphical representation of the financiers' demand and the household's supply for dollar bonds in period  $t = 0$ , as corresponding to (3) and (4) (Fig-

ure 6). The financiers' demand for dollar bonds is downward sloping—the stronger is the dollar, the less they want to hold it (as the exchange rate is expected to depreciate in the next period). The supply curve is upward sloping—the higher the level of exchange rate, the larger the trade deficit, and the greater the supply of dollars bonds from the households. When  $\iota_0$  rises, the supply curve shifts rightward, and this leads to a depreciation. When  $R$  increases, the demand curve could shift left or right depending on which effect (UIP or risk-bearing capacity) dominates.<sup>14</sup> The figure illustrates the case in which the conditions in (9) is satisfied so that the risk capacity effect dominates in response to a rise in U.S. interest rates. The equilibrium exchange rate thus depreciates on impact as a result of reduced demand from financiers.

#### 4.1 Simulating Changes in the International Monetary System

We now subject the model to a number of comparative statics to investigate how changes in the international monetary system may have affected the transmission of US macroeconomic policy shocks. First, we consider the possibility that the global economy has become more financialized, but in a very particular way. Namely, we consider the possibility that risk aversion has become more sensitive to interest rates over time. Second, we investigate how the increased dominance of the US dollar may have affected international monetary transmission. Finally, we consider the possibility that the widening US current account deficit may have played a role.

Our theory lends itself immediately to study the first of these factors. Figure 7 illustrates how the model's predictions change with the elasticity of risk aversion with respect to interest rates,  $\eta$ . It shows the response (in percent) of several variables to a one percentage point increase in the US interest rate as a function of the elasticity of risk aversion with respect to interest rates  $\eta$ .<sup>15</sup> As noted earlier, an increase in the US interest rate increases financiers' demand for dollars because of the higher returns on dollar bonds, but decreases their demand because increased risk aversion tightens their credit constraint. With  $\eta = 0$  risk aversion is unaffected by interest rates, the first channel dominates, and financiers' dollar exposure increases (top, left-hand panel in the figure). As  $\eta$  increases, risk aversion becomes increasingly interest-elastic, depressing financiers' dollar exposure as interest rates increase. With  $\eta$  above the threshold in (9), interest rate increases may even decrease dollar demand.

The top, right-hand panel of the figure shows the exchange rate response to an increase in the

<sup>14</sup>Corresponding to the mathematical formulations, the change in  $R$  induces a leftward rotation of the demand curve.

<sup>15</sup>Formally, the figure shows the percent difference in the variable in question between a model solved with  $R = 1/\beta + 0.01, R^* = 1/\beta$  and one with  $R = R^* = 1/\beta$ , where  $\beta = 0.95$ .

US interest rate, on impact. When the elasticity of risk aversion with respect to interest rates is low, the higher demand for dollars leads to a dollar appreciation, as in the conventional model. At higher levels of  $\eta$ , demand for dollars declines in response to an interest rate increase, leading to a dollar depreciation, consistent with our empirical findings. The depreciation is caused by heightened risk aversion following the interest rate increase. Hence, our empirical results can be rationalized if risk aversion in financial markets has become more sensitive to interest rates over time.<sup>16</sup>

We note an important difference between our theory and a class of theories based on the signalling channel of monetary policy (cf. Stavrakeva & Tang 2018). In these models US monetary contractions signal Fed optimism about the state of the economy. The dollar depreciates rather than appreciates if the dollar is a “safe haven” currency and is in lower demand when the state of world economy is improving. Note, however, that the monetary policy tightening itself still has the same causal effect on the exchange rate, leading to an appreciation of the dollar. It is the news of a healthier economy that leads to a depreciation. Instead, in our theory, rising interest rates themselves lead to a depreciation because they dampen risk aversion.

We next investigate a second factor that may have affected the international transmission of monetary policy: The role of the dollar as an anchor currency (Rey 2013, Gopinath 2015, Maggiori *et al.* 2018, Ilzetzki *et al.* 2019, Gopinath *et al.* 2020). To capture the fact that there might be additional demand for US dollars due to its international role, we add an exogenous foreign demand for borrowing and saving in US dollars through a parameter  $f^*$ , which is positive (negative) when the non-financial sector demands a long (short) position in the dominant currency. Figure 8 shows how this factor affects the international transmission of interest rate policy. Lower (or negative) values of  $f^*$  represent an increased demand for borrowing in US dollars, putting additional pressure on the financial system’s limited intermediation capacity (it being already long on the dollar). This in turn, magnifies the importance of interest rates as they tighten the financial system’s credit constraint through increased risk aversion. Accordingly, as one moves from right to left in Figure 8, financial intermediation ( $Q_0$ ) and the exchange rate respond more negatively to increases in the US interest rate, potentially leading to a depreciation following a Fed tightening. The model

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<sup>16</sup>It is less clear whether changes in the *level* of risk aversion could explain the puzzle. The figure shows how  $\eta$  affects the exchange rate response to US interest rates for two values of  $\psi$ , governing the level of risk aversion, as opposed to its interest rate elasticity. As (2) illustrates, the elasticities of risk aversion and  $\Gamma$  with respect to interest rates isn’t affected by  $\psi$ . However, the exchange rate doesn’t change one to one with  $\Gamma$  and the experiment is a one percentage point, rather than percent, change in interest rates. If anything, a reduction in risk aversion over time (which would lead to a larger financial sector in the model) makes it more difficult to resolve the puzzle.

can therefore explain the sign reversal in the effects of US interest rates on the exchange rate if dollar dominance manifests itself in increased net demand from the non-financial sector for dollar borrowing over time.

It is hard to assess how the aggregate net demand for borrowing in a currency is affected by its international status. On one hand, Maggiori *et al.* (2018) document that the vast majority of corporate debt is denominated in US dollars, including outside the US. Further, Ilzetzki *et al.* (2020) show that the share of US dollar borrowing by governments in developing countries has increased in recent decades. On the other hand, massive increases in central bank reserves are a large demand for long US dollar positions.

Another factor that changed between our two empirical sub-samples is the widening US current account deficit. In the model, we alter the value of  $\iota_0$  to reflect an increase in US consumer demand for foreign tradable goods. Figure 9 shows that higher values of  $\iota_0$ , which leads to a larger US current account deficit, contribute to a downward pressure on the US dollar when US interest rates rise. The intuition is the same as before: the financial sector finances the net currency positions arising from the US current account deficit. A larger deficit puts greater pressure on the the financial sector to have a long position in the US dollar. This magnifies the effect of changes in risk aversion on dollar demand from the financial sector and therefore on the exchange rate, in turn amplifying the force that allows for a dollar depreciation following an increase in US interest rates.

We have seen how three potential shifts in the international monetary system may have affected the transmission of US interest rate shocks in ways consistent with the empirical findings of the previous section. While the interest elasticity of risk aversion plays a direct role in the first channel studied in Figure 7, note that interest rate elastic risk aversion is a necessary condition for any of the factors studied here to lead to a sign reversal in the response of the exchange rate to interest rate shocks.

## 4.2 The Reversal in the Output Response

Our theory has the potential to elucidate one puzzling aspect of our empirical findings: the depreciation of the dollar following US interest rate increases. Our findings posed a second puzzle: US contractionary monetary shocks lead to an output expansion in the rest of the world, while depreciating the dollar. This is puzzling because both the decline in US demand and the relative decrease in the price of US goods would tend to contract foreign output. Our theory comprises of a model of the financial sector, without an important role for the real economy, and is therefore

unsuited to resolve this second puzzle.

