1 Introduction

Spillover effects of monetary policy have reemerged as a topic worth studying in macroeconomics due to recent changes in the conduct of monetary policy. The Federal Reserve has adopted unconventional monetary responses (quantitative easing) as a means of recovery from the global financial crisis which began in 2008. Quantitative easing refers to central bank purchases of long-term government and privately issued financial assets (as opposed to the traditional monetary policy tools of both the purchase or sale of short-term Treasury obligations as well as changes in the Federal Funds Rate). Thus, quantitative easing increases the excess reserves of banks, as assets are bought, as well as increases the prices of financial assets, which in turn lowers the yield of financial assets. Further, investors interpret quantitative easing as a statement by the Federal Reserve that it will tolerate somewhat higher rates of inflation in the future.

It is important to study spillover effects of unconventional monetary policy by a developed economy on emerging economies; since the domestic channels through which unconventional monetary policies work differ significantly from those for more traditional monetary policies, spillovers from unconventional monetary policies may differ in type and/or magnitude from those associated with traditional monetary policies. Thus, it would not be surprising to see differing international responses to the primary two monetary policy tools.

The literature to date has mainly focused on the spillover effects and responsiveness of foreign central banks to traditional U.S. monetary policy shocks (i.e. a change in the Federal Funds Rate). The general consensus is that there are two main avenues through which these spillover effects travel: exchange rates or the currency channel, and terms of trade or the trade channel. However, these two channels are not created equal, as the literature establishes that the currency channel is responsible for a larger magnitude of spillover effects than is the trade channel.

The Federal Reserve's recent decision to use quantitative easing as a regular monetary policy tool naturally raises new questions regarding spillovers of such policies. This paper is an empirical exploration into the transmission of unconventional U.S. monetary policy to emerging economies. I am using vector auto-regression methodology that has been used previously to study spillovers of traditional U.S. monetary policy. This will allow me to explore whether unconventional U.S. monetary policies have differing spillover effects than those from traditional monetary policies. Additionally, this methodology allows the dependent variables to respond to each other, which is consistent with theory regarding exchange rates and interest rates. Prior theoretical work suggests that unconventional monetary policy may in fact have different spillover effects on emerging economies.

This paper contributes to the existing literature by first examining the spillover effects of changes in the Federal Funds Rate through both the exchange rate channel and the terms of trade channel. This paper deviates from the existing literature with the introduction of quantitative easing as an additional exogenous variable to which the central banks of foreign emerging economies can respond.

This paper is organized as followed: Section 2 presents a review of the relevant literature on spillover effects of monetary policy shocks originating a large, developed country; Section 3 outlines the theoretical model underlying the methodology and the intuition behind understanding the results; Section 4 defines and explains the variables; Section 5 explores the methodology and, in particular, how to deal with problematic time series variables; Section 6 presents the econometric results; Section 7 discusses those results; and Section 8 presents conclusions.

2 Literature Review

Econometric developments, such as widespread use of vector auto-regressions and other time series models, allow researchers to test for contemporaneous movements in macroeconomic time series variables, which has in turn expanded the literature concerning spillover effects. Sims (1980) conducted the foremost study on the investigation of external effects of monetary policy. Sims looked at a comparison of monetary policy in the interwar (1920-1941) and postwar (1948-1978) periods, focusing mainly on the United States and Germany. Sims was one of the first researchers to employ vector auto-regression (VAR) models, which have since been relied on heavily when investigating questions of linear interdependence between time series variables.

Sims' model explored impulse responses to exogenous shocks to interest rates, money supply, wholesale price index, and industrial production, and found similarities in the dynamic responses between interwar and postwar business cycles, though the magnitudes of the impulse responses for each of the variables was larger in the interwar period than in the postwar period. His model moreover revealed that money supply accounted for a large percentage of variance in production in both time periods. The inclusion of short-term interest rates did not diminish the similarities between the two periods, but did reduce the central role of the money supply in explaining variance in the other variables.

More recently, Mackowiak (2007) employed Sims' VAR methodology to investigate the role of external shocks of macroeconomic fluctuations on emerging economies. Mackowiak examined the transmission of monetary policy shocks originating in the U.S. through both interest rates and exchange rates. Mackowiak estimated VARs for each of eight emerging economies in Latin America and East Asia over the period January 1986 through December 2000.

The model contained two vectors which included macroeconomic variables in the emerging market and macroeconomic variables external to the emerging market, respectively. Additionally, the model included a measure of shocks with domestic origin, and a differing measure of shocks with external origins.

Mackowiak assumed that each of these emerging economies represented a small open economy so that the model could better assess the effects of an external shock from the U.S. This assumption is frequently made so as to make sure that the small economy has no effect on interest rates in the large economy, either contemporaneously or with lags, but the large economy can affect interest rates in the small economy. The vector with variables external to the emerging economy included the Federal Funds Rate, world commodity prices, and money stock, real aggregate output and aggregate price level from the U.S. On the other hand, the vector with variables in the emerging market included the short-term interest rate, exchange rate, real aggregate output, and aggregate price level for each country.

Mackowiak found that for a typical emerging market, external shocks account for half of the variation in both the exchange rate and price level, 40% of the variation in real output, and a third of the variation in the short-term interest rate.

Along similar lines, Canova (2005) studied whether and how shocks originating in the U.S. from 1980-2002 were transmitted to a collection of Latin American countries with important financial ties with the U.S. and with divergent exchange rate regimes. Canova used the VAR methodology and found that U.S. monetary disturbances brought about large and significant responses in macroeconomic variables for Latin American countries, whereas real demand and supply shocks in the U.S. generated insignificant fluctuations in Latin American economies, and that interest rates provided the primary transmission channel, while the trade channel played an insignificant role.

