The Transmission Mechanisms of International Business Cycles: Output Spillovers through Trade and Financial Linkages*

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October 2021

Abstract

We study the transmission channels through which shocks affect the global economy and the cross-country comovement of real economic activity. For this purpose, we collect detailed data on international trade and financial linkages as well as domestic macro and financial variables for a large set of countries. We document significant international output comovement following U.S. monetary shocks, and find that openness to international trade matters more than financial openness in explaining cross-country spillovers. In particular, output in countries with a high share of exports and imports responds to U.S. monetary shocks significantly more than output in countries with a low share, whereas we do not find material heterogeneity depending on international investment positions or financial flows in the balance of payments. We further document strong network amplification associated with the patterns of bilateral trade flows, as indirect spillovers account for nearly half of the total effect. Studies that do not account for direct bilateral linkages between national economies—and the indirect linkages through the network they form—may thus present an incomplete view of international business cycles.

Keywords: Financial linkages; International spillovers; Monetary shocks; Trade networks
JEL Classification: E52, F42, F44, G15

*This draft is a preliminary version of the paper prepared for the IMF 22nd Jacques Polak Annual Research Conference and the *IMF Economic Review*. We thank Keith Barnatchez and Sam Tugendhaft for excellent research assistance. We thank Paul Bergin, Ryan Chahrour, Mario Crucini, Bill Dupor, Sacha Gelfer, Yuriy Gorodnichenko, Pierre-Olivier Gourinchas, Laura Jackson Young, Ralph Koijen, Ezgi Kurt, Giovanni Olivei, Nick Sander, Eric Sims, and Eva Van Leemput as well as seminar and conference participants at the Boston Area Macro-Finance Juniors meeting, SED 2021, Bentley University, and NBU for comments and suggestions. We thank Haver Analytics for providing some of the publicly available data used in this research. We are especially grateful to Rob Johnson and Eric Swanson for sharing their data. An earlier version of this paper circulated under the title "Output Spillovers from U.S. Monetary Policy: The Role of International Trade and Financial Linkages." The views expressed in this paper are those of the authors and do not indicate concurrence by the Federal Reserve Bank of Boston, the principals of the Board of Governors, or the Federal Reserve System.

1. Introduction

The transmission of shocks in the global economy and the cross-country comovement of business cycles are among the central questions of international macroeconomics (e.g., Kose, Otrok, and Whiteman 2003; Aguiar and Gopinath 2007; di Giovanni, Levchenko, and Mejean 2018). In this context, international trade and financial linkages may be an important channel through which economic shocks propagate across countries.[1] For example, a contractionary U.S. monetary policy shock may reduce U.S. demand for foreign goods through the income effect, with a negative impact on foreign economies. Moreover, U.S. banks may reduce the supply of credit to foreign borrowers. The strength of these effects likely depends on the size and the patterns of international trade and financial linkages. In addition, a chain of indirect effects could further amplify these direct spillovers. For example, the effect of U.S. policy on output in Germany depends, among other factors, on its effect on output in France, due to tight linkages between the French economy and the German. Despite the salience of such spillovers and the greatly increased economic effects of globalization in the last few decades, the literature provides only fragmented answers to many important questions: How large are international spillovers relative to domestic effects? Through which international linkages do shocks propagate across countries? Are the indirect effects of output spillovers quantitatively important?

In this paper, we shed new light on these questions by studying how domestic aggregate shocks transmit across borders through the networks formed by bilateral trade and financial linkages, thereby engendering cross-country comovement in real economic activity. We focus on U.S. monetary shocks, since they are often perceived as an important driver of international business cycles, due to the size of the U.S. economy and the dollar's role as a dominant currency (e.g., Goldberg and Tille 2008; Gopinath and Stein 2021). As U.S. monetary shocks may spread trough both international trade and finance, they can help us evaluate the relative importance of the two propagation channels. We also take advantage of a long-standing literature dedicated to the identification and analysis of the real effects of monetary shocks in the United States (e.g., Romer and Romer 2004; Nakamura and Steinsson 2018). Our paper extends these analyses to foreign economies, focusing on the transmission channels of international business cycles.

To estimate the spillover effects, we employ local projections with instrumental variables (Jordà 2005; Stock and Watson 2018), using high-frequency monetary shocks as instruments for the U.S. policy rate. Because a significant portion of our sample includes the zero lower bound (ZLB) period, we use the Wu and Xia (2016) shadow policy rate as our benchmark. Besides U.S. monetary shocks, we collect data on real GDP per capita, bilateral trade flows, the balance of payments,

[1] Frankel and Rose (1998), Forbes (2004), and Cravino and Levchenko (2017), among many others, emphasize international trade as a key transmission channel, while Kaminsky and Reinhart (2000), Ivashina, Scharfstein, and Stein (2015), Miranda-Agrippino and Rey (2020), and others focus on financial linkages.

international investment positions (IIPs), and other variables for 44 countries. The data cover the period 1995–2017 at a quarterly frequency. For a smaller sample, we also obtain data on value-added bilateral trade flows and bilateral banking claims.

We document three major findings. First, U.S. monetary tightening reduces foreign output, with larger effects in countries that are relatively more open to international trade. Second, U.S. shocks propagate through the network of bilateral trade linkages, generating significant indirect effects. Third, financial openness, measured in a variety of ways, does not appear to be as important as trade openness in explaining cross-country heterogeneity in output responses, and the associated indirect effects are small. Thus, trade linkages are more relevant for international output spillovers than financial linkages, playing an important role in the transmission mechanism of international business cycles.

We start by measuring the average output response in the full sample. We estimate that, following a U.S. monetary policy tightening of 1 percentage point, real GDP per capita abroad decreases on average by 1.9% over a three-year horizon. The estimates are robust to using alternative measures of policy instruments and to excluding the ZLB period. We also document a substantial passthrough from the federal funds rate to foreign interest rates—under a floating exchange rate regime as well as under a peg—which may in part explain the magnitude of our baseline estimates.

We then split our sample into two groups, based on the output share of exports and imports at the beginning of our sample period relative to the cross-country median. We find that output in countries with high trade shares responds to U.S. monetary policy significantly more than output in countries with low trade shares. Both consumption and investment decline relatively more in high-trade countries. The difference in output responses is particularly large under a peg. We also verify that the output effects in high-trade countries remain larger than in low-trade countries conditional on the degree of financial openness, measured by the ratio of IIP to GDP, and on the policy interest rate, for which we control using a sample of euro area members.

To better understand the differences between high-trade and low-trade countries, we examine the responses of other key variables. We find that the main difference is due to the trade responses rather than the interest-rate or exchange-rate responses. If anything, the interest rate pass-through is larger in low-trade countries, making their currencies appreciate relative to the high-trade countries' currencies. This price effect therefore works in the direction opposite to the dominating income (demand) effect. Moreover, as the interest rates increase in low-trade countries more than in high-trade countries, their stock prices decline more. Thus, the differences between the two groups cannot be explained by the financial wealth effect.

To examine the sources of heterogeneity further, we estimate the responses of output separately in each country, thereby allowing U.S. monetary shocks to have country-specific effects. We then regress these responses over a range of response horizons on openness to trade, measured by the output share of total gross trade and of total value-added trade (e.g., Johnson and Noguera 2017; Alfaro et al. 2019), and openness to foreign finance, measured by the IIP (stock measure) and by the flows (total or net) from the financial account normalized by output. We also control for the development level and other country characteristics. We find that trade openness is positively associated with the spillover effects: Countries with a higher degree of trade openness experience larger output spillovers from U.S. shocks. We do not find such an association with the spillovers for financial openness when we use our baseline proxies, such as the aggregate IIP or financial account measures, or when we break down each of the two aggregate measures into its sub-components that capture international linkages through direct investment, debt, equity, or derivatives. Nor do we find significant differences in the spillovers depending on net exports, suggesting that total trade flows are more important for business-cycle transmission than net trade flows.

To quantify the endogenous amplification through the international trade network, we estimate a spatial econometric model, wherein, in addition to heterogeneous *direct* effects of U.S. shocks, output in one country can affect output in other countries, engendering indirect effects. With this approach, we can measure the spillover effect for a given network, decompose the heterogeneous total effect into the direct and indirect effects, and then rank the networks based on the sizes of these effects. We measure the trade network using bilateral flows in gross and value-added trade (exports plus imports). We also consider alternative networks based on bilateral financial linkages in order to assess the relative importance of international trade and finance in the transmission of U.S. shocks.

Our results indicate strong amplification associated with the total-trade network, as conditional spatial correlation reaches values of 0.5. In the baseline spatial model, 48% of the total effect at the peak horizon is attributed to indirect spillovers. The share of the indirect effect increases somewhat over time, consistent with the delayed output response. We obtain qualitatively similar results when we use total value-added trade. We do not find, however, that U.S. monetary shocks propagate through the export network differently than through the import network. Our estimates are robust to a variety of spatial specifications proposed in the literature.

Given the decomposition into direct and indirect effects, we also document substantial heterogeneity across countries in the degree of spillovers, attributed primarily to heterogeneity in the direct effects. Countries that are relatively open to trade experience, on average, larger spillovers than countries that are relatively closed. Conditional on the degree of trade openness, we find no discernible cross-country differences in spillovers due to financial openness.

In contrast to trade flows, we estimate small and statistically insignificant indirect effects when using the network based on bilateral cross-border banking claims. While we estimate this model for a smaller sample of countries with available data, the evidence is consistent with other results on financial linkages. Overall, we conclude that total-trade linkages, rather than net-trade or financial linkages, are associated with a strong network amplification of output spillovers from U.S. shocks.

Related Literature. This paper contributes to several strands of the literature. First, it relates to the literature on international business cycles (e.g., Kose, Otrok, and Whiteman 2003; Lumsdaine and Prasad 2003; Imbs 2004; Baxter and Kouparitsas 2005; Aguiar and Gopinath 2007; Crucini, Kose, and Otrok 2011; di Giovanni, Levchenko, and Mejean 2018). In this context, Frankel and Rose (1998), Eichengreen and Rose (1999), Glick and Rose (1999), Forbes (2004), and others, using aggregate data, show that shocks can propagate across borders through international trade. Other papers study the international transmission with firm-level trade data from individual countries (e.g., Cravino and Levchenko 2017; di Giovanni, Levchenko, and Mejean 2018, 2020), value-added trade (e.g., Antràs et al. 2012; Johnson and Noguera 2012, 2017; Johnson 2014; Alfaro et al. 2019), and financial linkages (e.g., Kaminsky and Reinhart 2000; Van Wincoop and Yi 2000; Van Rijckeghem and Weder 2001; Caballero and Krishnamurthy 2004; Rey 2016; Miranda-Agrippino and Rey 2020). We contribute to this literature by differentiating between trade and financial transmission channels in a unified framework, combining aggregate data for a large sample of advanced and developing countries with detailed information on bilateral linkages between these countries.

Second, our paper contributes to the emerging literature that highlights the importance of networks in the propagation of shocks. Recent theoretical models emphasizing the network channel include Acemoglu et al. (2012), Carvalho and Gabaix (2013), di Giovanni, Levchenko, and Mejean (2014), and Acemoglu, Ozdaglar, and Tahbaz-Salehi (2017), among others. Focusing on input–output linkages, recent empirical work sheds first rays of light on the relevance of such network effects in closed economies (e.g., Barrot and Sauvagnat 2016; Ozdagli and Weber 2017; Giroud and Mueller 2019). Our paper extends these emerging analyses to open economies, and finds sizable amplification of shocks through the international trade network. While Chang et al. (2021) also emphasize the role of international trade linkages by studying propagation of the effects of natural disasters on financial variables, we show that trade linkages are important for the real effects of nominal shocks.

Third, our paper contributes to the literature on the international effects of U.S. monetary policy. In particular, several recent studies investigate these effects on foreign financial markets, including foreign exchange markets and international banking (e.g., Bruno and Shin 2015; Forbes, Hjortsoe, and Nenova 2018; Bräuning and Ivashina 2019). While Kim (2001), Dedola, Rivolta, and Stracca (2017), and Iacoviello and Navarro (2019) also study the responses of real variables, we emphasize international output comovement and significantly extend this literature in two directions: (1) by providing new evidence based on high-frequency identification methods, and (2) by analyzing the transmission mechanism and amplification effects from the network perspective.

This paper proceeds as follows. Section 2 summarizes the data. Section 3 presents the methodology and our estimates of the average foreign output response to U.S. monetary shocks. Section 4 studies the sources of heterogeneity in these responses, focusing on international transmission mechanisms. Section 5 analyzes spatial networks based on trade and financial linkages and measures the network amplification effects. Section 6 concludes.

2. Data

We use quarterly data for 44 countries during the period 1995–2017. To measure real economic activity, we collect real GDP data (in local currency) from the International Monetary Fund (IMF) and the Organization for Economic Cooperation and Development (OECD). We compute per-capita measures using population data from the Penn World Tables.

For U.S. monetary policy interest rates, we splice the federal funds rates prior to the ZLB period with the Wu and Xia (2016) shadow rates during the ZLB period. We also use data on the one-year Treasury yields. We obtain three measures of U.S. monetary shocks, based on the high-frequency identification methods, considered in the recent literature: Gürkaynak, Sack, and Swanson (2005), Gertler and Karadi (2015), and Nakamura and Steinsson (2018).[2] We also collect monetary policy and interbank rates for 32 other countries. When such data are not available, we use government bond yields (7 countries) or deposit rates (4 countries).

To measure trade openness at the country level, we obtain data on total exports and imports from the World Bank. To measure trade linkages, we rely on bilateral trade flows (exports and imports) obtained from the United Nations' Comtrade database. We take bilateral value-added trade from Johnson and Noguera (2012), which covers 30 countries in our baseline sample for the relevant period.

To measure financial openness, we use total and net IIPs from the IMF's International Financial Statistics (IFS). To measure international financial linkages, we collect data on bilateral banking claims from the Consolidated Banking Statistics Claims database compiled by the Bank for International Settlements (BIS). These data report, for example, the claims of all Italian banks on all Japanese counterparties (both bank and nonbank borrowers). We rely on the BIS data for three main reasons. First, these data are consistent for a relatively large number of countries and a relatively long period. Second, international banking flows (in contrast to investment fund flows, for example) comprise a major portion of financial linkages, especially for developing countries (e.g., Bräuning and Ivashina 2019). Third, banking flows strongly correlate with other types of financial flows. In contrast to the data on bilateral trade flows, the BIS data start in 2005 and are available for only 18 countries in our sample.

In addition to these main variables, we use several other measures. We take the current and financial accounts from the IFS Balance of Payments and exchange rates from the OECD. We follow Shambaugh's (2004) classification of exchange rate regimes, extended through the end of

[2]These data are publicly available at the authors' websites.

our sample period, and the BIS development classification. The list of countries and key summary statistics are provided in Appendix Table A.1.