We point to a growing literature that investigates the expansionary effects of an appreciation of the local currency (against the US dollar) that may explain this second puzzle. Avdjiev *et al.* (2019) show that a weak dollar leads to increased investment in emerging markets. Aoki *et al.* (2016) provide a theory that allows for a stronger dollar to be expansionary for the rest of the world through balance sheet effects. Intuitively, if domestic collateral is denominated in local currency, a dollar depreciation increases local borrowing capacity in dollar terms, facilitates foreign investment and makes a weak dollar a stimulant rather than a drag on non-US economic activity.

## 5 Conclusion

Using a variety of identification methods commonly used in macroeconomics, we show a substantial change in the world economy's response to US macroeconomic shocks. This is true of monetary policy shocks identified by three separate methods, government spending shocks, and tax shocks. In all cases, the US dollar shows a "textbook" response in the two decades following Bretton Woods, but the opposite response in the dollar-centric period from the end of the Cold War and into the 21st century. Spillovers to the real economy of the rest of the world also show a similar sign reversal.

The responses in the modern era are hard to reconcile with the textbook Mundell-Flemming model of exchange rate determination, its modern variants, and recent theories of exchange rate determination. We sketch out a simple theory consistent with our findings if the risk-absorption capacity of the financial sector decreases when interest rates are high. We put forth three hypotheses of changes in the international monetary landscape that might have changed the nature of international macroeconomic policy spillovers.

We hope our analysis will stimulate further analysis—both empirical and theoretical. On the empirical side, it would be interesting to trace out the response of additional macroeconomic variables to US policy shocks and expand the analysis to smaller countries. More could be done to find the global factors that best predict the regime change circa 1990. On the theoretical side, our theory could be subjected thorough quantitative analysis in a calibrated model. Our model has a reduced-form relationship between US interest rates and the banking system's riskiness. Carefully fleshing the model's micro-foundations, and unpacking the reasons for risk aversion's interest sensitivity, may yield further insights.

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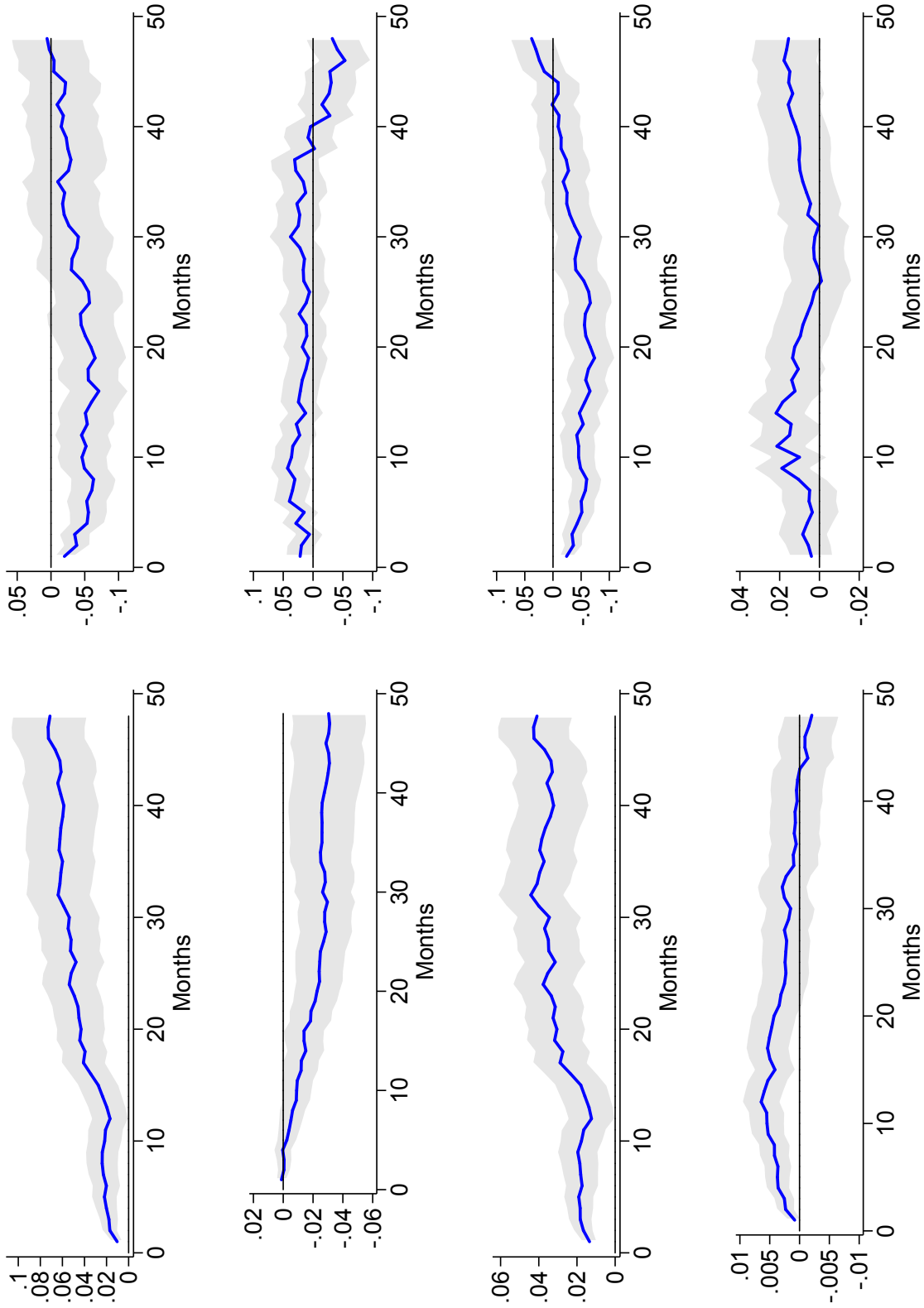
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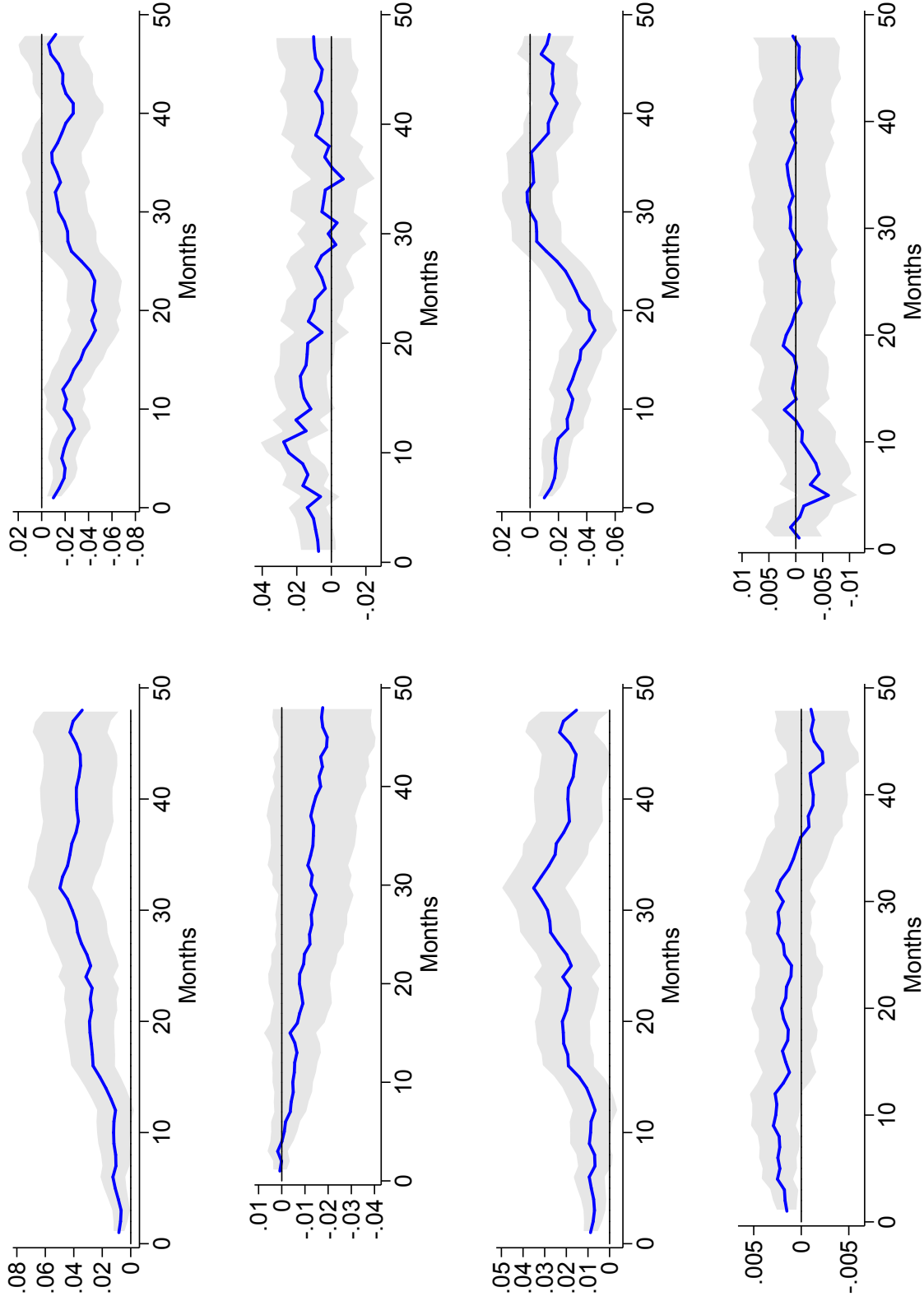
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Figure 1: Responses to (Romer&Romer, 2004) Monetary Policy Shocks