Canova modeled the relationship between the U.S. and each Latin American country as bilateral one, with the U.S. on one side and a Latin American country on the other side. The model was repeated for each country that Canova studied. His model was developed as a bivariate block VAR model, which contained a block of U.S. variables, a block of Latin American variables, and a block of world variables.

Importantly, Canova differentiated between currency floaters and currency non-floaters, a distinction allowing exploration of how differences in Latin American exchange rate policies affected the magnitude of spillover effects from U.S. shocks. Canova found that non-floaters' trade balances and real effective exchange rates had large and significant responses through the interest rate channel. Their domestic inflation rates were less sensitive to U.S. shocks. In the countries with floating currencies, Canova observed smaller and less significant interest rate responses, no changes in the trade balances or in real exchange rates, and significantly large and positive inflation responses to U.S. shocks.[1]

Kandil (2009) used different methods to study the spillover effects, including on terms of trade, from general economic fluctuations in the U.S. to Latin America and the Caribbean. One source of such macroeconomic fluctuations for Latin American and Caribbean countries was shocks from U.S. monetary policy, as such shocks affected macroeconomic conditions in the U.S. which then leaked over to Latin America and the Caribbean. Kandil studied eight Latin

[1] The paper does not include the regression output, so it is not clear whether Canova's claims of significance, or lack thereof, are in a statistical sense or not.

American countries over the period 1960-2006. Kandil estimated a first difference equation that replicated the reduced form equation for standard business cycle models.

Kandil focused on measuring how the degree to which the smaller economy was open to trade with the U.S. affected the size of the spillover effects. Kandil measured the openness of a particular country to the U.S. as the ratio of exports to and imports from the U.S. to GDP. Using a first difference form, Kandil found that economic conditions in the U.S. were an important determinant of business cycle fluctuations in Latin America, and that openness to the U.S. can accelerate the growth of exports to and imports from other countries besides the U.S. Kandil also found that geographical proximity, trade, and financial linkages were key explanatory factors of spillover effects of shocks born in the U.S. In regards to the transmission channels, Kandil found that trade openness was the most important; however financial linkages and labor mobility were both rising as other key channels.

Sato, Zhang and McAleer (2011) explored whether shocks from the U.S. influenced macroeconomic fluctuations in East Asian countries over the period 1978 through 2007. The authors' main question was whether macroeconomic fluctuations in the region could be explained more by external shocks from the U.S. or from autonomous development in regional economies.

The authors developed a VAR model with block exogeneity similar to Mackowiak's model. The model specified vectors of macroeconomic variables external to the domestic country, macroeconomic variables in the domestic country, structural shocks to the domestic economy with foreign origin, and structural shocks of domestic origin.

Their model included world oil price changes, real output growth in the U.S., and real output growth in Japan for the foreign block, and real output growth and domestic inflation for the country-specific block. The authors found that U.S. shocks were an important source of fluctuations in the real output of some South Asian countries, and that shocks originating from Japan and China were comparatively less important.

Valente (2009) looked at how market interest rates in Hong Kong and Singapore responded to monetary policy announcements from the U.S. Valente modeled the change in foreign bond yields on changes in short-term interest rates in the U.S. with an ordinary least squares (OLS) regression. Valente found that Federal Open Market Committee (FOMC) announcements affected market expectations about short-term interest rates, but that there were negative international interest rate differentials around FOMC meeting dates, which meant that U.S. interest rates react more to FOMC announcements than do international interest rates. Additionally, in the case of Singapore, domestic interest rates reacted both to U.S. and domestic monetary policy announcements, although the size of the response to domestic announcements was larger.

Hong and Wei (2009) used VAR techniques to investigate the effect of U.S. monetary policy on the world economy and on China's economy in particular. The authors considered Japan, Korea, Malaysia, and the Euro zone in addition to China, over the period 1993 through 2007, and looked at variables including real GDP growth rate, GDP deflator, first order differential of the U.S. trade balance, and the Federal Funds Rate. In order to get from a structural VAR to the standard form VAR, the authors imposed restrictions that the GDP deflator had an effect on real GDP, trade balance had an effect on real GDP, U.S. monetary policy had an effect on real GDP and on trade balance.

The model revealed that U.S. monetary policy shocks had significant negative effects on net exports in Korea. In fact, net exports fell by as much as 2.5% in the 10th quarter following negative shocks. Hong and Wei also found that U.S. monetary policy shocks led to an initial sharp decline of net exports in Malaysia (peaking at -0.27% in the second quarter following the shock), but then rebounded to a peak of 0.12% in the 11th quarter following the shock.

Mattoo, Mishra, and Subramanian (2012) switched the identity of the ‘large country’ from the U.S. to China, and examined how exchange rates in a large country impact exports of small competitor countries to an external third country. The authors specified China as the large country for three key reasons. First, China, as the world's largest exporter of goods, should have significant quantitative competitive consequences for other countries. Second, China competes with a broad range of countries because it is a highly diversified exporter. Lastly, China's exchange rate policy has been extremely controversial throughout the last decade, and provides an interesting lens through which to examine spillover effects of changes in exchange rates.

The authors regressed log of exports against the exchange rate and an index of competition. The authors claim that such a model could control for a wide range of omitted variables through a set of very general fixed effects. In order to control for such variables, the authors included all three-way combinations of importer, exporter, product, and time fixed effects variables.