3. Foreign Output Effects of U.S. Monetary Policy

3.1. Empirical Strategy

To estimate the semi-elasticity of foreign output with respect to the U.S. monetary policy rate, we combine the local projection method with instrumental variables in a panel setup (Jordà 2005; Stock and Watson 2018). We first estimate the average output response across all countries. For each response horizon h between 0 and 20 quarters, we estimate the following specification:

$$y_{i,t+h} = \alpha_i^h + \beta^h r_t + \sum_{k=1}^{4} \gamma_k^h y_{i,t-k} + \sum_{k=1}^{4} \delta_k^h r_{t-k} + \sum_{k=1}^{4} \zeta_k^{h\prime} \mathbf{s}_{t-k} + \boldsymbol{\theta}_i^{h\prime} \mathbf{x}_t + \varepsilon_{i,t+h}^h, \tag{1}$$

where the response variable $y_{i,t+h}$ is the logarithm of real GDP per capita after h quarters, r_t is the U.S. policy rate instrumented with the vector of shocks $\mathbf{s}_t$, $\mathbf{x}_t \equiv (t\ t^2)'$ is a vector of deterministic controls containing components of a quadratic time polynomial with country-specific loads $\boldsymbol{\theta}_i^h$, $\varepsilon_{i,t+h}^h$ is the error term, and $\{\alpha_i^h,\ \beta^h,\ \gamma_k^h,\ \delta_k^h,\ \zeta_k^h,\ \boldsymbol{\theta}_i^h\}$ are estimated parameters. We include the lags of output as well as the deterministic trend in order to control for preexisting output dynamics, while the lags of the policy rate and of the shocks account for serial correlation in the impulse variable. The coefficients $\hat{\beta}^h$ measure the output responses at different horizons pooled across all countries in the sample. The estimated standard errors are two-way clustered by quarters and countries, accounting both for the serial correlation arising from local projections and for the contemporaneous correlation of output across countries due to unobserved factors.

Relying on the high-frequency identification methods that exploit changes in asset prices occurring around the Federal Open Market Committee's policy announcements, we instrument the U.S. policy rate with several measures recently proposed in the literature. In our baseline specification, we use as instruments the Gürkaynak, Sack, and Swanson (2005) and Gertler and Karadi (2015) policy shocks.[3] Using multiple shocks enables us to exploit different information about monetary policy surprises. For example, the Gürkaynak, Sack, and Swanson (2005) shocks are based on movements in the federal funds *futures* rate, while the Gertler and Karadi (2015) shocks also exploit information from the macroeconomic variables typically used in vector autoregressions. Hence, using these shocks together may be advantageous during certain periods, such as the ZLB episode, thereby enriching our analysis applied to heterogeneous samples.

[3] We also consider the Nakamura and Steinsson (2018) shocks, which are highly correlated with the Gürkaynak, Sack, and Swanson (2005) shocks: The correlation coefficient in our sample is 0.83.

Nakamura and Steinsson (2018) point out that the monetary shocks identified using high-frequency methods may reflect the private information held by the central bank about the current and future states of the economy. While this so-called information effect could inhibit causal interpretation for the *domestic* effects of monetary policy (Ramey 2016), we could nonetheless study the foreign effects emanating from these shocks under some additional assumptions. To the extent that the central bank's private information concerns predominantly with domestic content, we can uncover the sources through which foreign output comoves with domestic output, conditional on shocks exogenous from the perspective of foreign economies.[4]

3.2. Identifying Assumptions

We now discuss formally the conditions required to identify the foreign output effect of U.S. monetary policy using specification (1). We also break down this effect in its constituent parts. For simplicity, we abstract from the timing of the response, but the reasoning below carries through.

Suppose foreign output, y^{f}, is a function of the U.S. interest rate, r; the foreign interest rate, r^{f}; and the shock, s: $y^{\mathrm{f}} = y^{\mathrm{f}}\big(r, r^{\mathrm{f}}, s\big)$. Suppose further that the U.S. interest rate is a function of the shock, $r = r(s)$, and the foreign interest rate depends both on the U.S. interest rate and on the shock: $r^{\mathrm{f}} = r^{\mathrm{f}}(r, s)$. Specifically, we assume that, in a large "closed" economy, the economic effects of foreign events are small relative to the effects of domestic events. Differentiating y^{f} with respect to s, we obtain:

$$\frac{\mathrm{d}y^{\mathrm{f}}}{\mathrm{d}s} = \frac{\partial y^{\mathrm{f}}}{\partial r}\frac{\mathrm{d}r}{\mathrm{d}s} + \frac{\partial y^{\mathrm{f}}}{\partial r^{\mathrm{f}}}\left(\frac{\partial r^{\mathrm{f}}}{\partial r}\frac{\mathrm{d}r}{\mathrm{d}s} + \frac{\partial r^{\mathrm{f}}}{\partial s}\right) + \frac{\partial y^{\mathrm{f}}}{\partial s}. \tag{2}$$

Our identification strategy requires that

$$\frac{\partial r^{\mathrm{f}}}{\partial s} = \frac{\partial y^{\mathrm{f}}}{\partial s} = 0, \tag{3}$$

or, in words, that the U.S. shock affect the foreign interest rate and output only through the U.S. interest rate.

With the restriction above, the effect of the U.S. interest rate on foreign output follows:

$$\frac{\mathrm{d}y^{\mathrm{f}}}{\mathrm{d}r} = \underbrace{\frac{\partial y^{\mathrm{f}}}{\partial r}}_{\equiv \varrho} + \underbrace{\frac{\partial y^{\mathrm{f}}}{\partial r^{\mathrm{f}}}}_{\varphi}\underbrace{\frac{\partial r^{\mathrm{f}}}{\partial r}}_{\varpi}. \tag{4}$$

Hence, the total effect of the U.S. interest rate on foreign output comprises two components: (1) a component independent of foreign policy (i.e., conditional on a fixed r^{f}), denoted by ϱ, and (2) a

[4]Despite the discussions of the private information that central banks may hold about their domestic economies, the literature provides little material evidence that central banks hold a significant amount of private information about foreign economies.

component operating through foreign monetary policy. The latter in turn is a product of the effect of foreign policy on foreign output, φ, and the degree to which the foreign central bank responds to the U.S. central bank's policy, ϖ.

With one instrument (shock) s, the two-stage least squares estimator of β in specification (1) reduces to indirect least squares, estimated as the ratio of the coefficients on s from the corresponding reduced-form specification and from the first-stage regression. The former estimates the total derivative $\mathrm{d}\,y^{\mathrm{f}}/\mathrm{d}s$ in (2), while the latter estimates $\mathrm{d}r/\mathrm{d}s$. Assuming that the identifying restrictions (3) hold, we divide the right-hand side of (2) by $\mathrm{d}r/\mathrm{d}s$ and obtain $\beta = \varrho + \varphi\,\varpi$. However, we cannot estimate ϱ separately from β unless we find an additional instrument for r^{f}. Due to data and space limitations, we do not pursue this approach in this paper.

We nevertheless can shed some light on the magnitude of ϱ indirectly, using back-of-the-envelope calculations. Under the assumption that the domestic effects of monetary policy do not substantially vary across countries, we can approximate φ using estimates of specification (1) for U.S. observations. We then estimate ϖ using r^{f}, instead of y^{f}, as a left-hand-side variable in (1). With β, φ, and ϖ at hand, we can back out the value of ϱ from (4). We note, however, that our baseline estimates of β, which include the endogenous responses of foreign central banks to the U.S. interest rate, are of interest in their own right. In fact, the transmission mechanisms considered in open-economy models, dating back at least to the textbook Mundell–Fleming model, typically allow for endogenous policy responses.

3.3. Estimates

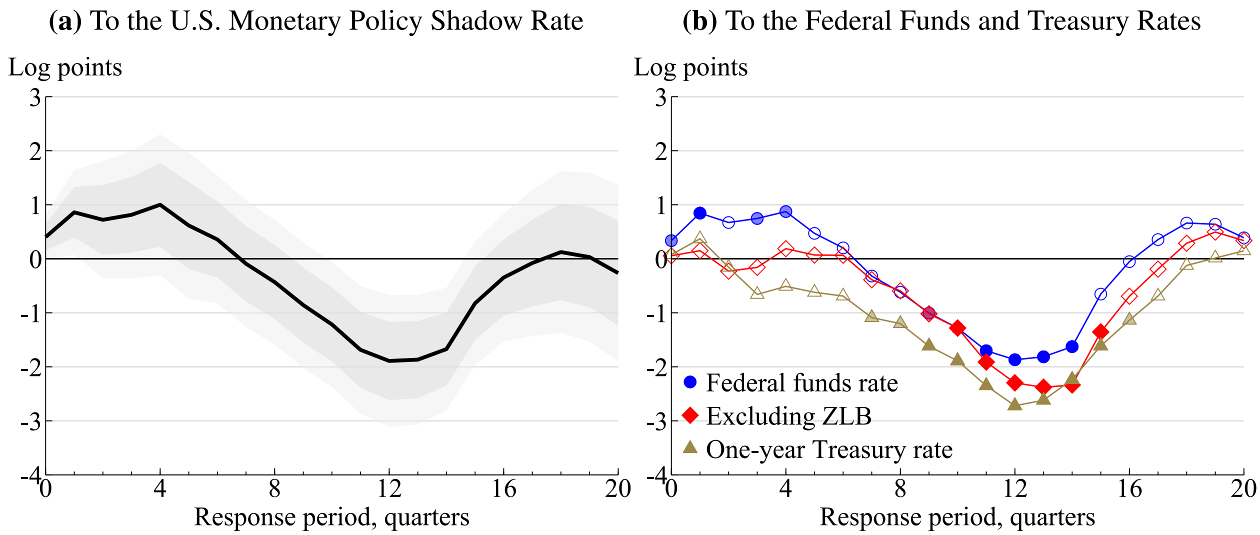
Figure 1a shows the output response abroad to a 1 percentage point increase in the U.S. monetary policy shadow rate.[5] Foreign output decreases significantly, with a delayed response materializing after 10 quarters and peaking at 12 quarters after the shock. At a three-year horizon, foreign output falls by 1.9%. Figure 1b shows that our baseline estimates are not sensitive to using alternative measures of monetary policy. In particular, we address a potential concern that the federal funds rate may not be a good policy indicator in the period following the onset of the Great Recession by excluding this period and, separately, by using the one-year Treasury rate (similar to Gertler and Karadi 2015) instead of the shadow rate.[6]

Next, we show the effects of a unit monetary shock on interest rates at home and abroad. Figure 2a shows the persistence of the federal funds rate response to the reference unit shock normalized to one on impact. This response remains close to one for about four quarters, swiftly

[5] We estimate symmetric responses, as we do not find significant quantitative differences between the effects of monetary tightening and easing in our sample.

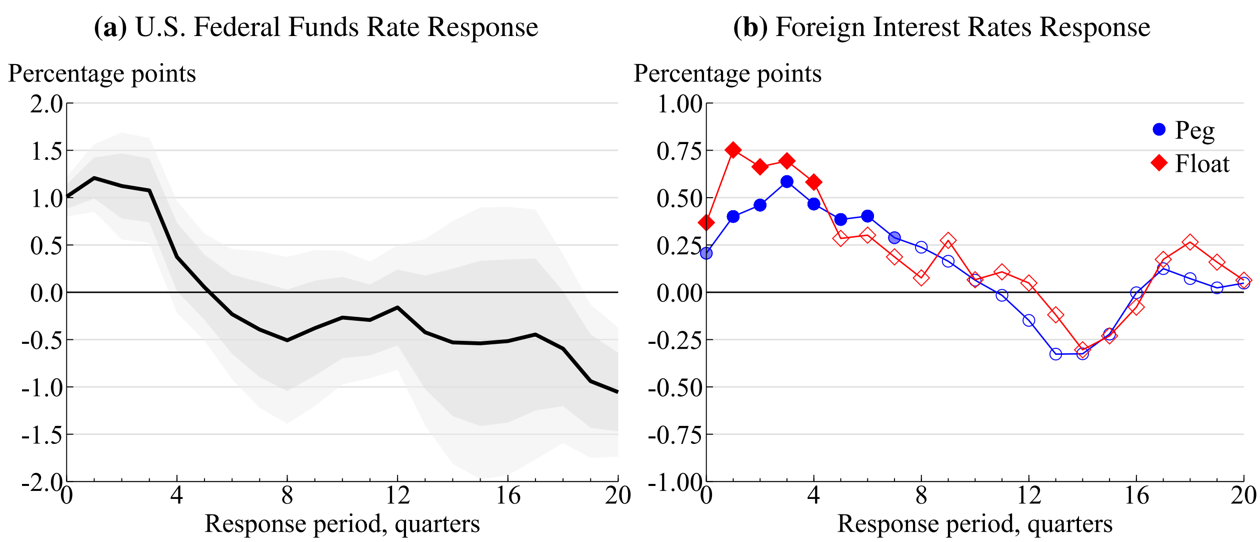
[6] We provide additional results and model diagnostics in the appendix. Figure A.1 confirms that the U.S. output responses are in line with those reported in the previous literature. Tables A.2, A.3 and Figure A.2 report detailed regression output for key horizons and statistical tests for the instruments.

Figure 1: Responses of Foreign Output per Capita



Notes: This figure shows the responses of the logarithm of real GDP per capita in a panel of 43 countries (not including the United States) to a 1 percentage point increase in the U.S. monetary policy shadow rate (Panel a) and to the federal funds and Treasury rates (Panel b), estimated by two-stage least squares using specification (1). The monetary shocks used as instruments are separately identified with high-frequency methods. The estimation sample is fixed across the response horizons, spanning the period 1995–2017 at a quarterly frequency, with the shocks from 1996 through 2012. The shaded areas in (a), and the solid and shaded symbols in (b), indicate significance relative to the 90% critical values and one-standard-error bands, respectively, based on standard errors two-way clustered by quarters and countries.

Figure 2: Persistence and Foreign Transmission of U.S. Monetary Policy



Notes: This figure shows the responses to a 1 percentage point U.S. monetary tightening, estimated by two-stage least squares applied to specification (1) with $r_{i,t+h}$ as the dependent variable. In Panel (a), the sample contains only U.S. observations. The corresponding standard errors are Newey–West with bandwidth $h+1$. In Panel (b), the sample includes 43 other countries. The standard errors are two-way clustered by quarters and countries. The shaded areas in (a), and the solid and shaded symbols in (b), indicate significance relative to the 90% critical values and one-standard-error bands, respectively.

falling to statistical zero thereafter.

Figure 2b shows the responses of foreign interest rates, separately for countries with floating and pegged exchange rates. The foreign interest rates respond strongly to U.S. monetary shocks, regardless of the exchange rate regime. While not surprising for the pegs, these results indicate a large pass-through for the floaters, too. This could be due to "fear of floating" (Calvo and Reinhart 2002), among other possible reasons. Hence, the international effects of U.S. monetary shocks are amplified through the policy responses by foreign central banks.

How important is this amplification mechanism quantitatively? We observe that our baseline estimates indicate that foreign output responds to U.S. shocks, on average, by roughly the same amount as does domestic output ($\varphi = \beta$ in Equation 4) and that the interest rate transmission (ϖ) peaks between 1/2 and 3/4. Thus, we can back out the policy transmission multiplier, $\beta/\varrho = 1/(1-\varpi)$, as being approximately between 2 and 4. Given our baseline estimate $\hat{\beta} \approx -2$, it implies that the partial effect of U.S. monetary policy, conditional on no change in foreign monetary policy, is as follows: $\partial y^{\mathrm{f}}/\partial r \in [-1, -0.5]$.