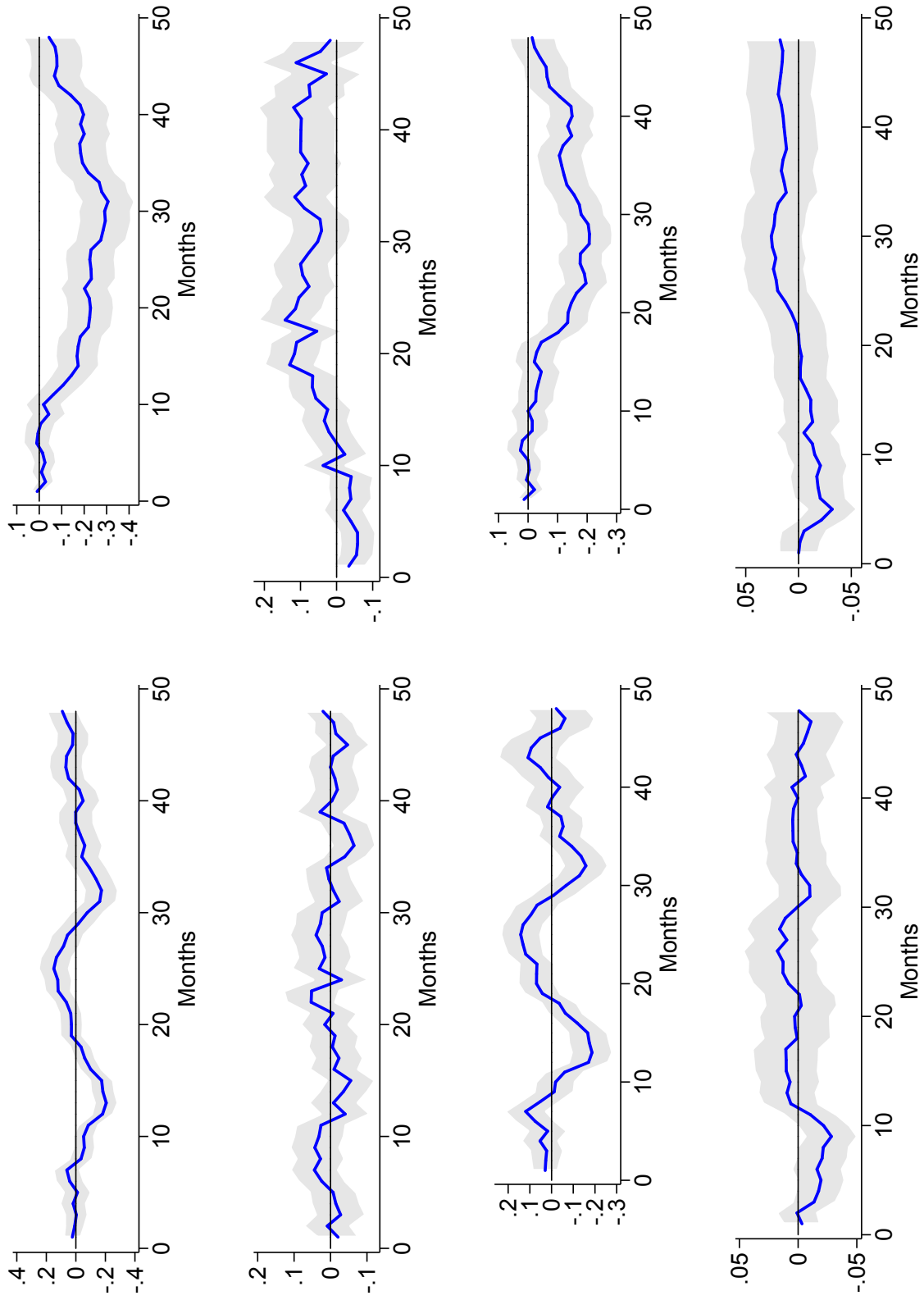
Note: The figure shows responses (in percent) to a 1 percentage point increase in the Federal Funds Rate identified by Romer & Romer (2004). The shocks are deviations from the Federal Reserve's systemic monetary policy response to its previous level; forecasts of the current, last quarters, and following two quarters of inflation and GDP; the change in these forecasts since the previous meeting of the Federal Open Market Committee; and its estimates of current unemployment. These are based on real-time Green Book data. The left-hand column gives responses for 1973-1990. The right-hand column gives responses for 1991-2007. The first row shows responses of the nominal exchange rate (increase reflecting US dollar appreciations). The second row shows responses of non-US industrial production. The third row shows responses of the real exchange rate. The fourth row shows the change in the policy interest rate in the rest of the world (in percentage points). Estimates are local projections with country fixed effects, controlling for a quadratic time trend. The specification is given by 1. The shaded areas represent 95% confidence bands.