Mattoo et. al. collected data covering the period 2000-2008 for a selection of 124 developing countries and 57 developed countries. The data covered a wide range of export industries to a variety of external third countries. The motivation for this analysis was that the more a country competes with China in exporting to a particular country, the more a depreciation (appreciation) of the renminbi will help (hurt) the other country's exports to the third market. In order to investigate this theory, the authors developed a competitiveness index between China and the other countries.

The authors found a statistically and economically significant spillover effect from changes in Chinese exchange rates. For countries with a high degree of competition with China, exports tended to rise or fall for a given appreciation or depreciation of the renminbi much more significantly than countries with lesser degrees of competition. In general, a depreciation of 10% of the renminbi increased a developing country's exports by between 1.5 and 2%, and up to as much as 6% for high degrees of competition. As expected, Mattoo et. al. also found that the spillover was greater for homogenous products, which have more substitution possibilities than differentiated products.

Kim (2000) looked at the international transmission of U.S. monetary policy shocks to non-U.S. G6 countries. Kim used the VAR methodology and found that a U.S. monetary expansion led to increases in real GDP and industrial production in G6 countries. A U.S. monetary expansion decreased the world interest rate, which in turn stimulated the global aggregate demand, and increased foreign output. Kim found that foreign output increased by a quarter to a half of the increase in U.S. output.

Ehrmann and Fratzscher (2006) examined the strength of transmission and the transmission channels of U.S. monetary policy to equity markets abroad. The authors looked at a selection of 50 countries, which included both developed and developing countries. Ehrmann and Fratzscher utilized a standard OLS model for the strength of transmission, which represented daily returns as a function of monetary policy shocks in the U.S. as well as a variety of controls (including past returns and day-of-the-week effects). The model analyzed transmission through two channels from the U.S.: short-term interest rates and foreign asset prices.

Ehrmann and Fratzscher found that the key determinant of transmission was the degree of global integration of countries, and not necessarily their bilateral integration with the US.

However, effects were more easily spilled over if there was a high degree of business cycle correlation between the given country and the U.S. The authors discovered that the transmission process was related to the degree of real and financial integration, so equity markets in countries that were relatively open to trade (and in particular those that held a large magnitude of cross-border financial assets) reacted two to three times more strongly to US monetary policy shocks than those of less integrated countries.

Additionally, equity markets in India and Malaysia (among other countries) hardly changed at all in response to US monetary policy shocks, whereas equity markets in Indonesia and Korea (among others) changed significantly in response to a US monetary policy shock. India, Peru, and Malaysia are all relatively 'closed' emerging economies and this may explain why their equity markets did not react significantly or only reacted very weakly to US monetary policy shocks. In general, the authors found that countries that have a high degree of trade and have a large size of financial assets and liabilities with the rest of the world reacted two to three times more strongly to US monetary policy shocks than countries with a low degree of such integration.

In an important theoretical contribution, Haberis and Lipinska (2012) extended a standard New Keynesian theoretical framework to include the zero lower bound of interest rates in the U.S. The authors investigated how monetary policy in a large economy affects the conduct of optimal monetary policy in a small open economy in response to a global demand shock that is large enough to send both economies to the zero lower bound. In Haberis and Lipinska’s model, the economies are open, although developments in the large economy affect the small economy, but developments in the small economy don't affect the large economy.

The authors found that the inability of the large economy to stabilize its own economy after a large global demand shock that pushes both economies to the zero lower bound created a spillover effect on the small economy. The spillover surfaced because monetary policy in the large economy was unable to correct for deviations from long run inflation and output gap levels in the large economy. Such a spillover effect influenced how well the small economy was able to stabilize its own economy. Additionally, Haberis and Lipinska found that the size of the spillover effect from the large to the small economy was determined by policy design in the large economy -- whether monetary policy is set under commitment (forward looking expectations) or discretion (backward looking expectations), and the direction of spillover effects was determined by whether the home and foreign goods were substitutes or complements for consumers in the home country. When the goods were substitutes, looser foreign monetary policy reduced welfare through a 'beggar-thy-neighbor' effect in the home country. When the goods were complements, the home country benefited from expansionary unconventional monetary policy in the foreign country.

Haberis and Lipinska's work is similar in spirit to earlier theoretical work by Lipinska, Spange, and Tanaka (2011), who used an analogous New Keynesian set-up to explore the policy spillovers that follow global cost-push shocks. Lipinska et. al. found that cost-push shocks introduced policy trade-offs between stabilizing inflation or output. If the large foreign economy decided to stabilize output and tolerate more inflation, perhaps because the foreign authority reacted differently to core inflation than to increased prices for globally traded commodities, this change in policy would have spillover effects in the home country. Whether the spillovers result in higher or lower welfare in the home country (compared to when the foreign country does not change policy in response to the global cost-push shock) depends on whose currency is used to price traded goods, and on whether the home and foreign produced goods are substitutes or complements.

3 Theoretical Model

The basic setup of my model is quite simple, setting foreign monetary policy (measured by the overnight interbank lending rate) against U.S. monetary policy (measured by both the Federal Funds Rate and by quantitative easing).

I chose to examine spillovers through two models – exchange rate and terms of trade – because there are some studies (Canova, 2005; Kandil, 2009) that indicate that both the currency channel and the trade channel are important in explaining how spillover effects from monetary policy shocks cross national borders. These studies generally indicate that the currency channel is much more important than the trade channel in fostering spillover effects. However, I chose to include the trade channel because of the objections raised by several foreign countries' (including Japan and Brazil) to quantitative easing 3, the latest quantitative easing package. Some foreign central banks feared that the U.S. was trying to foster the depreciation of the U.S. dollar, which in turn would increase U.S. exports and reduce its imports. Many abroad viewed this as a somewhat backhanded trade policy that was driven by unfair intervention in the foreign exchange market on the part of the Federal Reserve.[2] If these concerns were valid, I would expect to see trade as a significant channel for spillover effects from quantitative easing shocks.