4. International Trade and Financial Channels of Shock Transmission

4.1. Heterogeneity due to Output Shares of International Trade

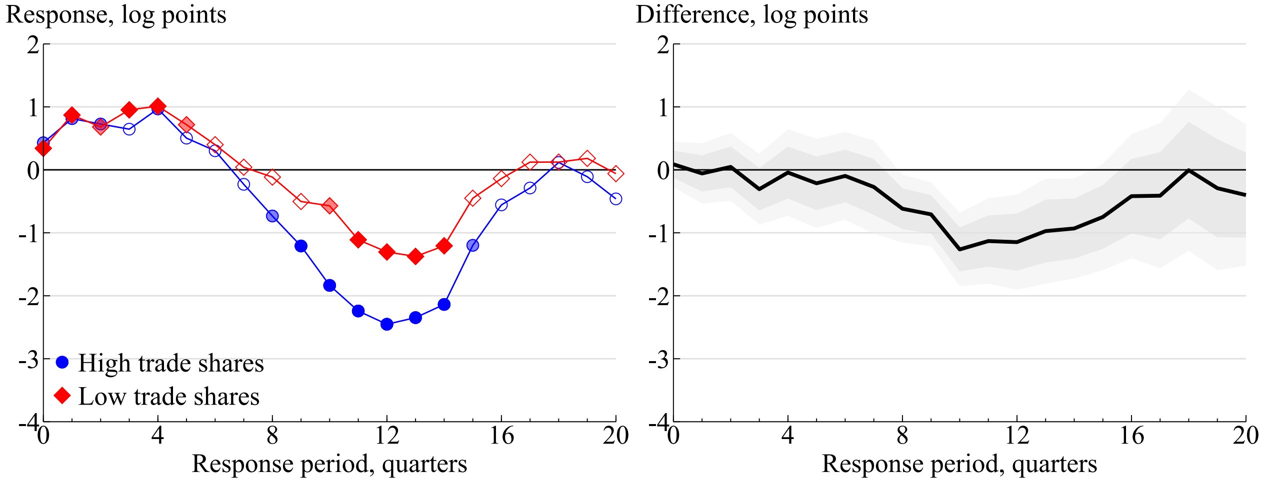
Next, we study whether heterogeneity in the output responses across countries depends on their openness to international trade and finance. Let I_i^{H} be a binary variable indicating country i's high exposure to international trade or finance, and let $I_i^{\mathrm{L}} \equiv 1 - I_i^{\mathrm{H}}$ be the indicator variable for low exposure. We estimate the following specification:

$$\begin{aligned} y_{i,t+h} = I_i^{\mathrm{H}} \times \left(\beta_h^{\mathrm{H}} r_t + \sum_{k=1}^{4} \gamma_{k;h}^{\mathrm{H}} y_{i,t-k} + \sum_{k=1}^{4} \delta_{k;h}^{\mathrm{H}} r_{t-k} + \sum_{k=1}^{4} \zeta_{k;h}^{\mathrm{H}\prime} \mathbf{s}_{t-k} \right) \\ + I_i^{\mathrm{L}} \times \left(\beta_h^{\mathrm{L}} r_t + \sum_{k=1}^{4} \gamma_{k;h}^{\mathrm{L}} y_{i,t-k} + \sum_{k=1}^{4} \delta_{k;h}^{\mathrm{L}} r_{t-k} + \sum_{k=1}^{4} \zeta_{k;h}^{\mathrm{L}\prime} \mathbf{s}_{t-k} \right) + \alpha_{i;h} + \boldsymbol{\theta}_{i;h}' \mathbf{x}_t + \varepsilon_{i,t+h;h}. \end{aligned} \tag{5}$$

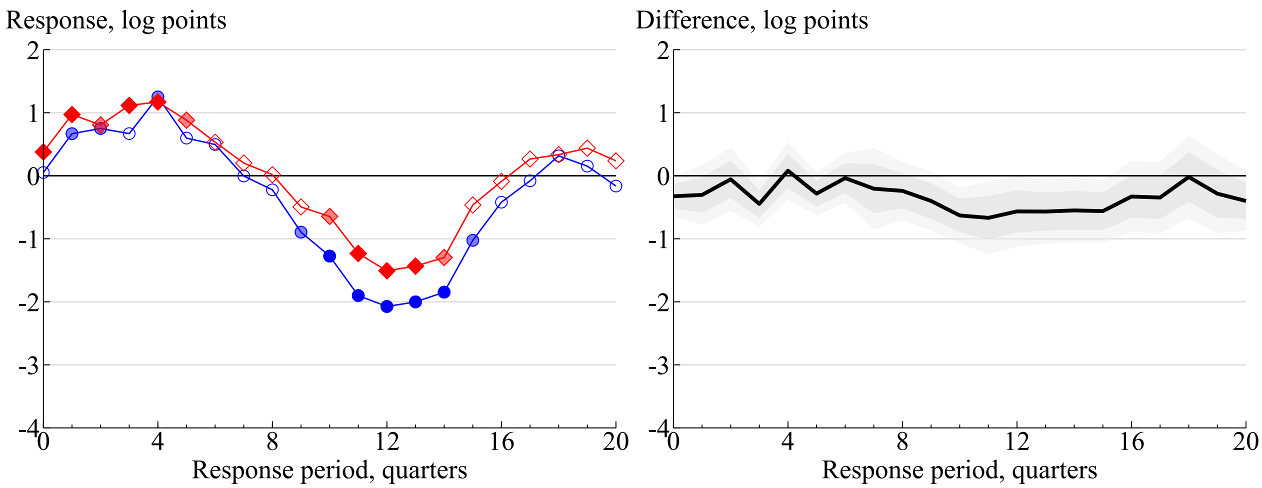
All variables are defined as before, and the model is estimated by two-stage least squares using $\mathbf{s}_t$ to instrument r_t. Superscripts H and L indicate parameters differing between the two samples. In particular, the coefficients β_h^{H} and β_h^{L} measure the output response to U.S. monetary policy in countries with high and low exposure, respectively, to international trade or finance. While these coefficients could also be obtained by estimating (1) separately in the samples of countries with high and low exposures, we estimate (5) jointly in order to account for correlation of errors across countries between as well as within the two groups. This approach allows us to easily test the

Figure 3: Output Responses to U.S. Monetary Policy in High-Trade and Low-Trade Countries

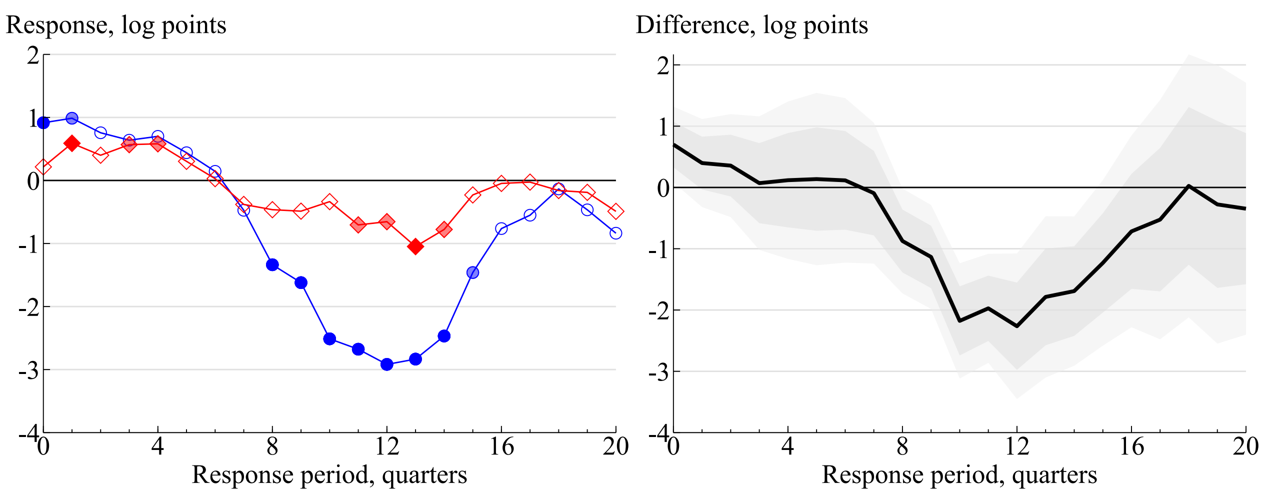
(a) Full Sample



(b) Floating Exchange Rate Sample



(c) Pegged Exchange Rate Sample



Notes: This figure shows estimates of β_h^H and β_h^L (left panels) and of the difference $\beta_h^H - \beta_h^L$ (right panels) obtained from Equation (5). The country groups are based on the trade-to-GDP ratios at the beginning of the sample period relative to the cross-country median. The exchange rate regimes are based on the Shambaugh (2004) classification extended through the end of our sample. The solid and shaded symbols in the left panel, and the shaded areas in the right, indicate significance relative to the 90% critical values and one-standard-error bands, respectively. Standard errors are Driscoll–Kraay.

hypothesis $\beta_h^{H} = \beta_h^{L}$.[7]

We start by separating countries into a high-trade and a low-trade group, according to their trade-to-GDP ratios at the beginning of our sample period. Countries with a ratio above (below) the median are assigned to the high-trade (low-trade) group. Figure 3a shows average responses for the two groups and the differences between them. Output responds stronger in high-trade countries than in low-trade countries, especially at horizons between two and four years. The differences between the two groups are statistically and economically significant, peaking at over 1 percentage point 10 quarters after the shock.

Next, we investigate whether the magnitude of these differences depends on the exchange rate regime. Figures 3b and 3c show that while our results stand when we focus on countries with either a floating or a fixed exchange rate, the differences between the high- and low-trade countries are substantially stronger in the sample of peggers. We also find that the IRFs are similar in the subsamples of countries with a low degree of financial openness (as per the average ratio of IIP to GDP) and with a high degree (Appendix Figure A.3), suggesting that the stronger output responses for high-trade countries are not driven by a positive correlation between openness to trade and openness to finance.

4.2. Responses of Other Key Variables and Transmission Mechanism

In terms of decomposition (4), the heterogeneity of output responses between high-trade and low-trade countries can be explained by heterogeneity in its constituent parts. Because we do not have separate instruments for monetary policy in each country group, we continue to hold the domestic effects of monetary policy fixed across countries. Then, the group-specific decomposition takes the form

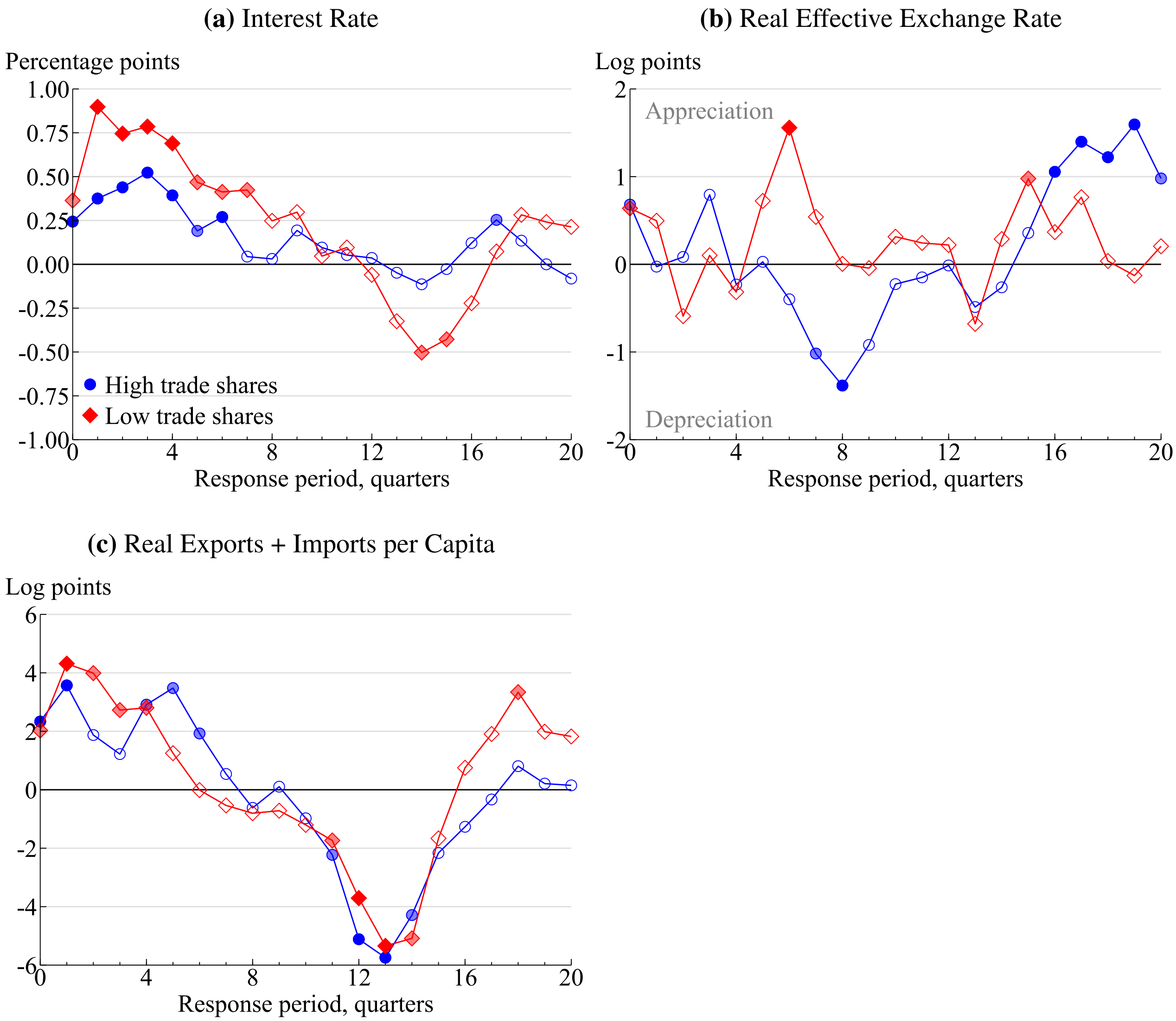
$$\beta_i = \varrho_i + \bar{\varphi}\, \varpi_i, \tag{6}$$

for $i = \{H, L\}$ and $\varphi_H = \varphi_L = \bar{\varphi}$. The difference between the total effects for the two groups can be written as $\beta_H - \beta_L = \varrho_H - \varrho_L + \bar{\varphi}\,(\varpi_H - \varpi_L)$.

Figure 4a compares the responses of interest rates in the high-trade and low-trade groups. We observe a higher degree of monetary policy transmission in low-trade countries than in high-trade countries, $\varpi_H < \varpi_L$. Hence, the difference $\beta_H - \beta_L$ likely represents the lower bound, in magnitude, of $\varrho_H - \varrho_L \equiv \partial y_H^f/\partial r - \partial y_L^f/\partial r$. Consistent with this conjecture, we find that the difference in output responses between high- and low-trade members of the euro area are nearly twice as large

[7] Due to a small number of countries in each subsample, we cannot cluster the errors by country, because this procedure is valid only for large N. Instead, we report Driscoll–Kraay standard errors. In addition to being clustered by time, the standard errors are robust to heteroskedasticity and serial correlation. And because this procedure relies on the Bartlett (Newey–West) truncated kernel within each panel, Driscoll–Kraay standard errors are valid for large T but possibly small N. As required by local projections, we set a minimal bandwidth at $h+1$.