Figure 2: Responses to VAR Monetary Policy Shocks (Eichenbaum & Evans 1995, Christiano *et al.* 1999)



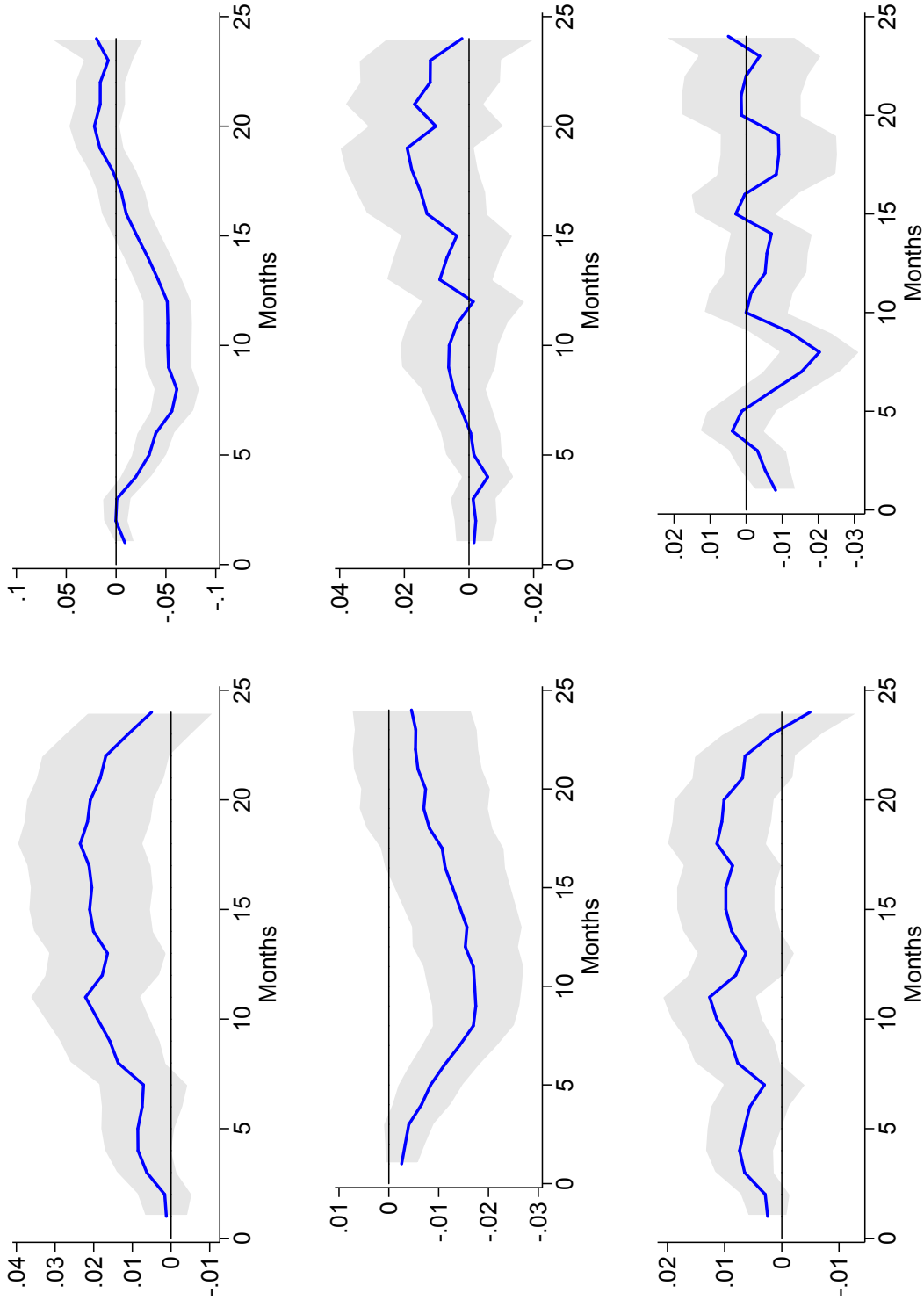
Note: The figure shows responses (in percent) to a 1 percentage point increase in the Federal Funds Rate identified as residuals from VARs, as in Eichenbaum & Evans (1995), Christiano *et al.* (1999). The shocks are residual Fed Funds Rate movements in a VAR also including US industrial production, CPI, and non-borrowed reserves. The left-hand column gives responses for 1973-1990. The right-hand column gives responses for 1991-2007. The first row shows responses of the nominal exchange rate (increase reflecting US dollar appreciations). The second row shows responses of non-US industrial production. The third row shows responses of the real exchange rate. The fourth row shows the change in the policy interest rate in the rest of the world (in percentage points). Estimates are local projections with country fixed effects, controlling for a quadratic time trend. The specification is given by 1. The shaded areas represent 95% confidence bands.

Figure 3: Responses to High Frequency Monetary Policy Shocks (Gertler & Karadi 2015)



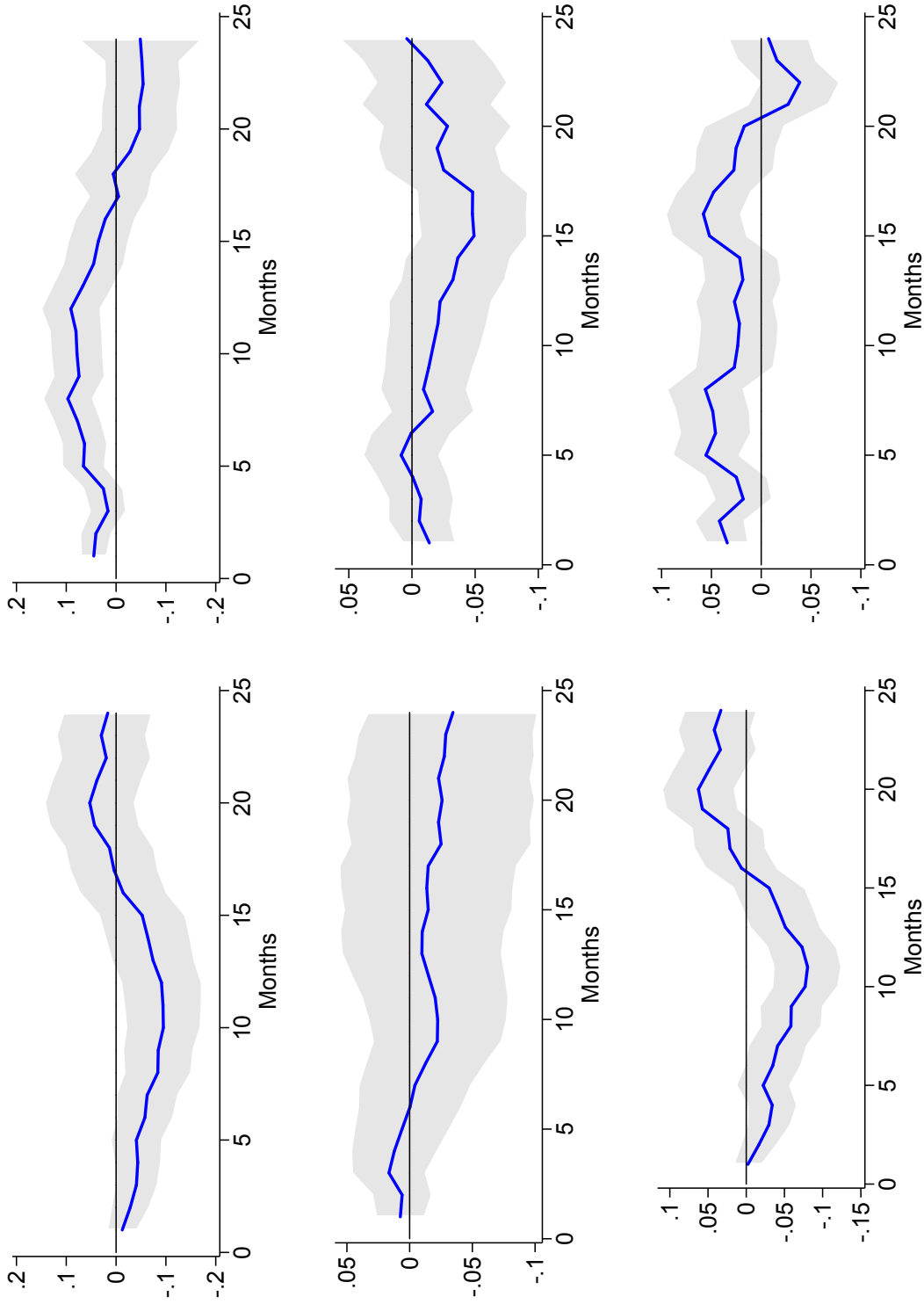
Note: The figure shows responses (in percent) to a 1 percentage point increase in the Federal Funds Rate identified as the move the daily changes in one month Federal Funds futures prices on the day of Fed announcements Gertler & Karadi (2015). The left-hand column gives responses for 1973-1990. The right-hand column gives responses for 1991-2007. The first row shows responses of the nominal exchange rate (increase reflecting US dollar appreciations). The second row shows responses of non-US industrial production. The third row shows responses of the real exchange rate. The fourth row shows changes in the policy interest rate in the rest of the world (in percentage points). Estimates are local projections with country fixed effects, controlling for a quadratic time trend. The specification is given by 1. The shaded areas represent 95% confidence bands.