Much of the intuition behind the basic exchange rate model comes from the uncovered interest parity (UIP). In its most simplified form, the UIP tries to explain the relationship between short-term interest rates and exchange rates. In order to satisfy the efficient markets

[2] http://online.wsj.com/article/SB10000872396390444165804578006513150635592.html

hypothesis, where no further opportunities for arbitrage exist, the expected percentage change in the exchange rate will equal the home interest rate minus the foreign interest rate:

$$\% \Delta e^{e}{}_{t+1} = R_H - R_F$$

Even though simple versions of the UIP are not confirmed by empirical studies, it still provides the basis for many econometric models that look at the effect of some variable on investment conditions across countries. Two explanations – risk premiums and rational expectations – are quite popular in explaining why the simplest versions of UIP, which seem intuitive enough, do not hold empirically. Investing abroad is often viewed as riskier than investing at home, meaning that the return abroad must be above the return at home by some amount (i.e. a foreign risk premium) in order for home investors to invest abroad. This explanation indicates that an additional variable should be included in the model. Alternatively, the rational expectations theory states that economic agents tend to view the levels and term structure of interest rates as containing the best available information about future interest rates – and thus only random errors can explain why agents' predictions of future time periods may not be entirely correct.

UIP theory states that if the Federal Reserve decreases the Federal Funds Rate, this expansionary monetary policy leads to a depreciation of the U.S. dollar (alternately viewed as an appreciation of the foreign currency). If the foreign central bank does not respond, UIP says the exchange rate (measured as foreign currency per U.S. dollar) will decrease, as it takes more U.S. dollars to purchase a unit of foreign currency. Alternatively, if the foreign central bank were to respond, UIP theory indicates that it would implement its own expansionary monetary policy and reduce the overnight interbank lending rate in an effort to prevent the appreciation of its currency.

If the Federal Reserve implemented quantitative easing purchases as another form of expansionary monetary policy, this could lead to a devaluation of the dollar through two different channels. First, since quantitative easing entails the purchase of longer term assets, the yields of those assets will fall. UIP applies to longer-term interest rates as well as short-term interest rates, so the U.S. dollar should depreciate to some degree as a result of quantitative easing. Alternatively, quantitative easing may work through a credible promise by the central bank to accept higher inflation (which at the zero lower bound is expansionary because it leads to a decrease in the real interest rate). The promise to accept higher inflation, however, will also lead to depreciation of the U.S. dollar, since assets denominated in U.S. dollars are now less attractive than before. So, as with conventional expansionary monetary policy, if the foreign central bank does not respond to quantitative easing, its currency will appreciate. Conversely, if the foreign central bank does respond to quantitative easing, then it will decrease the overnight interbank lending rate in an effort to counteract the appreciation of its currency.

UIP theory alone does not provide a sufficient basis for interpreting the results from my regressions. Thus, the most significant part of my analysis is determining which other factors might explain the differences across countries regarding both policy spillovers from and foreign central bank responses to changes in U.S. monetary policy. I investigate four primary theories: bilateral trade integration, business cycle synchronization, the gravity model, and exchange rate regime classification.

Bilateral trade integration refers to the intensity of trade between the U.S. and each emerging economy. In theory, the more integrated two countries are via trade, the more responsive the foreign central bank will be when it faces exchange rate fluctuations from a monetary policy spillover. In the case of a U.S. monetary expansion, the dollar will depreciate relative to foreign currencies. As a result, a country that is heavily integrated with the U.S. will find it in its best interest to devalue its own currency in order to preserve trade relations. Bilateral trade integration is measured as percent of total imports or exports that are with the U.S.

Business cycle synchronization looks at the growth rates of countries relative to one another. Theory posits that the more synchronized two economies are, the larger will be the magnitude of spillovers and responses. For example, if two countries are both in need of monetary expansions and the U.S. enacts an expansionary policy, as detailed above, the dollar will depreciate relative to the foreign currency. Consequently, the foreign central bank will not only have to enact the original monetary expansion (due to the economic downturn) but it will have to increase the magnitude of its expansionary policy to counteract the appreciation of its currency relative to the dollar. I measure business cycle synchronization as the standard deviation of the absolute value of the difference in GDP growth rates between the U.S. and each of Brazil, India, and Mexico,

The gravity model of trade was proposed as an alternative theory to the Heckscher-Ohlin model of trade. The gravity model posits that the closer two countries are in terms of economic size, the greater will be their trade relations. The model's prediction is empirically accurate in describing trade relationships, however there is very little theory underlying the model. Traditionally, economic size is measured as total GDP or total population. I propose extrapolating the gravity model to monetary relationships between countries, as well as the inclusion of size of the financial sector as a different indicator of economic size. I measure size of the financial sector as total foreign direct investment inflows and outflows.

Lastly, exchange rate regime refers to how central banks react to currency fluctuations. In this sample, most observations are categorized as independent floating, meaning that the value of currency is completely market determined. However, there are some observations of managed floating regimes, which means that the currency is generally allowed to float on the market, but where the central bank maintains significant intervention power in altering the currency value. In theory, a foreign central bank would be forced to be more responsive to monetary policy spillovers if the currency is not independently floated. Additionally, I would expect the highest magnitude of responses to come the closer a country is to a fixed regime.