Figure 4: Responses of Key Variables in High- and Low-Trade Countries



Note: The solid and shaded symbols indicate significance relative to the 90% critical values and one-standard-error bands, respectively, based on Driscoll–Kraay standard errors.

as in the baseline at a three-year horizon (Appendix Figure A.3c). Thus, not only the differential effects hold conditional on the monetary policy response, but they are larger.

Figures 4b and 4c compare the responses of the real effective exchange rate and gross international trade flows, respectively, providing further evidence on the transmission mechanism of U.S. monetary policy.[8] Consistent with the differential response of the interest rates shown previously, the currencies of high-trade countries depreciate relative to low-trade countries' currencies. And consistent with the simultaneous decline in domestic and foreign output, gross trade diminishes

[8]The role of exchange-rate responses in the transmission of U.S. monetary shocks is emphasized in Ilzetzki and Jin (2021), among others.

in both groups. While the intensive margin of the decline is similar in the two groups, international trade by definition makes up a larger share of output in the high-trade group. Hence, the decline in trade of comparable percentage should have a larger effect on output in high-trade countries than in low-trade countries.

Due to space constraints, we show the responses of other notable variables in Appendix Figure A.4. For example, following U.S. monetary tightening, local currencies in both trade groups depreciate relative to the U.S. dollar. We also find that both foreign consumption and investment drop, contributing to the output decline. Moreover, both consumption and investment decline more in high-trade countries than in low-trade countries, explaining the differential output effects.

4.3. Openness to International Trade versus Financial Openness

We now estimate heterogeneous output responses, focusing on the extent to which a country's openness to trade and finance can explain such heterogeneity. To do this, we relax the assumption that the output responses β^h are the same for all countries or only differ between two groups. Specifically, to allow the response coefficients β_i^h to vary by country i, we estimate the following equation (with instruments) separately for each i:

$$y_{i,t+h} = \alpha_i^h + \beta_i^h r_t + \sum_{k=1}^{4} \gamma_{i,k}^h y_{i,t-k} + \sum_{k=1}^{4} \delta_{i,k}^h r_{t-k} + \sum_{k=1}^{4} \boldsymbol{\zeta}_{i,k}^{h\prime} \mathbf{s}_{t-k} + \boldsymbol{\theta}_i^{h\prime} \mathbf{x}_t + \varepsilon_{i,t+h}^h. \tag{7}$$

We then estimate the relationship between β_i^h and country characteristics as follows:

$$\hat{\beta}_i^h = b_0^h + b_1^h \text{ Trade Openness}_i + b_2^h \text{ Financial Openness}_i + b_3^h \text{ Controls}_i + u_i^h, \tag{8}$$

where *Trade Openness* is the ratio of total trade (exports plus imports) to GDP at the beginning of the sample period; *Financial Openness* is measured by total IIP (assets plus liabilities) as a share of GDP; and *Controls* include other country-specific characteristics, such as the current account—to control for income transfers—and the development indicator. To measure trade and financial openness, we also use net exports and net IIP (assets minus liabilities).

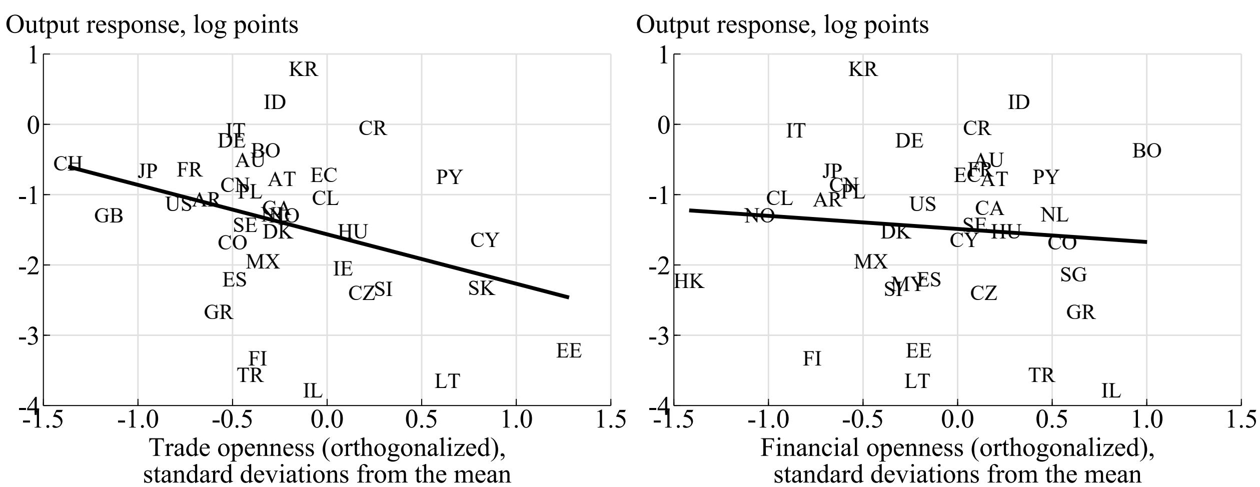
Table 1 shows estimates of Equation (8) at key horizons. To make the coefficients comparable, we normalize all continuous regressors to have a zero mean and a unit variance. We find a strong negative relationship between the spillover effects and trade openness. At a peak horizon, a one-standard-deviation increase in total trade leads to an increase (in absolute value) in the semi-elasticity of output by 0.4 (columns 5–6), about one-fifth of the mean response. Moreover, when we exclude the trade measures from the regression, the *R*-squared drops by roughly a half. Note that direct trade with the United States does not explain this result, as the strong relationship holds even if we

Table 1: The Effects of Trade and Financial Openness on the Size of Output Spillovers

	13 quarters		14 quarters		15 quarters		16 quarters	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Total trade	−0.35**	−0.34**	−0.41**	−0.40**	−0.39***	−0.40***	−0.17*	−0.16*
	(0.15)	(0.15)	(0.15)	(0.16)	(0.08)	(0.08)	(0.09)	(0.09)
Total IIP	0.02	0.01	0.24*	0.16	0.01	−0.02	0.00	−0.06
	(0.22)	(0.21)	(0.13)	(0.19)	(0.08)	(0.15)	(0.10)	(0.14)
Net exports		−0.00		0.28		0.13		0.21
		(0.39)		(0.30)		(0.26)		(0.26)
Net IIP		−0.15		0.16		0.24		0.06
		(0.37)		(0.46)		(0.36)		(0.34)
Current account	0.48**	0.54	0.32*	0.08	0.37***	0.19	0.23*	0.07
	(0.23)	(0.46)	(0.18)	(0.34)	(0.10)	(0.24)	(0.13)	(0.22)
Developing (indicator)	0.83*	0.77	0.66	0.67	0.23	0.29	0.26	0.24
	(0.47)	(0.55)	(0.52)	(0.64)	(0.41)	(0.50)	(0.40)	(0.44)
Constant	−2.24***	−2.21***	−1.99***	−2.00***	−0.96***	−0.99***	−0.43*	−0.42
	(0.31)	(0.36)	(0.33)	(0.39)	(0.27)	(0.31)	(0.24)	(0.27)

Notes: This table presents estimates of Equation (8) at selected horizons. The dependent variable ($\hat{\beta}_i^h$) is the estimated response of the logarithm of real GDP per capita to a unit U.S. monetary tightening, obtained from Equation (7). All continuous independent variables are divided by GDP and then normalized to have a zero mean and a unit variance. Our sample includes 43 countries during the period 1995–2017 (1996–2012 shocks) at a quarterly frequency. Standard errors robust to heteroskedasticity are in parentheses. Significance levels at 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Figure 5: The Relative Effects of Trade and Financial Openness on Output Response at the Peak Horizon



Notes: This figure plots the output responses at the peak horizon (vertical axes) against trade openness (horizontal axis, left panel) and financial openness (horizontal axis, right panel). The country codes are based on the ISO2 definitions.

exclude U.S. trade from the openness measure. In contrast, we find no visible negative relationship between the output response and financial openness. Interestingly, while total trade flows appear important, net trade flows do not. However, the coefficient on the current account is significant, likely due to income transfers. We also find somewhat larger effects of U.S. monetary policy on developed countries.

To understand how individual countries contribute to our results, in Figure 5 we plot the coefficient $\hat{\beta}_i^*$ at the peak horizon against trade openness (left panel) and financial openness (right panel) by country i. Both variables are orthogonalized with respect to each other and all other covariates.[9] We focus on the cluster of observations within 1.5 standard deviations on each side of the mean and also exclude from the figure two observations with $\hat{\beta}_i^* < -4$. We confirm a negative slope associated with trade openness and a much flatter slope for financial openness. Appendix Figure A.5 shows that these conclusions are not affected by the influential observations.

Considering alternative measures of trade and financial openness, we by and large confirm our baseline findings. These additional exercises are relegated to the appendix. For example, we use a measure of trade openness based on the share of total *value-added* trade as opposed to *gross* trade (Appendix Table A.4). We also consider measuring financial openness by separate IIP components—such as direct investment, equity, debt securities, and derivatives—and by financial flows, instead of stocks. We compute total flows as the sum of inflows and outflows in the balance of payments (Table A.5).[10]

5. Network Amplification and Indirect Spillover Effects

5.1. Measuring Network Effects

To what extent are the foreign effects of U.S. shocks amplified through the international trade network? What share of the total effect is driven by indirect output spillovers? To answer these questions, we employ a model in which not only U.S. shocks have heterogeneous direct effects, but output comoves across countries. Such comovement gives rise to indirect effects. To estimate the network amplification effects, we extend the model in Equation (7) to directly account for

[9]Note that whereas in standard neoclassical models of the Heckscher–Ohlin–Mundell type, an increase in trade integration reduces incentives for financial integration, we find a moderate, positive correlation between trade and financial openness, both for the aggregate measures and for bilateral linkages. The correlation coefficient for the baselines measures is 0.4. This positive correlation is consistent with financial frictions, as emphasized in Antràs and Caballero (2009).

[10]We do not find a significant negative effect of capital account restrictions, measured by the Chinn and Ito (2006) index. Since our further analysis requires data on *bilateral* linkages, we do not explore capital restrictions data in detail.

international output spillovers:

$$y_{i,t+h} = \alpha_i^h + \beta_i^h r_t + \sum_{j \neq i} \eta_{i,j}^h y_{j,t+h} + \kappa \, \text{Controls} + \varepsilon_{i,t+h}^h, \tag{9}$$

where $\eta_{i,j}^h$ is the theoretical effect of output in country j on output in country i. To associate the strength of these output spillovers with a network effect, suppose that the individual output effects ($\eta_{i,j}^h$) are proportional to predetermined bilateral trade linkages ($w_{i,j}$) and the aggregate network effect (ρ^h), so that $\eta_{i,j}^h = \rho^h w_{i,j}$. We can then estimate the aggregate network effect ρ^h for a given network structure $w_{i,j}$. The coefficients ρ^h determine the total spillover effect and the direct and indirect effects that make up this total effect.

To derive the expressions for direct and indirect effects in closed form, we switch to vector notation. Denote the vector of log output in quarter t as $\mathbf{y}_t = \left(y_{1,t}, \ldots, y_{i,t}, \ldots, y_{N,t}\right)'$. Denote further the matrix of elements $w_{i,j}$ as $\mathbf{W}$, setting the diagonal elements $w_{i,i}$ to zero. Then, the model in Equation (9) can be written as follows:

$$\mathbf{y}_{t+h} = \alpha^h + \beta^h r_t + \rho^h \mathbf{W} \mathbf{y}_{t+h} + \kappa \, \text{Controls} + \varepsilon_{t+h}^h, \tag{10}$$

where the vector β^h collects the elements β_i^h, and the vector α^h collects the country-specific intercepts α_i^h. The residuals ε_{t+h}^h can be either i.i.d. Gaussian or correlated across countries, as in spatial error models. Our control variables are the same as in Equation (7).[11] To adapt Equation (8) to the spatial specification, we allow for heterogeneity in α_i^h and β_i^h, but the slope coefficients on the controls are pooled across countries. For the identification and conventional interpretation of ρ^h, we follow the literature and normalize each weight in $\mathbf{W}$ by the sum of weights in the corresponding row. With this normalization, the spatial lag $\mathbf{W}\mathbf{y}_{t+h}$ contains the mean values of trading partners' output growth weighted by the trade shares. (We discuss the weight matrix and the spatial lag in detail in Section 5.2.)

A crucial parameter summarizing the network amplification is ρ^h. If $\rho^h = 0$, the above model collapses to a linear model, as in Equation (7). Solving for $\mathbf{y_{t+h}}$ and taking the derivative with respect to r_t—for simplicity, abstracting from the intercept and controls—we obtain an expression for the heterogeneous marginal effects:

$$\begin{aligned} \frac{\partial \mathbf{y}_{t+h}}{\partial r_t} &= \left(\mathbf{I}_N - \rho^h \mathbf{W}\right)^{-1} \beta^h \\ &= \beta^h + \rho_h \mathbf{W} \beta^h + \rho_h^2 \mathbf{W}^2 \beta^h + \rho_h^3 \mathbf{W}^3 \beta^h + \ldots, \end{aligned} \tag{11}$$

[11] Based on the spatial Durbin model, our baseline specification includes a spatial lag, a spatial error, and spatial controls. In the appendix, we compare our benchmark results with estimates obtained from alternative spatial models.

where $\mathbf{I}_N$ is the $N \times N$ identity matrix. Again, if $\rho^h = 0$, the marginal effects are the same as in the linear case (β^h), and the indirect effects are zero. If $\rho^h > 0$, the initial output responses induce endogenous amplification through an infinite chain of bilateral linkages.[12]

To highlight the role of network effects in the cross-border transmission of shocks, we decompose the total effect in Equation (11) into a direct effect and an indirect effect. Denoting $\mathbf{J} \equiv (\mathbf{I}_N - \rho^h \mathbf{W})^{-1}$, the vectors of direct and indirect effects are as follows:

$$\frac{\partial \mathbf{y}_{t+h}}{\partial r_t}^{\text{direct}} = \text{diag}(\mathbf{J})\,\beta^h \tag{12}$$

$$\frac{\partial \mathbf{y}_{t+h}}{\partial r_t}^{\text{indirect}} = \big(\mathbf{J} - \text{diag}(\mathbf{J})\big)\,\beta^h, \tag{13}$$

where diag($\mathbf{J}$) sets all off-diagonal elements of $\mathbf{J}$ to zero. We estimate the model parameters with maximum likelihood, and adjust standard errors to account for the instrumented U.S. policy rate following Murphy and Topel (1985).

By estimating heterogeneous β_i^h, we allow for a full flexibility in the direct and indirect effects of U.S. shocks and do not restrict these effects by our choice of $\mathbf{W}$. In fact, a U.S. shock can affect foreign output only indirectly ($\beta_i^h = 0$ for all $i \neq$ US), as in the case of pure local shocks. Or it can affect output in other countries directly ($\beta_i^h \neq 0$ for some $i \neq$ US), resembling a global shock. Clearly, even if $\beta_i^h = 0$ for all countries other than the United States, the effect of U.S. shocks on output in other countries is, in general, nonzero because of the indirect spillovers stemming from U.S. output (e.g., due to U.S. demand for foreign products).