Figure 4: Responses to (Ramey, 2011) Government Spending Shocks



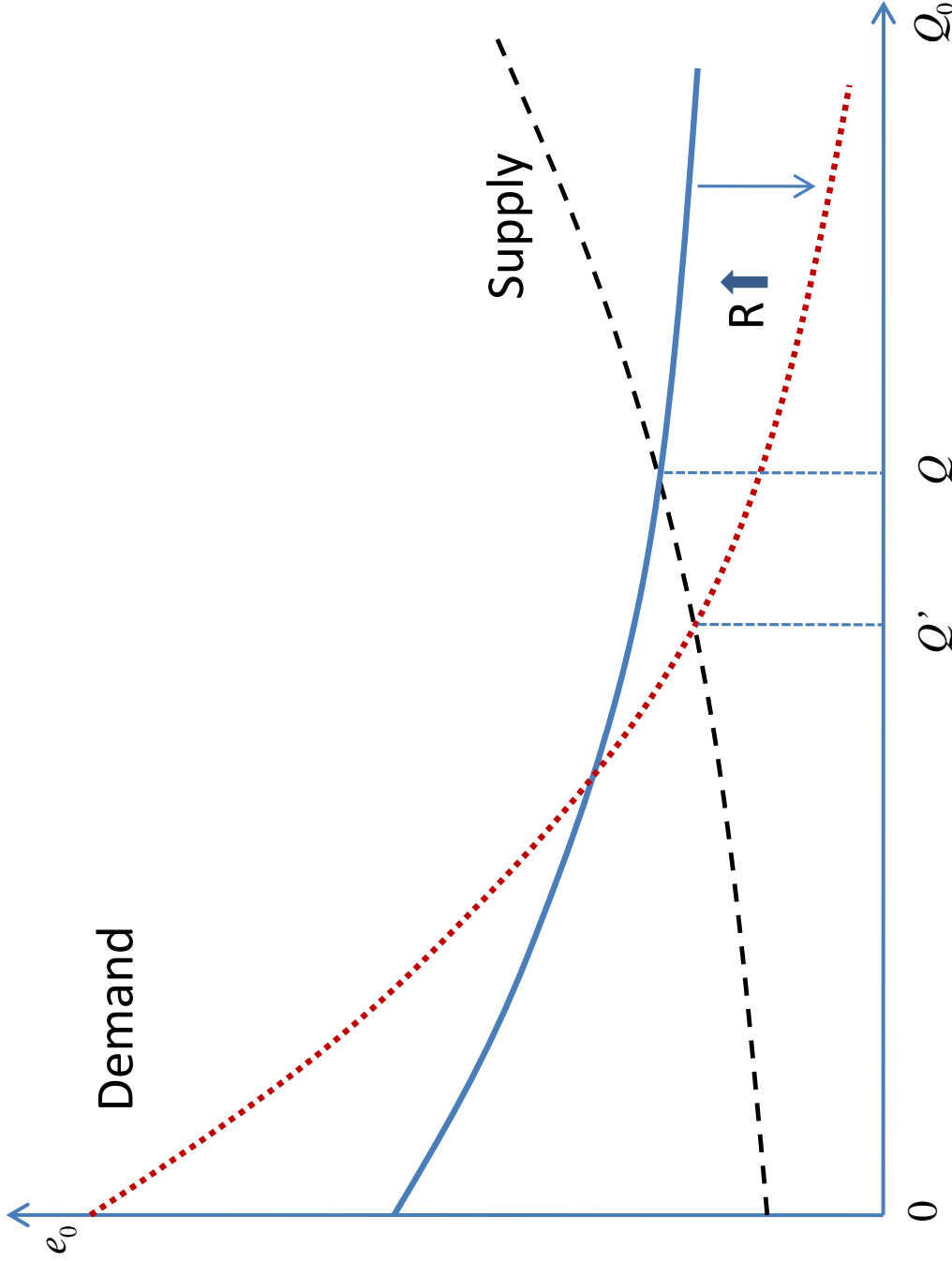
Note: The figure shows responses to news of a 1 percent of GDP increase in public spending identified by Ramey's (2011) historical narrative of military buildups. The left-hand column gives responses for 1973-1990. The right-hand column gives responses for 1991-2007. The first row shows responses of the nominal exchange rate (increase reflecting US dollar appreciations). The second row shows responses of non-US industrial production. The third row shows responses of the real exchange rate. Estimates are local projections with country fixed effects, controlling for a quadratic time trend. The specification is given by 1. The shaded areas represent 95% confidence bands.