4 Data

In order to examine the effects of U.S. monetary policy on emerging economies, I performed a vector auto-regression, looking both at the currency and the trade channels of transmission, with the U.S. Federal Funds Rate and quantitative easing purchases as exogenous variables. I collected data for emerging market economies in both Latin America and South Asia: Bolivia, Brazil, Chile, India, Malaysia, Mexico, Pakistan, Peru, Philippines, South Korea, and Venezuela. These countries were chosen not just because they represent the emerging market class, but also because they have significant economic linkages (i.e. trade, investment) with the U.S., and thus would be more likely to experience any potential spillover effects of U.S. monetary policy. The time period of my study is 1990 through 2012, with monthly frequency, although some countries cover a shortened time span due to data availability issues.

In using the vector auto-regression methodology for econometric analysis, I need to identify two dependent variables that co-move with one another. In my first model, the variables of interest are the exchange rate (measured as foreign currency per U.S. dollar) and overnight interbank lending rate, as a proxy for foreign monetary policy. In the second model, exchange rate is replaced by terms of trade, which is calculated as price of exports divided by price of imports, and the overnight interbank lending rate remains. It is important to include the measure of foreign monetary policy in both models because I need to account for any movements that foreign central bankers make in response to changes in U.S. monetary policy. I chose exchange rate and terms of trade as the two models because they represent the two main avenues through which monetary policy tends to spill over into other countries. Several studies (Mackowiak, 2007; Canova, 2005; Kandil, 2009) have looked at the ways in which shocks in one country transfer to another country, and these studies found that exchange rates and terms of trade are among the most significant transmission channels.

I collected monthly exchange rate data, measured as foreign currency per U.S. dollar, from the Federal Reserve Board Economic Research and Data for Brazil, Mexico, South Korea, Malaysia, Venezuela, and India. These were the only currencies that the Federal Reserve Board tracked among the countries I studied. I obtained exchange rate data for Chile from the Monthly Statistics of International Trade in the OECD iLibrary. I acquired data for Peru from the Central Reserve Bank of Peru’s Statistical Tables, data for Pakistan from the State Bank of Pakistan’s Economic Data, data for Bolivia from the Banco Central de Bolivia statistics, and data for the Philippines from the Bangko Sentral ng Pilipinas statistics.

In each of the models, I used the percentage change in exchange rates as one of the dependent variables, measured as the log difference of observations in two consecutive time periods. I performed this data transformation because the exchange rates, reported as levels, were non-stationary, and the percentage change in exchange rates was stationary.

I assembled the monthly overnight interbank lending rate data for each foreign country from Global Financial Data. Global Financial Data reported four values for overnight interbank lending rate: open, high, low, and close. Due to data availability and a desire to remain consistent amongst the variables, I chose the open measure of the interest rate. The overnight lending rate was not available for Brazil during this time period, so I chose the next highest frequency interest rate, which was the one-month lending rate. Similarly, overnight lending rate data was not available for Mexico, and the next highest frequency was the 28-day lending rate. I computed the one-period difference in overnight interbank lending rate due to the non-stationary nature of the data. After this transformation, the lending rate data was stationary.

I also collected data on monthly import and export price indices for the foreign countries from Global Financial Data. These indices were measured with 2005 as the base year – so both the import and export price indices were normalized to 1 in that year. Again, because of data availability and for the sake of consistency, I used the open measure on both indices. To calculate the terms of trade index, I divided the export price index by the import price index. Due to concerns with non-stationary data, the model includes the percentage change in terms of trade.

The last variable for the foreign countries is an exchange rate regime dummy variable. There are a handful of exchange rate regime classification systems, as well as some complete datasets, but these datasets are not publicly available. My interest in the exchange rate regime dummy variable is mainly to see whether a particular regime has any sort of effect on the magnitude or mode of transmission. Thus, I created my own exchange rate regime variable based on publicly available data.[3] I classified my dummy as 0 if the regime was closer to floating and 1 if the regime was closer to fixed. Interestingly, I found that nine of my eleven selected countries were classified as closer to floating for the entire duration of the study. The only two that resembled a fixed exchange rate regime were Malaysia and Venezuela, who both switched from

[3] For all countries except Venezuela, I classified the exchange rate regime based off of the following website: http://intl.econ.cuhk.edu.hk/exchange_rate_regime/. I classified Venezuela based off the following website: http://www.cadivi.gov.ve/institucion/sistemacambiario.html.

floating to fixed during the time span of my study. Thus, the exchange rate regime dummy variable was only included in the models for Malaysia and Venezuela.

For the U.S., I collected data on monetary policy from the Federal Reserve Board. The Federal Open Market Committee, which meets approximately every six weeks, has used two primary avenues for controlling the monetary policy of the U.S., namely, the Federal Funds Rate and quantitative easing purchases. I collected Federal Funds Rate data on a monthly frequency from the Economic Research and Data section of the Federal Reserve Board. I used the one-period difference in the Federal Funds Rate in both models. I collected data on quantitative easing purchases by reading the Federal Reserve Board's archives of the Federal Open Market Committee's minutes from each meeting. Of the three separate quantitative easing rounds, two were stated in monthly terms (QE2 and QE3). QE1, on the other hand, was stated as total purchases, so I divided the total purchases by the number of months in that round of quantitative easing to get an amount of monthly purchases. In my models, I tested both the level of quantitative easing (as monthly purchases) as well as a quantitative easing dummy (1 if purchases were made in that month and 0 if not).