Special Case: $N = 3$ Countries

To provide intuition for the mechanics of the model, we consider the case of $N = 3$ countries and contemporaneous responses ($h = 0$). The Jacobian matrix of this system takes the following form:

$$\frac{\partial \mathbf{y}_t}{\partial r_t} = \frac{1}{D}\begin{pmatrix} 1 - \rho^2 w_{23}w_{32} & \rho\, w_{12} + \rho^2 w_{13}w_{32} & \rho\, w_{13} + \rho^2 w_{12}w_{23} \\ \rho\, w_{21} + \rho^2 w_{23}w_{31} & 1 - \rho^2 w_{13}w_{31} & \rho\, w_{23} + \rho^2 w_{21}w_{13} \\ \rho\, w_{31} + \rho^2 w_{32}w_{21} & \rho\, w_{32} + \rho^2 w_{31}w_{12} & 1 - \rho^2 w_{12}w_{21} \end{pmatrix}\begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{pmatrix}, \tag{14}$$

where

$$\begin{aligned} D &\equiv \det(\mathbf{I}_3 - \rho\,\mathbf{W}) \\ &= 1 - \rho^2 w_{12}w_{21} - \rho^2 w_{13}w_{31} - \rho^2 w_{23}w_{32} - \rho^3 w_{12}w_{23}w_{31} - \rho^3 w_{13}w_{32}w_{21}. \end{aligned}$$

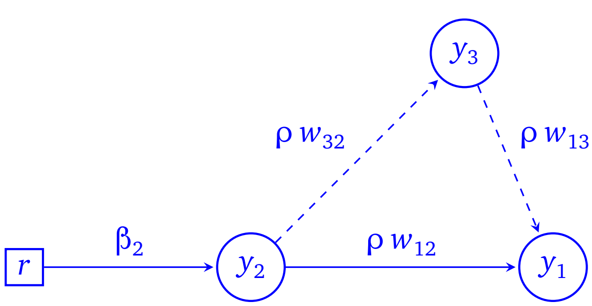
[12] With standard normalizations, the model converges if $\left|\rho^h\right| < 1$.

Focusing on country 1, we can decompose the total effect into the direct and indirect effects.

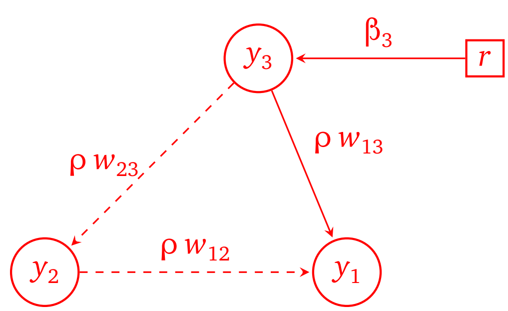
$$\frac{\partial y_{1,t}}{\partial r_t} = \overbrace{\beta_1 D^{-1}\left(1-\rho^2 w_{23}w_{32}\right)}^{\text{Direct Effect}} + \underbrace{\beta_2 D^{-1}\left(\rho\, w_{12}+\rho^2 w_{13}w_{32}\right)}_{\text{Indirect Effect from } y_2} + \underbrace{\beta_3 D^{-1}\left(\rho\, w_{13}+\rho^2 w_{12}w_{23}\right)}_{\text{Indirect Effect from } y_3}. \tag{15}$$

With normalized weights ($0 \leq w_{ij} \leq 1$) and positive, nonexplosive output comovement ($0 < \rho < 1$), the direct effect is larger in absolute value than the initial response β_1, which amounts to the total effect in the linear case. Thus, a chain of subsequent output spillovers amplifies the initial response. Note that, without loss of generality, index 1 can be assigned to the home country. Hence, the network characterized by a positive comovement of output amplifies the *domestic* effects as well as the foreign effects.

The indirect effect (the bottom line in Equation 15) can be positive or negative, depending on the signs of the initial output responses in country 2 (β_2) and in country 3 (β_3)—as well as the weights, in case β_2 and β_3 have the opposite signs. Figure 6 demonstrates these indirect effects schematically. In Panel (a), we show the indirect effect on output in country 1 emanating from the initial response of output in country 2. A unit shock initially raises output in country 2 by β_2. The bilateral linkage between countries 2 and 1 amplifies this effect by $\rho\, w_{12}$, and the trilateral linkage $2 \rightarrow 3 \rightarrow 1$ by $(\rho\, w_{32}) \cdot (\rho\, w_{13})$. Next, we need to add the indirect effect emanating from the initial output response in country 3 (Panel b). At last, because the chain of responses is infinite, these indirect effects are scaled further by $D^{-1} > 1$ (under the regularity conditions). The share of the indirect effect in the total effect is a useful statistic that depends both on the strength (ρ) and the structure ($\mathbf{W}$) of the network. Note that as $\rho \rightarrow 0$ (and so $D \rightarrow 1$), the total effect and the direct effect converge to β_1 and the indirect effect converges to zero, as in the linear case.



(a) Indirect Effect on y_1 from y_2



(b) Indirect Effect on y_1 from y_3

Figure 6: Indirect Spillover Effects of Shock r on Output in Country 1 (y_1)

5.2. International Trade Network

In our baseline model, we use weights $\mathbf{W}$ based on bilateral gross trade flows (exports plus imports). We normalize each weight by the sum of the elements in the corresponding row, so that these exogenous linkages correspond to the *relative* sizes of bilateral trade.[13] Because of the heterogeneous coefficients β_i^h, however, the effects can depend endogenously on an individual country's overall exposure to international trade, among other country characteristics. To abstract from the effects of output growth and spillovers on trade patterns, we fix the weights at their 1995 values (i.e., at the beginning of the sample period).

Figure 7 visualizes our baseline trade network. The size and the shade of each *node* correspond to the degree of network centrality.[14] The larger and darker nodes represent countries that are important trading partners for other countries, and hence the shocks originating in such countries—or propagating through them—are likely to be amplified. In contrast, the shocks originating in (or reaching) the countries represented by relatively small nodes are likely to have small spillover effects. Given our normalization, we measure network centrality for country i as the average weight in the ith column of $\mathbf{W}$. That is, we use the average share of country i in total trade for every other country in our sample. Predictably, large open economies such as the United States and Germany are central to the international trade network. However, the correspondence between the size and network centrality is not absolute. For instance, Sweden, a relatively small economy, has a centrality index comparable to China's, due to the Swedish economy's being relatively more open. Note that this centrality measure reflects not only a country's overall amount of trade but the geographical diversification of its trading partners.

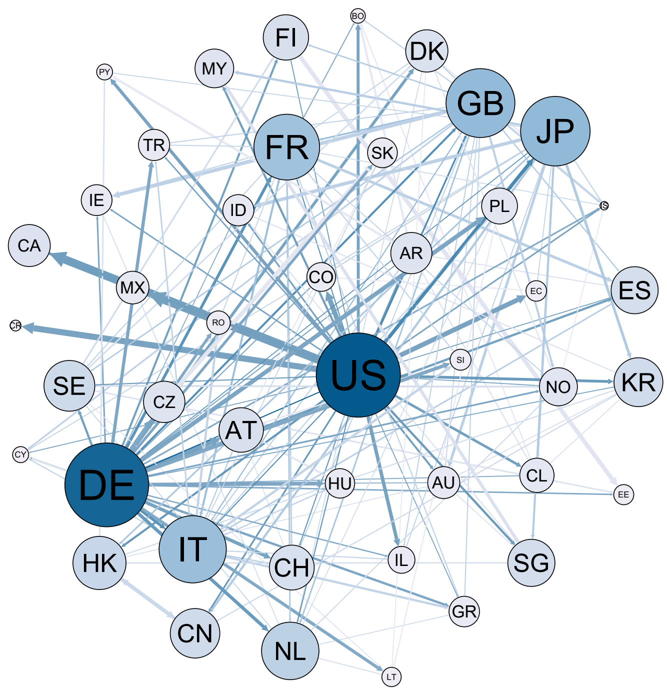
The size and the shade of each *arrow* in Figure 7 correspond to bilateral trade shares. Thicker and darker arrows represent larger trade shares. Typically, countries with a high index of network centrality are represented also by thicker arrows originating in the corresponding nodes. For example, the United States (represented by a large, dark node) is an important trading partner for Canada and Mexico, among many other countries. These linkages are indicated by the thick, dark arrows pointing from the U.S. node to the Canada and Mexico nodes. Thus, through direct trade linkages, changes in U.S. output driven by a domestic demand shock are likely to spillover to disproportionately many countries, with the potential for particularly strong effects on output in Canada and Mexico.

Next, we use these benchmark weights to illustrate the spatial correlation in output growth. In Panel (a) of Figure 8, we plot the year-over-year growth rates of real GDP per capita ($y_{i,t}$) against the trade-weighted average growth rates for the trading partners ($\mathbf{W}\mathbf{y}_t$), referred to as the spatial lag

[13] We also consider alternative normalizations that account for overall trade openness, such as the largest-eigenvalue normalization. We reach qualitatively similar conclusions.

[14] The nodes' locations are not informative. They are chosen subjectively to enhance visibility.

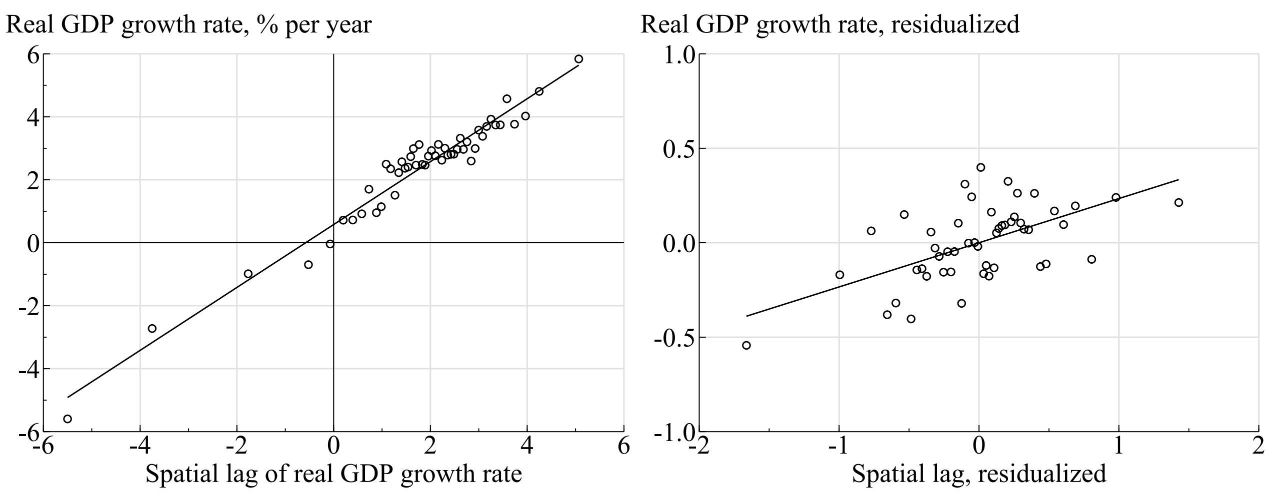
Figure 7: International Trade Network



Note: The figure visualizes the network based on gross trade flows (exports plus imports) in 1995 for our baseline sample of 44 countries. The size and the shade of each node correspond to the degree of network centrality. The size and the shade of each arrow correspond to the weight size (see the text for more detail). To enhance visibility, only weights larger than 5% are represented by an arrow. The country codes are based on the ISO2 standard.

Figure 8: Spatial Correlation in Output Growth

(a) Raw **(b)** Residualized



Note: Panel (a) shows a scatterplot using 50 bins for the growth rate of real GDP per capita (vertical axis) against its spatial lag (horizontal axis). In Panel (b), we orthogonalize these variables with respect to four temporal lags of output growth as well as country and time fixed effects.

of output growth.[15] We find a strong positive correlation between a country's output growth and its trading partners' growth—with trade linkages fixed at the base year.

Because this result may be explained in part by global business cycles (e.g., Kose, Otrok, and Whiteman 2003), in Panel (b) we show that the correlation between growth rates and their spatial lags remains positive when we partial out four temporal lags of output growth (to control for preexisting trends) as well as country and time fixed effects. Thus, the unconditional spatial correlation is not driven exclusively by the common effects of global shocks or by the tendency of high-growth countries to trade predominantly with other high-growth countries.

5.3. Spatial Model Estimates

In Table 2, we show estimates of the direct and indirect spillover effects obtained from our baseline spatial model with heterogeneous coefficients (Equation 10). As weights, we use (normalized) bilateral trade flows (exports plus imports). We find evidence for large and highly significant spatial correlation, supporting endogenous feedback loops. The spatial-lag coefficient ρ is in the range 0.43–0.52 three to four years after the shock. Following derivations in Equations (11) through (13), we use these estimates of ρ in combination with the estimates of β to compute the total, direct, and indirect spillover effects. The average total effect peaks at -2.3 (column 4), with direct and indirect effects of -1.2 and -1.1, respectively. The peak total effect estimated from the spatial model is 21% larger in absolute value than in the linear model. Thus, ignoring spatial dependence could lead to a substantial underestimation of international spillovers.

Figure 9 provides further evidence on the dynamics of the total effect and of the indirect effect's share. In line with the previous analyses, the responses at horizons shorter than two years or longer than four years are small and statistically insignificant. Up to 48% of the total effect at peak horizons is due to the indirect effect.[16]

Appendix Table A.6 presents our results when, as a measure of economic linkages, we separately use bilateral exports (Panel a) or bilateral imports (Panel b), instead of total trade. Similar to the baseline model, we find that about 48% of the total effect results from indirect spillovers in either case, and the estimates of the total effect are similar to the baseline results. Indeed, the correlation between these export and import weights is high.

We also analyze value-added trade flows. In this exercise, each element of the weighting matrix is computed as value-added trade within each pair of countries (Appendix Table A.7, top panel).[17] Because the data on bilateral value-added flows are available for only 30 countries, we fix the

[15] To enhance visibility, we present a scatterplot for 50 bins. These bins are based on quarterly data for 44 countries during the period 1995–2017.

[16] Appendix Figure A.6 shows that the share of the indirect effect is similar in the model with homogeneous β.

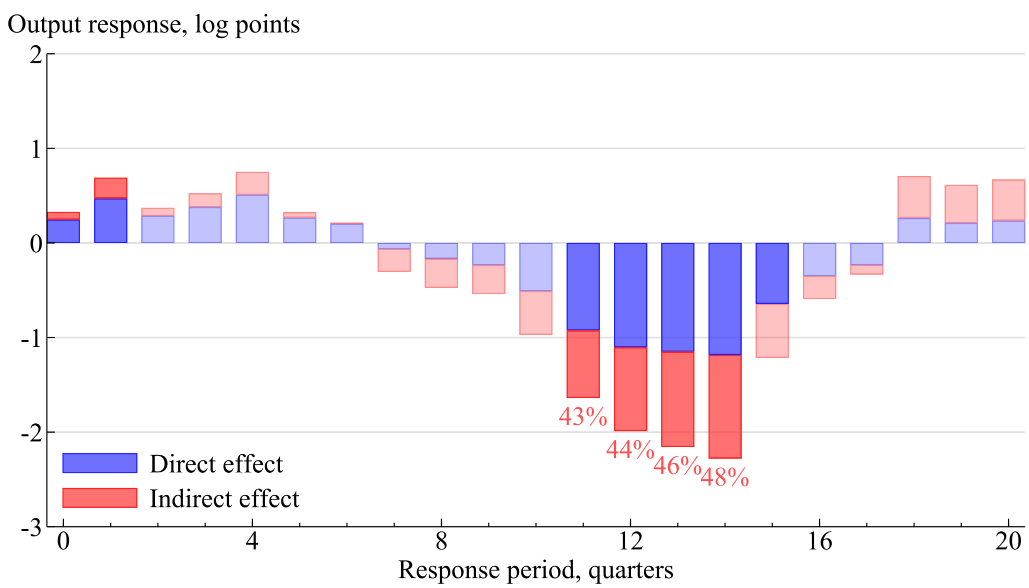
[17] The results are similar when we consider separately value-added exports and imports.