Figure 5: Responses to (Romer&Romer, 2010) Tax Policy Shocks



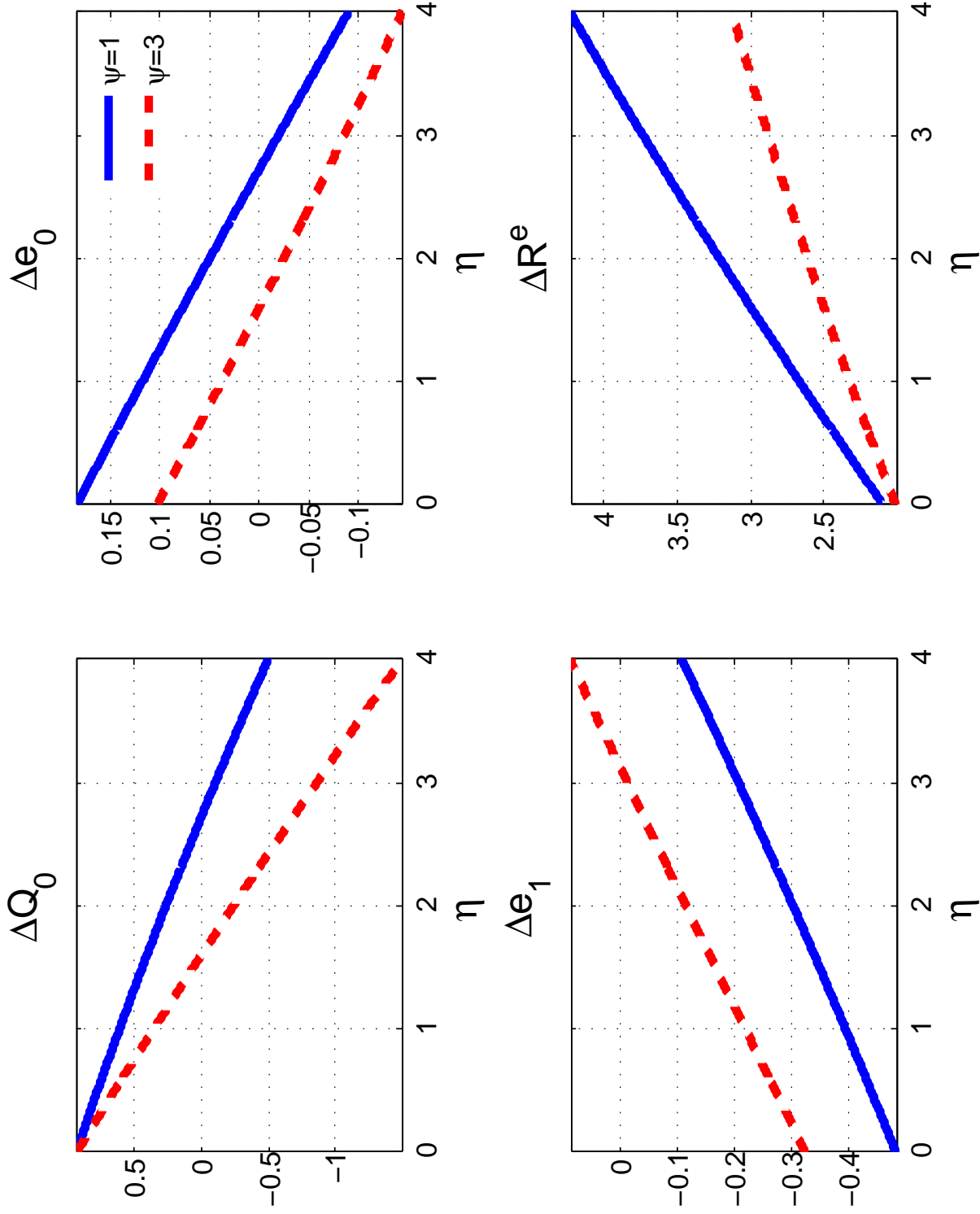
Note: The figure shows responses to news of a 1 percent of GDP increase in tax revenues identified by Romer & Romer's (2010) historical narrative of tax legislation. The left-hand column gives responses for 1973-1990. The right-hand column gives responses for 1991-2007. The first row shows responses of the nominal exchange rate (increase reflecting US dollar appreciations). The second row shows responses of non-US industrial production. The third row shows responses of the real exchange rate. Estimates are local projections with country fixed effects, controlling for a quadratic time trend. The specification is given by 1. The shaded areas represent 95% confidence bands.

Figure 6: Demand and Supply of dollars: an increase in interest rates



Note: The figure illustrates supply and demand for dollar bonds in the model of exchange rate determination with interest-elastic risk aversion of Section 4. The price on the y axis is the current (time zero) exchange rate in yen per dollar. The quantity on the x axis is net demand and supply of long dollar positions or dollar bonds (relative to yen bonds). The (upward sloping) supply curve is determined by the current account deficit, where a stronger dollar (higher  $e_0$ ) worsens the current account deficit, inducing greater net dollar borrowing from the non-financial sector. The (downward sloping) demand curve is determined by limits on the financial sector's lending capacity: limits on its net FX exposure. A stronger dollar (higher  $e_0$ ) implies a greater expected dollar depreciation, which lowers the financial sector's expected returns and lowers their demand for long dollar positions. An increase in the US interest rate has two effects. First, it increases dollar returns and thus increases the financial sector's demand for long-dollar position at any given current exchange rate. Second, it reduces risk aversion, thus lowering the financial sector's demand for net FX exposure, lowering its demand for dollar bonds.

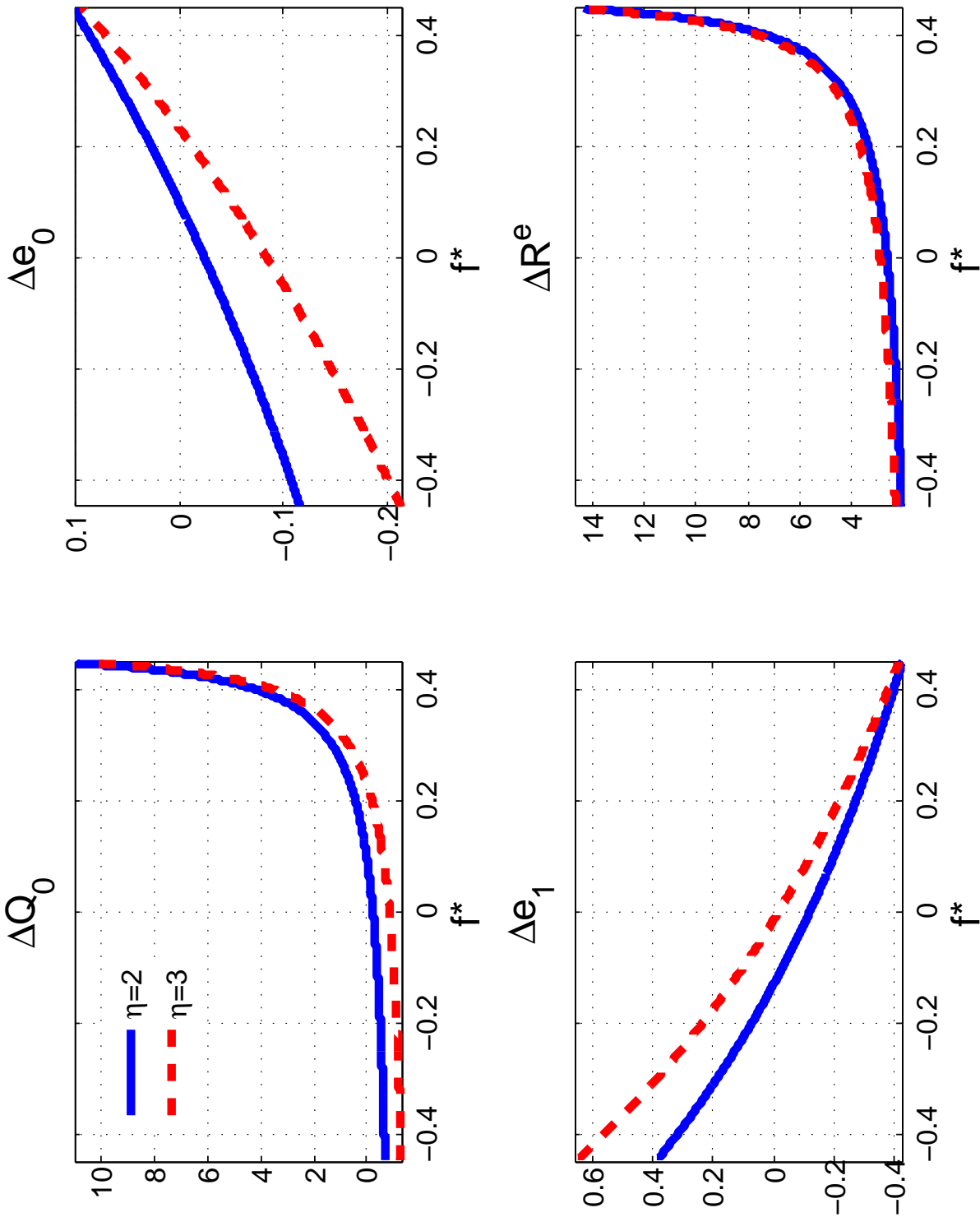
Figure 7: Effect of an Increase in US Interest Rates: The Role of the Interest Elasticity of Risk Aversion



Note: The figure presents the response of a number of variables to a one percentage point increase in the US interest rate in the theoretical model of Section 4. The horizontal axis represents values of the elasticity of risk aversion with respect to the US interest rate  $\eta$ . Going clockwise from the upper-left-hand corner, the panels represent (i) the net foreign exchange (dollar) position of the financial sector; (ii) the response of the exchange rate on impact, with an increase representing a US dollar appreciation; (iii) excess returns obtained by financiers; (iv) the long run exchange rate response. The US dollar appreciates less (depreciates more) in response to an increase in US interest rates as the elasticity of risk aversion with respect to interest rates increases.