5 Methodology

I chose to separate the countries and run separate models for each country. This meant that my data was time series in nature. Thus, the base models of exchange rate and terms of trade vector auto-regression took the structural forms:

$$\%\Delta ER_t = \sum_{j=1}^{n} \alpha_j * \%\Delta ER_{t-j} + \sum_{k=0}^{n} \beta_k * diff\_i_{t-k} + \gamma * diff\_ffr_t + \delta * qe\_dummy_t$$

$$diff\_i_t = \sum_{j=0}^{n} \alpha_j * \%\Delta ER_{t-j} + \sum_{k=1}^{n} \beta_k * diff\_i_{t-k} + \gamma * diff\_ffr_t + \delta * qe\_dummy_t$$

$$\%\Delta TT_t = \sum_{j=1}^{n} \alpha_j * \%\Delta TT_{t-j} + \sum_{k=0}^{n} \beta_k * diff_{i_{t-k}} + \gamma * diff_{ffr_t} + \delta * qe\_dummy_t$$

$$diff\_i_t = \sum_{j=0}^{n} \alpha_j * \%\Delta TT_{t-j} + \sum_{k=1}^{n} \beta_k * diff\_i_{t-k} + \gamma * diff\_ffr_t + \delta * qe\_dummy_t$$

Where $\%\Delta ER_t$ represents the percentage change in the exchange rate,

$diff\_i_t$ represents the one-period difference in the overnight interbank lending rate,

$diff\_ffr_t$ represents the one-period difference in the Federal Funds Rate,

qe_dummy_t represents the quantitative easing purchases dummy variable,

and $\%\Delta TT_t$ represents the percentage change in terms of trade.

In its structural form, I cannot solve for coefficient values from vector auto-regressions because there are not enough equations given the number of unknowns. Due to this problem of under-identification, I must impose restrictions on the structural form so that I can solve for the values of the coefficients. I impose the restriction that the two dependent variables, exchange rates and overnight interbank lending rate in the first model, and terms of trade and overnight interbank lending rate in the second model, do not affect each other in the current time period.[4] Only lagged values of the dependent variables are included as independent variables. This yields the following reduced form vector auto-regressions:

[4] This assumption, that dependent variables do not contemporaneously affect each other, is a fairly common assumption made in VAR methodology. I believe this is an appropriate assumption in this case because there will generally be some sort of delay in market and central bank responses after a policy is changed.

$$\%\Delta ER_t = \sum_{j=1}^{n} \alpha_j * \%\Delta ER_{t-j} + \sum_{k=1}^{n} \beta_k * diff\_i_{t-k} + \gamma * diff\_ffr_t + \delta * qe\_dummy_t$$

$$diff\_i_t = \sum_{j=0}^{n} \alpha_j * \%\Delta ER_{t-j} + \sum_{k=1}^{n} \beta_k * diff\_i_{t-k} + \gamma * diff\_ffr_t + \delta * qe\_dummy_t$$

$$\%\Delta TT_t = \sum_{j=1}^{n} \alpha_j * \%\Delta TT_{t-j} + \sum_{k=1}^{n} \beta_k * diff_{i_{t-k}} + \gamma * diff_{ffr_t} + \delta * qe\_dummy_t$$

$$diff\_i_t = \sum_{j=0}^{n} \alpha_j * \%\Delta TT_{t-j} + \sum_{k=1}^{n} \beta_k * diff\_i_{t-k} + \gamma * diff\_ffr_t + \delta * qe\_dummy_t$$

Where the variables are the same as in the structural model.

In this model, the Federal Funds Rate and quantitative easing are all treated as exogenously given variables. This follows from the theory that an emerging economy (often classified as a small economy) does not influence the conduct of monetary policy in a large, developed country, such as the U.S., whereas the conduct of monetary policy in a small economy is often affected by decisions made by the U.S. regarding their own monetary policy.

According to the vector auto-regression methodology, dependent variables are regressed on lagged values of all dependent variables. Thus, I must find the optimal number of lags for each regression for each country. There are several different criteria available for choosing the lag structure of a model. I chose to use the Akaike Information Criterion (AIC) because the AIC tends to work better with smaller samples, and since I separate my countries into eleven isolated models, each model contains fewer than 300 observations. Another criterion, the Schwartz-Bayes Information Criterion (SBIC), works better with larger datasets but is quite poor at estimating the proper lag length if the number of observations is not sufficient. In order to find the optimal lag structure of my models, I had to minimize the AIC over a plausible range of lags (I allowed the maximum lag length in this process to be 36 months). For both the exchange rate and terms of trade vector auto-regressions, I found the optimal lag structure with the Federal Funds Rate as the only exogenous variable, with quantitative easing as the only exogenous variable, and with both as exogenous variables.

In my more advanced model, I allowed for lags of the Federal Funds Rate and quantitative easing variables. I followed a similar strategy in finding the optimal number of lags of the exogenous variables; however I limited the maximum lag length to only 12 months.[5] As with the methodology in the base model, I found the optimal lag structure with Federal Funds Rate as the only exogenous variable, with quantitative easing as the only exogenous variable, and with both as exogenous variables in both the exchange rate and terms of trade models.

When I first ran regressions using just the reported levels of all my variables, I found that several variables were non-stationary, as indicated by the results of the Dickey-Fuller unit root test. Non-stationary data are data that have means, variances, and covariances that change over time. Non-stationary data thus present a problem because they are unpredictable, making them ill fitted for models. Using non-stationary data in models can lead to unreliable results that may indicate a relationship where in fact, none exists. In dealing with non-stationary data, I must make the data stationary, either by de-trending or differencing, so that it has a constant mean, variance, and covariance over time. I handled the non-stationary nature of my variables as is detailed in the data section.