Table 2: Direct and Indirect Effects

	11 quarters (1)	12 quarters (2)	13 quarters (3)	14 quarters (4)	15 quarters (5)
Spatial lag, ρ	0.433***	0.454***	0.484***	0.506***	0.521***
	(0.052)	(0.053)	(0.055)	(0.058)	(0.062)
Total effect	−1.64***	−1.99***	−2.16***	−2.28***	−1.21
	(0.58)	(0.60)	(0.66)	(0.72)	(0.77)
Direct effect	−0.93***	−1.10***	−1.15***	−1.18***	−0.64*
	(0.34)	(0.35)	(0.36)	(0.38)	(0.38)
Indirect effect	−0.71***	−0.88***	−1.01***	−1.10***	−0.57
	(0.26)	(0.29)	(0.33)	(0.38)	(0.40)

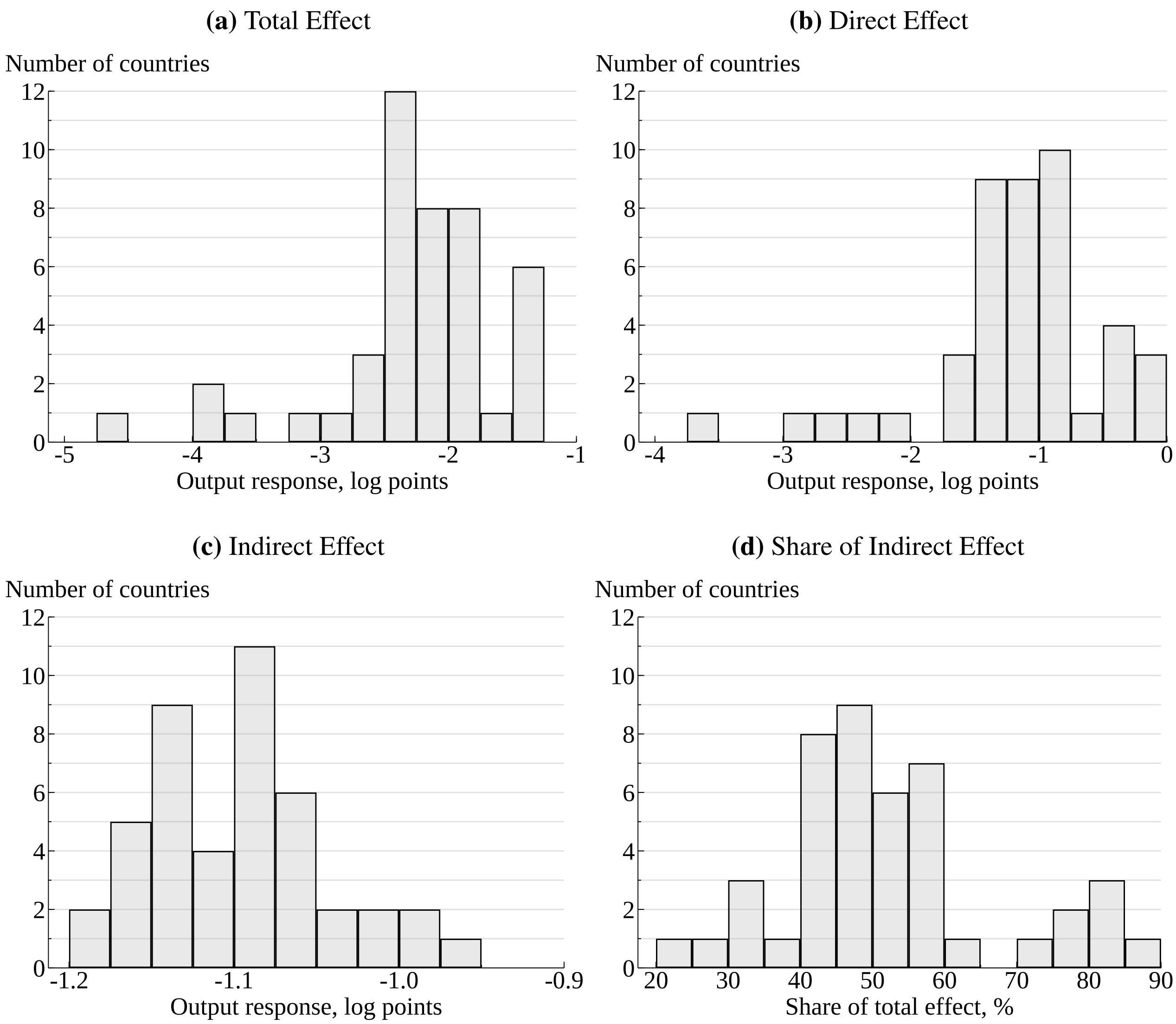
Note: This table shows the average total, direct, and indirect effects of U.S. monetary policy on (log) real GDP per capita. The decomposition into direct and indirect effects is obtained using bilateral linkages based on total trade (exports plus imports) in the base year. Our sample includes 44 countries from 1995 through 2017. Significance at the 1%, 5%, and 10% level is denoted by ***, **, and *, respectively.

Figure 9: The Share of Indirect Effects over Response Horizon



Note: The dependent variable is (log) real GDP per capita. Our data include 44 countries from 1995 through 2017 at a quarterly frequency. The decomposition into direct and indirect effects is obtained using the total-trade bilateral linkages. The solid bars represent significant effects at the 10% level. The shares of indirect effects are shown below the bars for significant responses.

Figure 10: Heterogeneity in Spillover Effects across Countries



Note: The decomposition of output responses into direct and indirect effects is obtained using the total-trade bilateral linkages.

sample (in the bottom panel). We do not find material quantitative differences between the estimates based on gross and value-added trade.

We then compare our baseline results with those obtained from alternative spatial model specifications. In particular, we consider models wherein we set to zero the spatial error coefficient and/or the coefficients on the spatial controls, which are used in the baseline. When we remove both components, we obtain a spatial autoregressive (spatial lag) model. Setting the spatial error component to zero (Panel b of Appendix Table A.8) leads to an increase in the estimates of ρ to 0.67, and the share of indirect effects rises to 63% at the 14 quarter horizon. The total effect, however, remains almost unchanged. Removing the spatial controls (Panel c) leads to similarly sized decreases in these two metrics (to 0.28 and 27%, respectively). While we observe some variation in the estimates across these various specifications, our conclusions about the role of spatial spillovers and indirect effects in the international transmission of monetary policy hold.

Similar to the linear case, we document significant cross-country heterogeneity in output spillovers, both in the size of the total effect and in the share of the indirect effect. The distribution of total effects, depicted in Panel (a) of Figure 10, has a significant mass of semi-elasticities in the interval between -3 and -1, with the largest negative effect about -4.5. As Panels (b) and (c) show, this result is due mostly to heterogeneity in the direct effects. The indirect effects are relatively homogeneous: All indirect effects fall into a narrow interval of -0.95 to -1.2. Consequently, the share of indirect effects (Panel d) varies significantly, between 20% and 90%. Importantly, for a majority of countries, the share of indirect effects is above 40% and hence plays a nontrivial role in overall spillovers.

International Financial Network

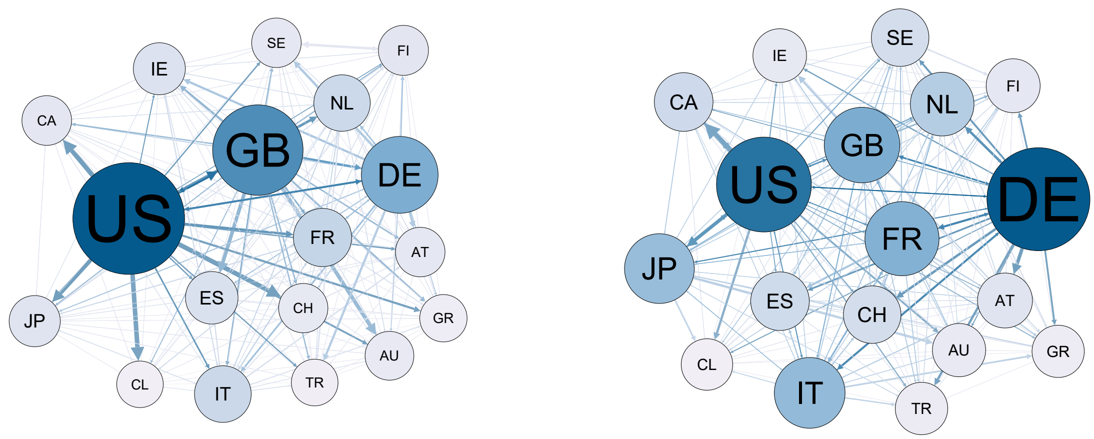
We use international banking statistics data from the BIS to construct alternative spatial matrices that focus on financial linkages. This approach helps us to assess whether shocks propagate through financial networks in a similar way as they do through trade networks. Figure 11 visualizes the financial linkages (Panel a) as well as the trade linkages across the countries for which financial data are available (Panel b).[18] While we observe certain similarities between the two networks (e.g., in both cases, the United States is an important partner for many countries), the two networks also exhibit important differences. For example, the United Kingdom plays a relatively more important role in the financial network than it does in the trade network. On the other hand, Germany has a larger centrality index in the trade network than in the financial network.

In Table 3, we compare estimates obtained from the spatial models using the two networks. In Panel (a), using the financial network, we report small and insignificant estimates of the spatial

[18] Note again that bilateral claims data are available for only 18 countries (for which we have also bilateral trade data) and start in 2005.

Figure 11: International Financial Network versus Trade Network

(a) Financial Network **(b)** Trade Network (constant sample)



Note: This figure compares the financial linkages with the trade linkages for the constant sample of 18 countries. The country codes are based on the ISO2 standard.

Table 3: Spillovers through the Financial Networks versus Trade Network

	11 quarters (1)	12 quarters (2)	13 quarters (3)	14 quarters (4)	15 quarters (5)
	(a) Financial Linkages				
Spatial lag, ρ	0.230	0.193	0.196	0.153	0.076
	(0.190)	(0.176)	(0.179)	(0.195)	(0.197)
Indirect effect	−0.25	−0.23	−0.23	0.03	0.11
	(0.28)	(0.27)	(0.29)	(0.15)	(0.29)
% of total	23.6	19.7	19.9	13.3	7.3
	(b) Trade Linkages (finance sample)				
Spatial lag, ρ	0.371*	0.344	0.335**	0.336**	0.206*
	(0.205)	(0.228)	(0.170)	(0.143)	(0.119)
Indirect effect	−0.57	−0.60	−0.38	0.23	0.36
	(0.43)	(0.48)	(0.34)	(0.30)	(0.25)
% of total	39.8	35.9	34.7	31.4	20.3

Note: Panel (a) uses the financial network based on bilateral banking claims, while Panel (b) uses the trade network based on total bilateral gross flows for the same sample. This sample includes 18 countries from 2005 through 2017 at a quarterly frequency. Significance at the 1%, 5%, and 10% level is denoted by ***, **, and *, respectively.

lag parameter and of the indirect effect. In Panel (b), we re-estimate our baseline model based on the trade network for the sample with available banking claims data, and find somewhat smaller average indirect effects than in the full sample: in this smaller sample, the indirect effects account for less than 40% of the total effects.[19] Thus, we do not find evidence for the hypothesis that real output spillovers are transmitted through financial linkages rather than through trade linkages.

6. Conclusion

In this paper, we document three major results. First, U.S. monetary tightening shocks reduce foreign output, with heterogeneous effects depending on country characteristics. These spillovers are larger in countries that are relatively more open to trade. Second, monetary shocks generate significant indirect effects that propagate through the network of bilateral trade linkages. Third, a country's financial openness does not appear to be important in explaining these heterogeneous responses, and the associated indirect effects are small. Overall, trade linkages appear to be more potent than financial linkages in explaining international spillover effects of monetary shocks on real economic variables. Future research may find it fruitful to study the transmission channels for other types of shocks, such as fiscal and supply shocks.

Based on these findings, we conclude that the models that do not account for direct and indirect linkages between countries are likely incomplete. We conjecture that both empirical and theoretical studies of international business cycles should incorporate measures of endogenous amplification through network effects. Abstracting from these indirect spillovers may result in mismeasurement of the effects and potentially yield both quantitatively and qualitatively different theoretical predictions. Monetary authorities in open economies, large and small, should consider these spillover effects—and the potential feedback loops—when designing optimal policy. To understand and to predict the effects of foreign shocks, policymakers could benefit from analyzing their countries' trade linkages.

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[19]The drop in the spatial lag coefficient, ρ, is driven mostly by the smaller cross-section of countries and not by the shorter time series.