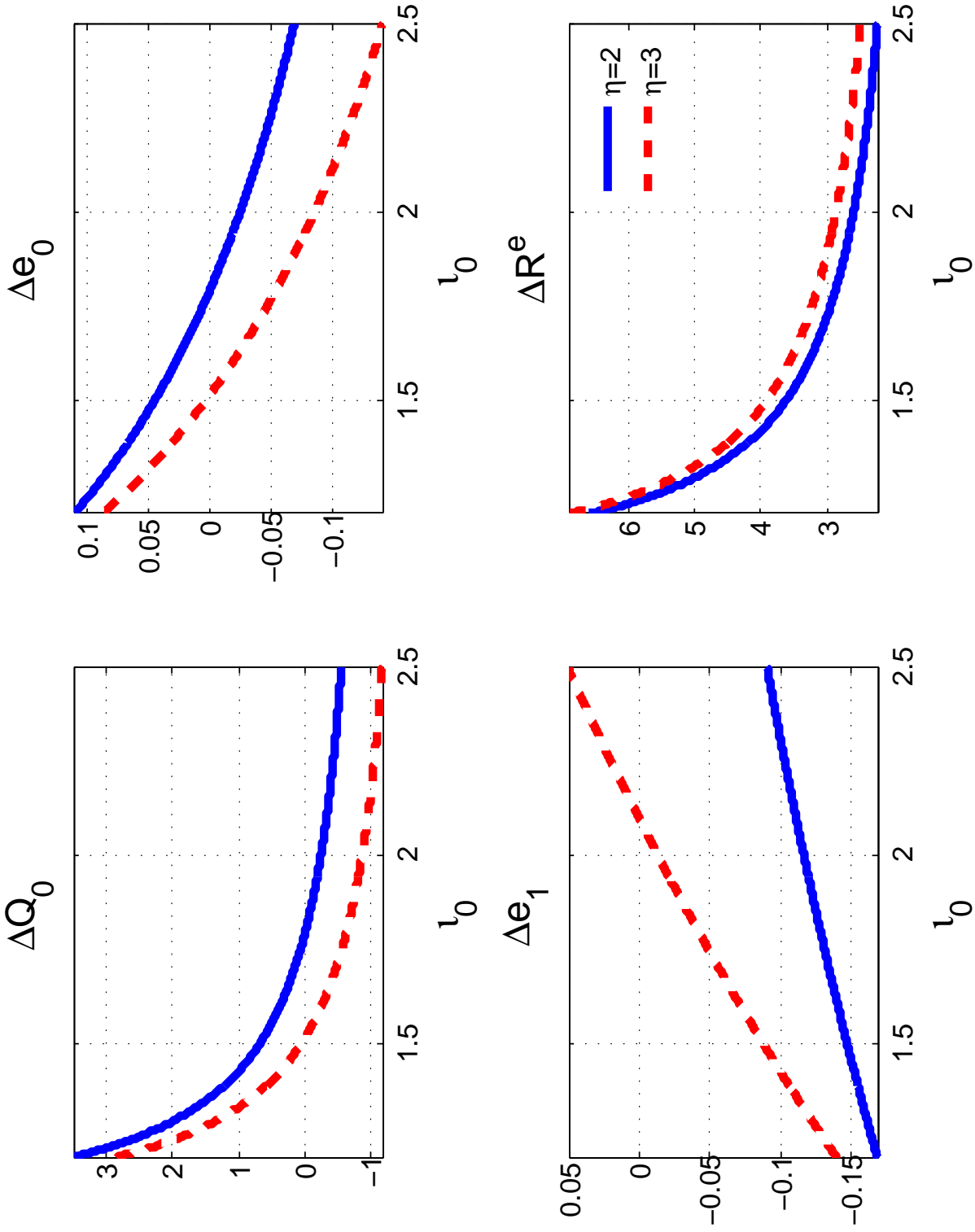


Figure 8: Effect of an Increase in US Interest Rates: The Role of Dollar Demand



Note: The figure presents the response of a number of variables to a one percentage point increase in the US interest rate in the theoretical model of Section 4. The horizontal axis represents values of an exogenous demand for a long position in US dollars from the non-financial sector  $f^*$ . Going clockwise from the upper-left-hand corner, the panels represent (i) the net foreign exchange (dollar) position of the financial sector; (ii) the response of the exchange rate on impact, with an increase representing a US dollar appreciation; (iii) excess returns obtained by financiers; (iv) the long run exchange rate response. The US dollar appreciates less (depreciates more) in response to an increase in US interest rates as the non-financial sector's demand for dollar borrowing increases.

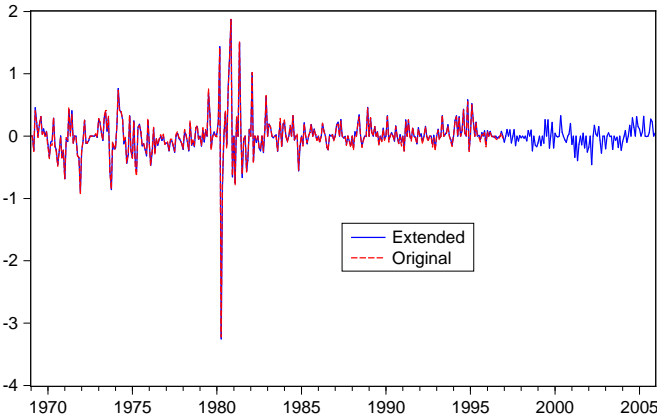
Figure 9: Effect of an Increase in US Interest Rates: The Role of a Widening US Current Account



Note: The figure presents the response of a number of variables to a one percentage point increase in the US interest rate in the theoretical model of Section 4. The horizontal axis represents values of the weight on foreign tradable goods in the US consumer demand. Going clockwise from the upper-left-hand corner, the panels represent (i) the net foreign exchange (dollar) position of the financial sector; (ii) the response of the exchange rate on impact, with an increase representing a US dollar appreciation; (iii) excess returns obtained by financiers; (iv) the long run exchange rate response. The US dollar appreciates less (depreciates more) in response to an increase in US interest rates as US consumers increase their demand for foreign tradable goods (leading to a larger US current account deficit).