I also included in my model an exchange rate regime dummy variable. Due to the classification scheme of this variable as defined in the data section, it was only included in the regressions for Malaysia and Venezuela, because these were the only two countries that switched exchange rate regimes during the course of my study. Both Malaysia and Venezuela switched

[5] I limited the lag length to 12 months due to computational reasons. I had to calculate the AIC values by hand.

from a relatively floating regime to a regime that was relatively fixed to the U.S. dollar. I interpret the value of the coefficient on this dummy variable to be the importance of the type of exchange rate regime on changes in Malaysian and Venezuelan central bank lending rates in response to spillover effects from changes in U.S. monetary policy.

Across all countries, I am testing for the value and significance of the coefficients on the Federal Funds Rate and quantitative easing variables. These will indicate the direction and magnitude of spillover effects in exchange rates and terms of trade, and how foreign central banks change their lending rates in response to changes in U.S. monetary policy.

6 Results

Full estimation results are available upon request. The coefficient estimates and standard errors generated by the base model are available below in Tables 1 and 2. Table 1 includes coefficient estimates and standard errors when the Federal Funds Rate and quantitative easing are each the only exogenous variables in the model, and Table 2 includes results from regressions with both variables as exogenous together.

The results presented in Table 1 show that the Federal Funds Rate and quantitative easing variables are statistically significant at the .05 level for Brazil in the model with percentage change in exchange rate as the dependent variable. Additionally, the Federal Funds Rate variable is significant at the .05 level for both Pakistan and South Korea in the model with change in overnight interbank lending rate as the dependent variable. Moving onto the terms of trade model, the results suggest that only the Federal Funds Rate variable is significant at the .05 level for Pakistan with the change in overnight interbank lending rate as the dependent variable. The contents of Table 2 indicate the same conclusions are appropriate as those from Table 1 regarding statistically significant coefficients on the exogenous variables.

Consistent with the existing literature as outlined in my literature review, I found that the currency channel seems to be the primary avenue for the transmission of spillover effects. The trade channel was far less significant for both the Federal Funds Rate and quantitative easing.

Table 1.

Base Model Results

	Exchange Rate as Dependent						*Interest Rate as Dependent (with ER)*					
	Federal Funds Rate			Quantitative Easing			Federal Funds Rate			Quantitative Easing		
Country	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**
Bolivia	0.0362011	0.08819	0.41	0.0001826	0.00054	0.34	-0.6529147	0.41595	-1.57	-0.0023541	0.00254	-0.93
Brazil	**-3.308147**	**1.55453**	**-2.13**	**-0.014743**	**0.00721**	**-2.04**	0.2073918	0.20174	1.03	0.0003265	0.00094	0.35
Chile	-1.587992	0.926	-1.71	-0.0086745	0.005	-1.74	0.4919248	0.86729	0.57	-0.0025524	0.00468	-0.55
India	-0.5166582	0.61002	-0.85	-0.006075	0.00382	-1.59	0.1835104	1.11204	0.17	-0.000374	0.00699	-0.05
Malaysia	-0.2862747	0.46995	-0.61	-0.0026515	0.00275	-0.96	0.5354638	0.54742	0.98	-0.0024426	0.00321	-0.76
Mexico	-0.800461	1.32955	-0.6	-0.0069446	0.00717	-0.97	2.233391	1.26232	1.77	0.0030301	0.00687	0.44
Pakistan	0.0621986	0.51057	0.12	-0.0023414	0.00251	-0.93	**2.478054**	**0.8036**	**3.08**	-0.0028107	0.00408	-0.69
Peru	-0.0307024	0.40416	-0.08	-0.0034854	0.00211	-1.65	1.514619	2.34483	0.65	0.0013771	0.01249	0.11
Philippines	0.0930965	0.06963	1.34	-0.0051865	0.00488	-1.06	-0.0166176	0.11816	-0.14	0.0017371	0.00827	0.21
South Korea	-1.248204	0.92584	-1.35	-0.0089942	0.00568	-1.58	**1.606284**	**0.49759**	**3.23**	0.0002249	0.00311	0.07
Venezuela	1.300083	2.14306	0.61	0.0205948	0.0133	1.55	-1.045588	3.98779	-0.26	-0.0072969	0.02491	-0.29

	Terms of Trade as Dependent						*Interest Rate as Dependent (with TT)*					
	Federal Funds Rate			Quantitative Easing			Federal Funds Rate			Quantitative Easing		
Country	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**
Bolivia	0.1985516	2.54306	0.08	-0.0031521	0.01426	-0.22	-0.6362618	0.4277	-1.49	-0.0021895	0.00241	-0.91
Brazil	0.0124948	2.00102	0.01	0.0007572	0.01065	0.07	-0.2878471	0.24912	-1.16	-0.0003678	0.00133	-0.28
Chile	-0.5103057	2.67983	-0.19	-0.0049829	0.01484	-0.34	0.4759079	0.86267	0.55	-0.0026641	0.00478	-0.56
India	-0.0687466	1.0066	-0.07	-0.0019713	0.0063	-0.31	-0.0830128	1.23872	-0.07	-0.0043074	0.00775	-0.56
Malaysia	-0.3174461	0.89094	-0.36	-0.001509	0.00558	-0.27	0.438689	0.67972	0.65	-0.0009924	0.00426	-0.23
Mexico	-0.0524621	1.28951	-0.04	-0.0013104	0.00729	-0.18	0.3614359	0.7531	0.48	-0.0004253	0.00426	-0.1
Pakistan	-1.088309	2.82654	-0.39	-0.0080426	0.01515	-0.53	**1.790889**	**0.789**	**2.27**	-0.0011686	0.0043	-0.27
Peru	-0.9866976	3.56119	-0.28	-0.0072549	0.01964	-0.37	1.795331	2.55957	0.7	-0.0023593	0.01413	-0.17
Philippines	0.148101	0.11732	1.26	0.0017251	0.00834	0.21	0.0033773	0.15589	0.02	0.0005998	0.01105	0.05
South Korea	-0.1076243	1.1544	-0.09	0.0045319	0.00737	0.62	1.025213	0.55309	1.85	-0.0004193	0.00355	-0.12
Venezuela	-0.6730197	4.50491	-0.15	-0.0007886	0.02684	-0.03	-0.5359028	4.131	-0.13	-0.0062764	0.02461	-0.26