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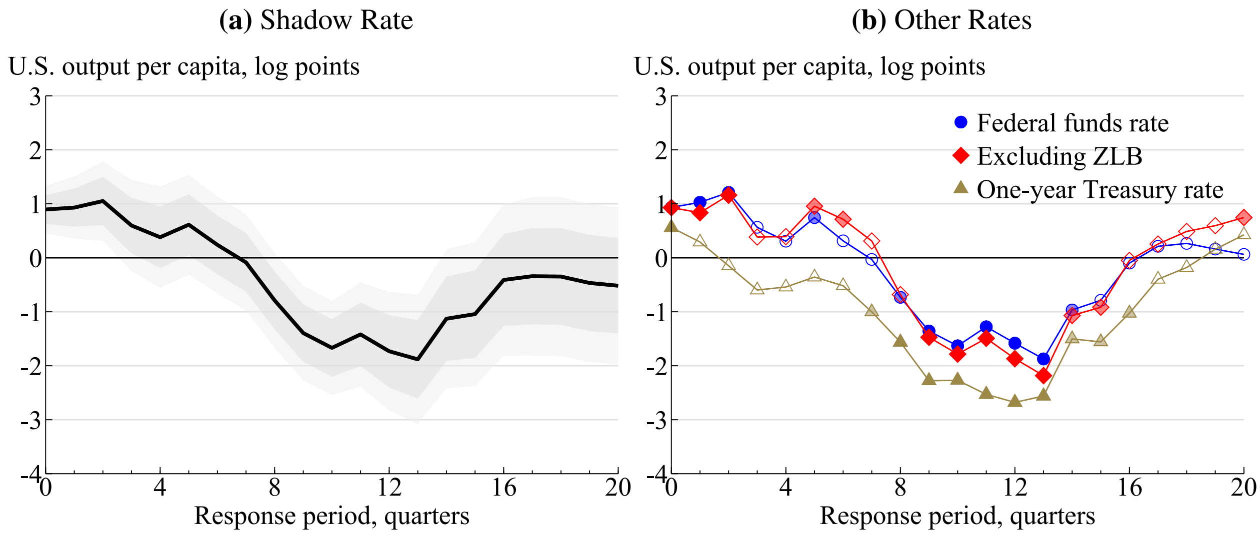
Appendix (Not for Publication)

Table A.1: Country Characteristics

Country	Total Trade Above Median (1)	Total IIP Above Median (2)	Exchange-Rate Peg (3)	Emerging Market (4)
Argentina	N	N	N	Y
Australia	N	Y	N	N
Austria	Y	Y	Y	N
Bolivia	N	Y	N	Y
Canada	Y	Y	N	N
Chile	N	N	N	Y
China	N	N	Y	Y
Colombia	N	N	N	Y
Costa Rica	Y	N	N	Y
Cyprus	Y	Y	Y	N
Czech Republic	Y	N	N	Y
Denmark	Y	Y	Y	N
Ecuador	N	N	Y	Y
Estonia	Y	N	Y	N
Finland	Y	Y	Y	N
France	N	Y	Y	N
Germany	N	Y	N	N
Greece	N	N	Y	N
Hong Kong	Y	N	Y	N
Hungary	Y	Y	N	Y
Iceland	Y	Y	N	N
Indonesia	N	N	N	Y
Ireland	Y	Y	Y	N
Israel	N	N	N	Y
Italy	N	N	Y	N
Japan	N	N	N	N
Korea	N	N	N	Y
Lithuania	Y	N	Y	N
Malaysia	Y	Y	N	Y
Mexico	N	N	N	Y
Netherlands	Y	Y	Y	N
Norway	Y	Y	N	N
Paraguay	Y	Y	N	Y
Poland	N	N	N	Y
Romania	N	N	N	Y
Singapore	Y	Y	N	N
Slovakia	Y	N	N	N
Slovenia	Y	Y	Y	N
Spain	N	Y	Y	N
Sweden	Y	Y	N	N
Switzerland	Y	Y	N	N
Turkey	N	N	N	Y
United Kingdom	N	Y	N	N
United States	N	N	N	N
Y count	22	22	16	18

Figure A.1: Domestic Effects: U.S. Output Response to Monetary Tightening



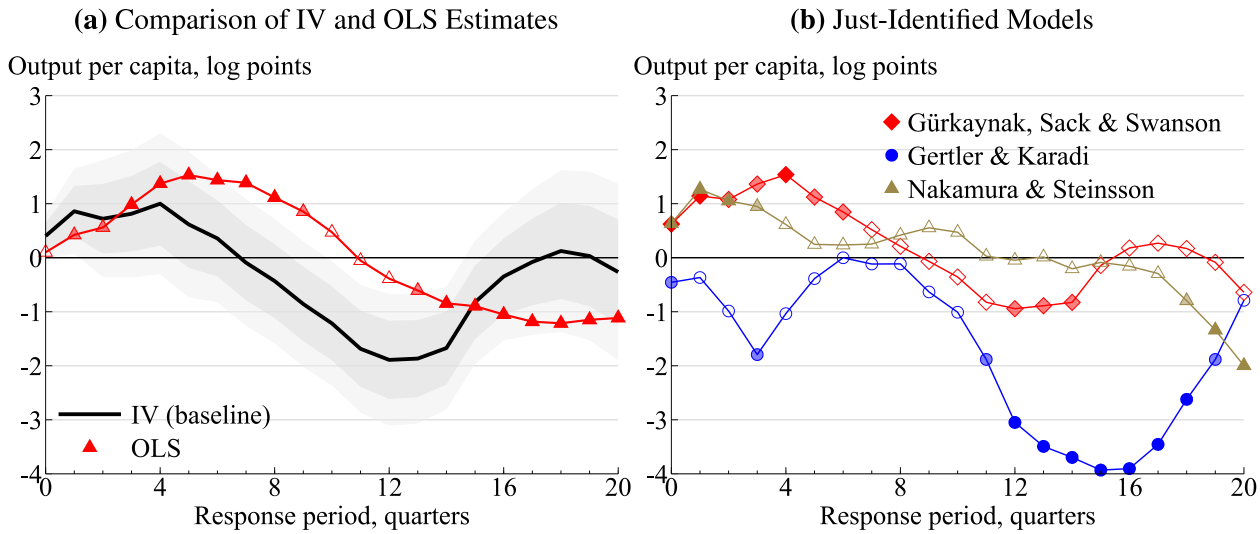
Notes: This figure shows estimates of specification (1) for the U.S. sample. Standard errors are Newey–West with a bandwidth of $h+1$ quarters. The shaded areas, and the solid and shaded symbols, indicate 90% and 68% confidence intervals.

Table A.2: Baseline Estimates and Model Diagnostics

	10 quarters (1)	11 quarters (2)	12 quarters (3)	13 quarters (4)	14 quarters (5)
Output per capita, log points	-1.22^{*}	-1.69^{**}	-1.89^{**}	-1.87^{**}	-1.67^{**}
	(0.69)	(0.70)	(0.73)	(0.71)	(0.68)
Instrument tests					
Hansen J-statistic	0.435	1.398	3.833	4.624	4.233
p-value	0.509	0.237	0.050	0.032	0.040
First-stage tests					
Kleibergen–Paap LM statistic	10.120	10.120	10.120	10.120	10.120
p-value	0.006	0.003	0.003	0.006	0.006
First-stage F-statistic	26.374	26.374	26.374	26.374	26.374
Number of observations	2,924	2,924	2,924	2,924	2,924

Notes: Panel (a) tabulates estimates shown in Figure 1a at the response horizons with significant slope coefficients. Panel (b) shows the instrument diagnostics for the corresponding specifications. The standard errors, shown in parentheses, and test statistics are robust to correlations clustered by quarters and countries. Significance levels at 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Figure A.2: Robustness of the Baseline Specification



Notes: Panel (a) compares estimates of specification (1) using OLS with the baseline IV estimates. Panel (b) considers alternative measures of the U.S. monetary policy rate, r_t. See notes to Figure 1 for estimation details. Standard errors are two-way clustered by countries and quarters. The shaded areas in panel (a), and the solid and shaded symbols in both panels, indicate significance at the 90% and 68% levels, respectively.

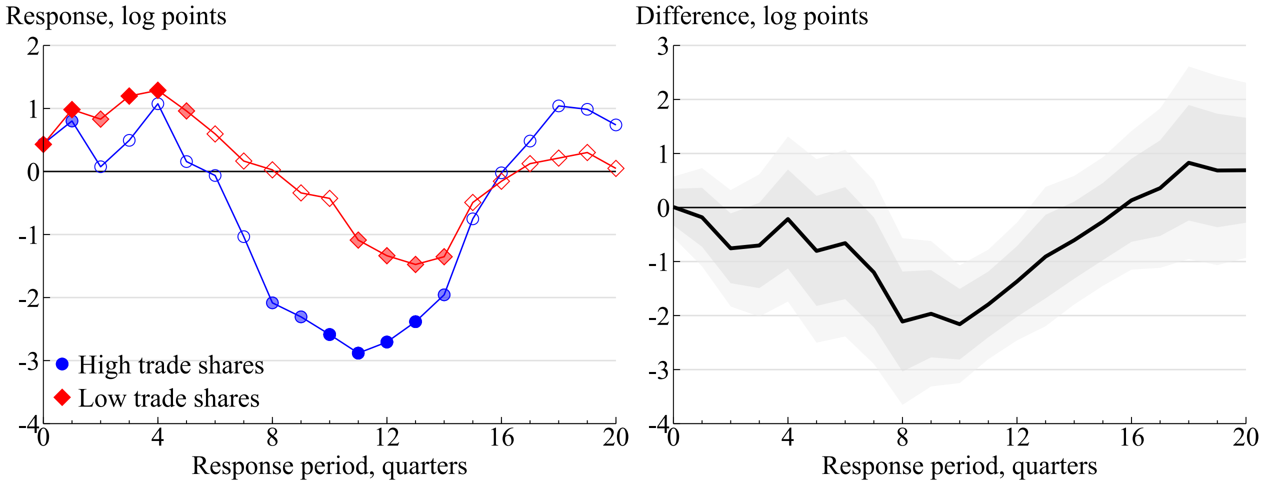
Table A.3: Diagnostic Tests for Alternative Sets of Instruments

Instrument tests	Baseline (1)	GSS (2)	GK (3)	NS (4)
Kleibergen–Paap LM statistic	10.120	7.128	6.113	4.891
p-value	0.006	0.008	0.013	0.027
First-stage F-statistic	26.374	42.023	9.065	24.505

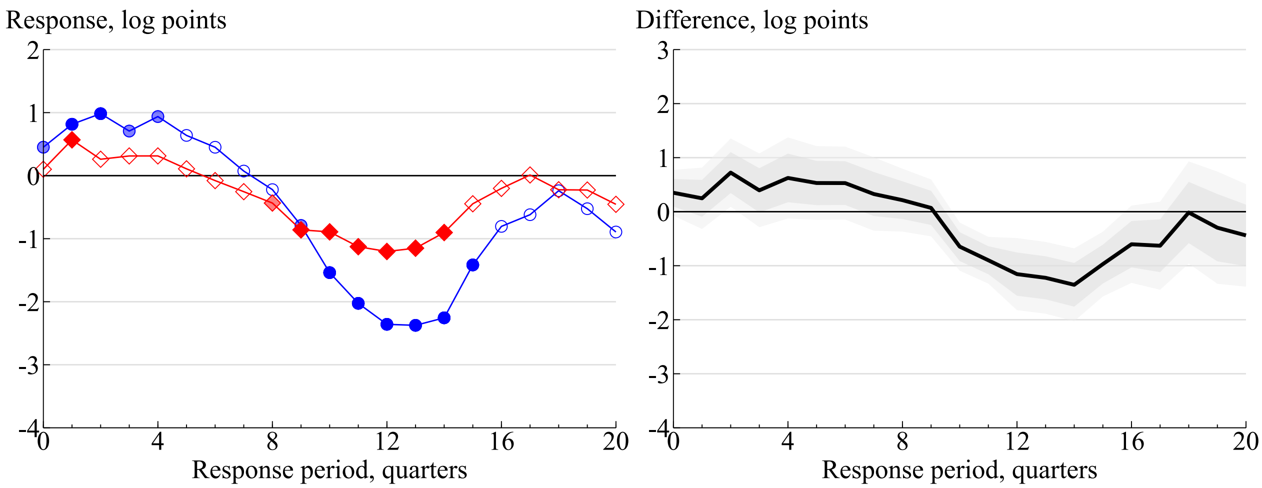
Notes: This table shows the diagnostic tests of instrument validity and relevance for alternative identification strategies. GSS stands for the federal funds rate shock from Gürkaynak, Sack, and Swanson (2005), GK for the policy surprise from Gertler and Karadi (2015), and NS for the policy news shock from Nakamura and Steinsson (2018).

Figure A.3: The Effects of U.S. Monetary Policy on Output per Capita in Different Country Samples

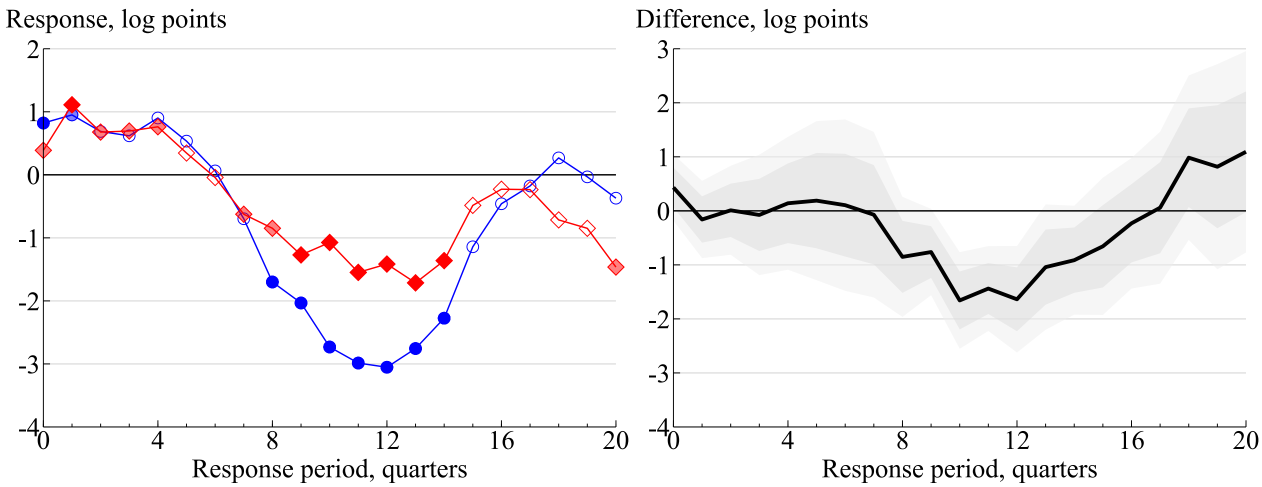
(a) Low IIP Countries



(b) High IIP Countries



(c) Euro Area Countries



Note: The country groups are based on the trade-to-GDP and IIP-to-GDP ratios at the beginning of the sample period relative to the corresponding cross-country median.