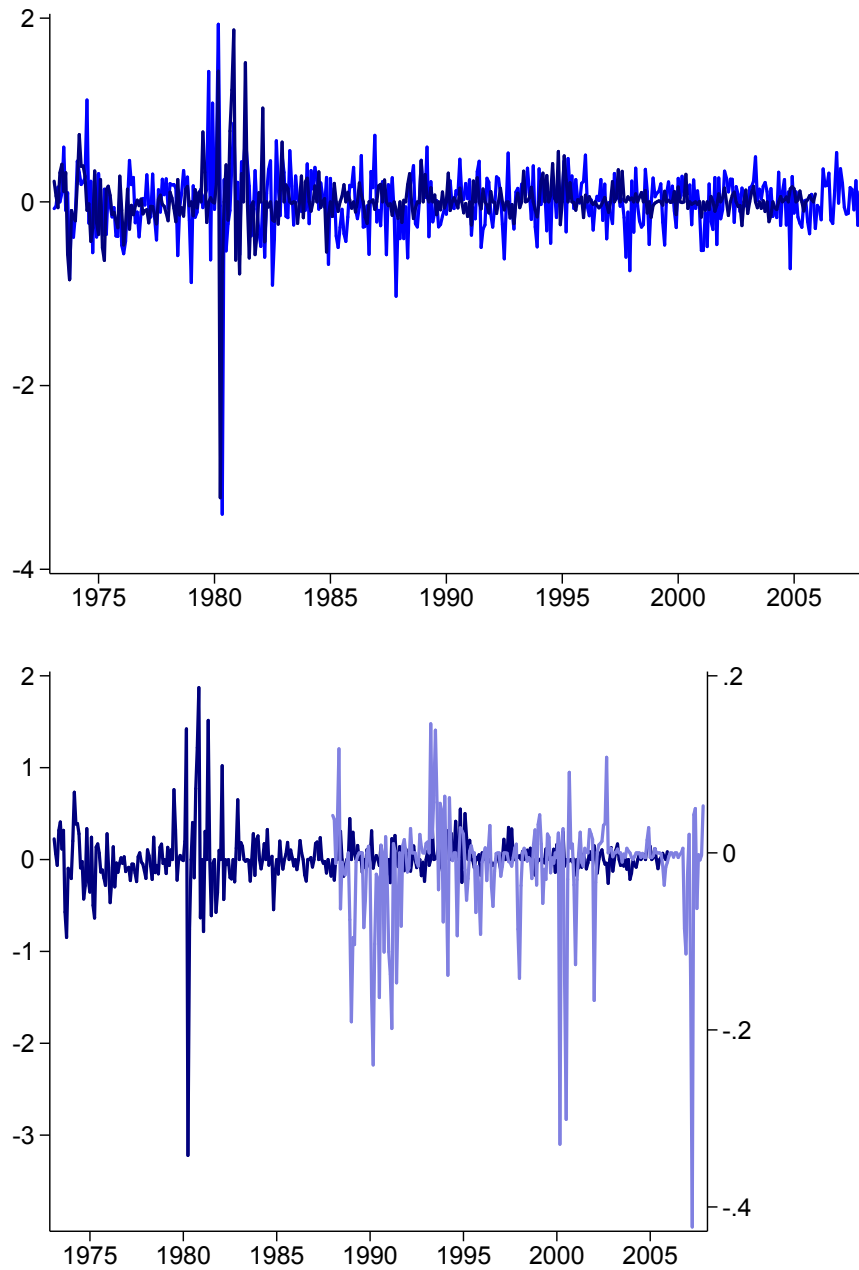
# A Appendix Figures

Figure A.1: Extending the Romer & Romer (2004) Series of Monetary Policy Shocks



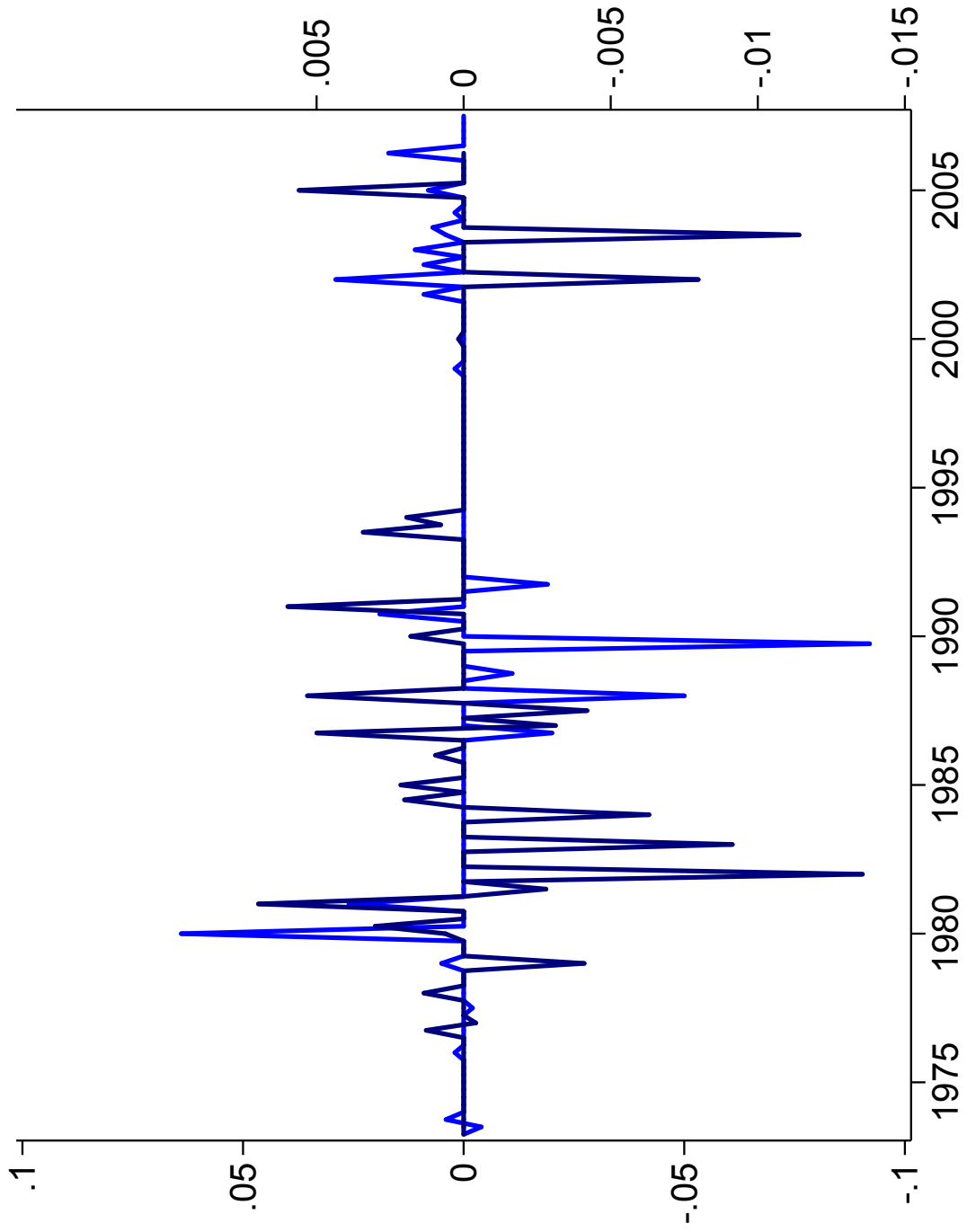
Note: The figure compares the original Romer & Romer (2004) shocks with our replication and extension of the series.

Figure A.2: Comparing Monetary Policy Shocks



Note: The figure compares monetary policy shocks using three different identification methods. The top panel compares Romer & Romer (2004) shocks (darker shade) with residuals from a VAR along the lines of Eichenbaum & Evans (1995) or Christiano *et al.* (1999) (lighter shade; correlation 0.14). The bottom panel compares Romer & Romer (2004) shocks (darker shade, left hand scale) to Gertler & Karadi (2015) high frequency shocks (lighter shade, right hand scale; correlation -0.02).

Figure A.3: Fiscal Policy Shocks



Note: The figure shows government spending shocks based on Ramey (2011) news shocks (lighter shade, left hand scale) and tax shocks based on Romer & Romer (2010) narrative (lighter shade, right hand scale; correlation: -0.10).