Figure A.4: Responses of Other Key Variables

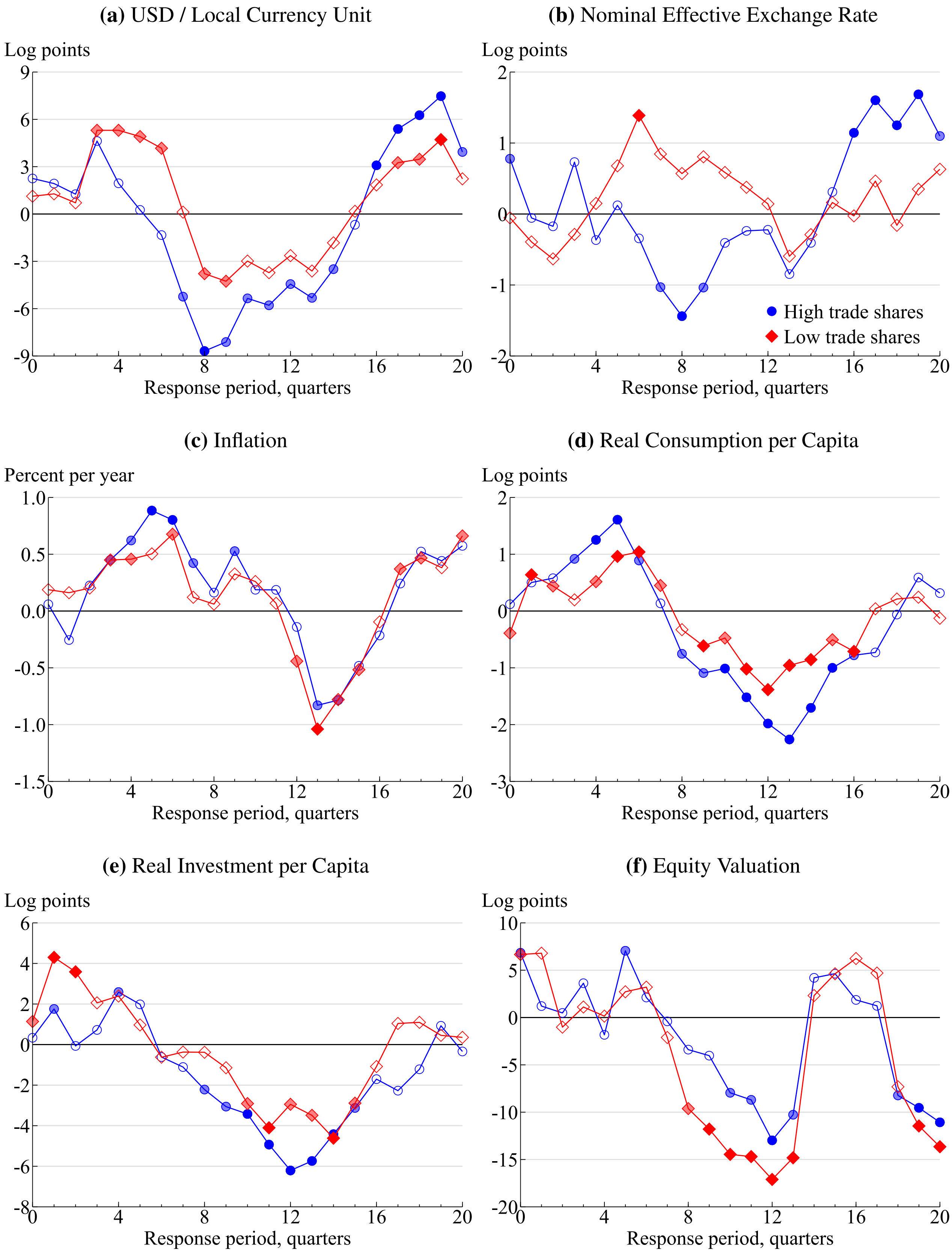
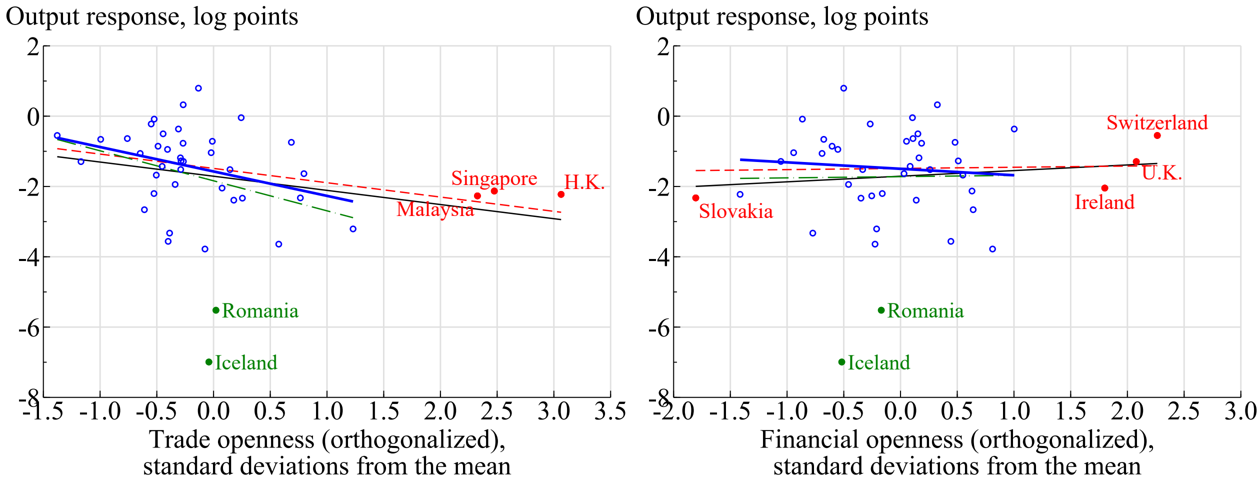


Figure A.5: The Effects of Trade Financial Openness: Outliers



Notes: This figure explores the role of influential observations in Figure 5. The black solid lines show the fit in our baseline estimation sample, and the blue solid line when the outliers are removed as in Figure 5. The green dash-dot lines show the influence of Iceland and Romania, two countries with large negative output responses. The red dashed lines show the influence of countries with a disproportionately large degree of openness to trade (left panel) and finance (right panel).

Table A.4: Results with Trade Openness Measured by Value-Added Flows

	10 quarters		12 quarters		14 quarters	
	(1)	(2)	(3)	(4)	(5)	(6)
Total value-added trade	−0.50	−0.58**	−0.54**	−0.52**	−0.40**	−0.33
	(0.29)	(0.27)	(0.19)	(0.20)	(0.17)	(0.19)
Total IIP	0.40	0.39	0.43	0.39	0.37	0.35
	(0.59)	(0.57)	(0.49)	(0.43)	(0.27)	(0.29)
Value-added net exports		−0.46		−0.19		0.21
		(0.50)		(0.38)		(0.36)
Net IIP		−0.28		−0.57		−0.18
		(0.65)		(0.56)		(0.73)
Current account	0.72	1.17	0.51	0.78	0.35	0.20
	(0.51)	(0.75)	(0.38)	(0.53)	(0.47)	(0.71)
Developing (indicator)	1.17*	1.26*	0.54	0.49	0.25	0.15
	(0.60)	(0.67)	(0.55)	(0.55)	(0.66)	(0.69)
Constant	−1.78***	−1.78***	−2.05***	−1.99***	−1.75***	−1.71***
	(0.32)	(0.32)	(0.25)	(0.25)	(0.27)	(0.30)

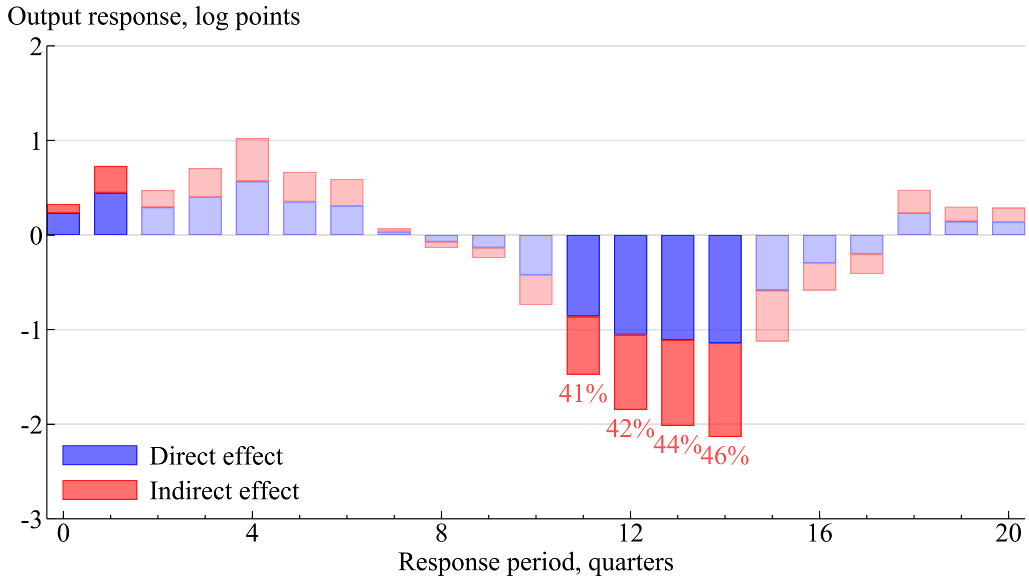
Notes: In this table, we replace our baseline measure of trade openness (based on gross flows) in Table 1 with a measure based on value-added flows. These data are available for 27 countries in our sample. Standard errors robust to heteroskedasticity are in parentheses. Significance levels at 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Table A.5: Financial Openness Based on Different Stock and Flow Definitions

	Total (1)	Direct Investment (2)	Equity (3)	Debt Securities (4)	Derivatives (5)
	(a) IIP (stock measures)				
Total trade	−0.40**	−0.58**	−0.74**	−0.37	−0.26
	(0.16)	(0.25)	(0.33)	(0.22)	(0.30)
Total financial openness	0.16	0.24	0.32	0.03	0.01
	(0.19)	(0.19)	(0.22)	(0.15)	(0.28)
Net exports	0.28	0.19	0.28	0.20	0.06
	(0.30)	(0.29)	(0.44)	(0.34)	(0.33)
Net financial openness	0.16	−0.50*	0.24	0.21	0.06
	(0.46)	(0.29)	(0.16)	(0.17)	(0.16)
Current account	0.08	0.83	0.21	0.55	0.73*
	(0.34)	(0.53)	(0.58)	(0.47)	(0.39)
Developing (indicator)	0.67	0.31	0.55	0.47	0.57
	(0.64)	(0.61)	(0.62)	(0.61)	(0.62)
Constant	−2.00***	−2.01***	−2.12***	−2.06***	−2.04***
	(0.39)	(0.35)	(0.38)	(0.41)	(0.34)
	(b) Financial Account (flow measures)				
Total trade	−0.31**	−0.40**	−0.25	−0.30	−0.37**
	(0.12)	(0.15)	(0.24)	(0.24)	(0.17)
Total financial openness	0.33	0.12	0.06	−0.20	−0.08
	(0.35)	(0.12)	(0.14)	(0.13)	(0.15)
Net exports	0.17	0.30	0.25	0.41	0.59
	(0.28)	(0.28)	(0.32)	(0.25)	(0.37)
Net financial openness	−0.33	−0.14	0.04	0.23	0.33*
	(0.33)	(0.32)	(0.20)	(0.32)	(0.19)
Current account	0.22	0.20	0.35	0.19	−0.06
	(0.26)	(0.28)	(0.39)	(0.33)	(0.36)
Developing (indicator)	0.64	0.41	0.66	0.43	0.68
	(0.51)	(0.64)	(0.59)	(0.48)	(0.63)
Constant	−2.02***	−1.90***	−1.96***	−1.85***	−2.11***
	(0.33)	(0.35)	(0.36)	(0.32)	(0.41)

Notes: In this table, we replace our baseline measure of financial openness in Table 1 with alternative measures, focusing on the peak responses. In Panel (a), we use stock-based measures as captured by the International Investment Position (IIP). In Panel (b), we use flow measures based on financial accounts (FA). Column (1) shows results for the total IIP and FA, while columns (2) through (5) break them down into different components. For IIP, "Total" refers to the sum of assets and liabilities, while "net" refers to their difference. For FA, "Total" ("net") refers to the sum (difference) of inflows and outflows. Standard errors robust to heteroskedasticity are in parentheses. Significance levels at 1%, 5%, and 10% are denoted by ***, **, and *, respectively.

Figure A.6: The Share of Indirect Effects over Response Horizons: The Pooled β Specification



Note: The dependent variable is (log) real GDP per capita. Our data include 44 countries from 1995 through 2017 at a quarterly frequency. The decomposition into direct and indirect effects is obtained using the total-trade bilateral linkages. The solid bars represent significant effects at the 10% level. The percentage of indirect effects are shown below the bars for significant output responses.

Table A.6: Export and Import Linkages

	11 quarters (1)	12 quarters (2)	13 quarters (3)	14 quarters (4)	15 quarters (5)
	(a) Export Linkages				
Spatial lag, ρ	0.443***	0.464***	0.492***	0.509***	0.514***
	(0.053)	(0.054)	(0.057)	(0.062)	(0.069)
Indirect effect	−0.75***	−0.94***	−1.07***	−1.16***	−0.63
	(0.28)	(0.31)	(0.35)	(0.40)	(0.41)
% of total	44.2	45.4	47.4	48.5	47.0
	(b) Import Linkages				
Spatial lag, ρ	0.431***	0.451***	0.481***	0.503***	0.521***
	(0.052)	(0.052)	(0.054)	(0.057)	(0.061)
Indirect effect	−0.70***	−0.86***	−0.98***	−1.06***	−0.55
	(0.25)	(0.28)	(0.33)	(0.37)	(0.39)
% of total	43.3	44.2	46.3	47.7	46.6

Note: This table presents alternative estimates for the model shown in Table 2, with linkages based separately on export flows (Panel a) and import flows (Panel b). The baseline sample includes 44 countries.

Table A.7: Value-Added Trade Linkages

	11 quarters (1)	12 quarters (2)	13 quarters (3)	14 quarters (4)	15 quarters (5)
	(a) Value-Added Trade Linkages				
Spatial lag, ρ	0.391***	0.418***	0.463***	0.507***	0.538***
	(0.063)	(0.061)	(0.059)	(0.057)	(0.056)
Indirect effect	−0.76***	−0.89***	−1.04***	−1.06**	−0.54
	(0.30)	(0.33)	(0.40)	(0.48)	(0.56)
% of total	38.5	40.1	43.5	46.4	44.4
	(b) Gross Trade Linkages (VA sample)				
Spatial lag, ρ	0.389***	0.413***	0.457***	0.500***	0.531***
	(0.060)	(0.059)	(0.058)	(0.058)	(0.058)
Indirect effect	−0.75***	−0.87***	−1.01***	−0.97**	−0.52
	(0.28)	(0.30)	(0.36)	(0.41)	(0.47)
% of total	37.8	39.2	42.5	45.2	43.4

Note: This table presents alternative estimates for the model shown in Table 2, with linkages based on value-added trade (Panel a) and gross trade in the corresponding sample (Panel b). The data on value-added bilateral flows matches 30 countries in the baseline sample.

Table A.8: Alternative Spatial Models

	11 quarters (1)	12 quarters (2)	13 quarters (3)	14 quarters (4)	15 quarters (5)
			(a) Baseline Model		
Spatial lag, ρ	0.433***	0.454***	0.484***	0.506***	0.521***
	(0.052)	(0.053)	(0.055)	(0.058)	(0.062)
Indirect effect	−0.71***	−0.88***	−1.01***	−1.10***	−0.57
	(0.26)	(0.29)	(0.33)	(0.38)	(0.40)
% of total	43.5	44.4	46.7	48.1	47.0
			(b) No Spatial Error		
Spatial lag, ρ	0.559***	0.585***	0.628***	0.667***	0.696***
	(0.032)	(0.031)	(0.029)	(0.027)	(0.025)
Indirect effect	−0.88***	−1.09***	−1.24***	−1.37***	−0.69
	(0.31)	(0.34)	(0.40)	(0.47)	(0.53)
% of total	56.2	57.2	60.4	63.2	62.3
			(c) No Spatial Controls		
Spatial lag, ρ	0.242***	0.253***	0.260***	0.276***	0.287***
	(0.069)	(0.070)	(0.072)	(0.074)	(0.075)
Indirect effect	−0.55**	−0.67**	−0.71**	−0.77**	−0.44
	(0.25)	(0.27)	(0.29)	(0.32)	(0.28)
% of total	24.4	25.1	25.5	26.8	26.9
			(d) Spatial Lag Only		
Spatial lag, ρ	0.656***	0.672***	0.693***	0.711***	0.721***
	(0.028)	(0.027)	(0.026)	(0.025)	(0.024)
Indirect effect	−1.53***	−1.80***	−1.94***	−2.03***	−1.21*
	(0.48)	(0.51)	(0.55)	(0.60)	(0.62)
% of total	65.2	65.6	66.9	67.9	66.9

Note: This table presents estimates of alternative spatial specifications. The baseline model is in Panel (a). The weights are based on bilateral trade flows.