Note: The above results are for when Federal Funds Rate and Quantitative Easing are each the only exogenous variables.

Table 2.

Base Model Results

	Exchange Rate as Dependent						*Interest Rate as Dependent (with ER)*					
	Federal Funds Rate			**Quantitative Easing**			**Federal Funds Rate**			**Quantitative Easing**		
Country	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**
Bolivia	0.03558	0.08818	0.4	0.000178	0.00054	0.33	-0.6449924	0.41523	-1.55	-0.0022707	0.00253	-0.9
Brazil	**-3.308084**	**1.53075**	**-2.16**	**-0.0147427**	**0.00709**	**-2.08**	0.2073904	0.20165	1.03	0.0003264	0.00093	0.35
Chile	-1.628713	0.91893	-1.77	-0.0088917	0.00496	-1.79	0.4805291	0.86694	0.55	-0.0024883	0.00468	-0.53
India	-0.5256569	0.60695	-0.87	-0.0061056	0.00382	-1.6	0.1829749	1.11208	0.16	-0.0003633	0.00699	-0.05
Malaysia	-0.2929636	0.46914	-0.62	-0.0026767	0.00275	-0.97	0.5294735	0.54689	0.97	-0.0023971	0.00321	-0.75
Mexico	-0.8344585	1.32701	-0.63	-0.0070619	0.00717	-0.98	2.2495	1.26204	1.78	0.0033463	0.00682	0.49
Pakistan	0.0710827	0.50925	0.14	-0.0023479	0.00251	-0.93	**2.489558**	**0.80223**	**3.1**	-0.0030403	0.00396	-0.77
Peru	-0.0666529	0.39679	-0.17	-0.0034894	0.00211	-1.65	1.460126	2.34198	0.62	0.0014642	0.01248	0.12
Philippines	0.074757	0.07991	0.94	-0.0026134	0.0056	-0.47	-0.005837	0.13567	-0.04	0.0015362	0.0095	0.16
South Korea	-1.268334	0.92156	-1.38	-0.0091001	0.00566	-1.61	**1.607078**	**0.49763**	**3.23**	0.0003591	0.00306	0.12
Venezuela	1.383933	2.12697	0.65	0.0208124	0.01329	1.57	-1.075668	3.98789	-0.27	-0.007466	0.02491	-0.3

	Terms of Trade as Dependent						*Interest Rate as Dependent (with TT)*					
	Federal Funds Rate			**Quantitative Easing**			**Federal Funds Rate**			**Quantitative Easing**		
Country	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**	**Coefficient**	**St. Error**	**Z-score**
Bolivia	0.185083	2.54351	0.07	-0.0031271	0.01427	-0.22	-0.6460694	0.42691	-1.51	-0.0022771	0.00239	-0.95
Brazil	0.0147459	2.00123	0.01	0.0007584	0.01065	0.07	-0.2890108	0.24908	-1.16	-0.000392	0.00133	-0.3
Chile	-0.528014	2.67955	-0.2	-0.0050398	0.01484	-0.34	0.4667237	0.86218	0.54	-0.0026138	0.00478	-0.55
India	-0.0750742	1.0066	-0.07	-0.0019807	0.0063	-0.31	-0.0968116	1.23818	-0.08	-0.0043195	0.00775	-0.56
Malaysia	-0.3229106	0.89102	-0.36	-0.0015534	0.00558	-0.28	0.4354088	0.67982	0.64	-0.0009325	0.00425	-0.22
Mexico	-0.0597221	1.29002	-0.05	-0.0013209	0.00729	-0.18	0.3594448	0.75345	0.48	-0.0003623	0.00426	-0.09
Pakistan	-1.102993	2.82407	-0.39	-0.0081001	0.01515	-0.53	**1.78894**	**0.78887**	**2.27**	-0.0010753	0.00423	-0.25
Peru	-1.009518	3.56048	-0.28	-0.0073503	0.01964	-0.37	1.78853	2.55979	0.7	-0.0021904	0.01412	-0.16
Philippines	0.2144648	0.13544	1.58	0.0093665	0.0096	0.98	0.0102024	0.1803	0.06	0.0009633	0.01279	0.08
South Korea	-0.0943933	1.15376	-0.08	0.0045207	0.00737	0.61	1.024343	0.55318	1.85	-0.000297	0.00353	-0.08
Venezuela	-0.6758563	4.50575	-0.15	-0.0008671	0.02685	-0.03	-0.5566471	4.1309	-0.13	-0.0063411	0.02461	-0.26

Note: The above results are for when Federal Funds Rate and Quantitative Easing are exogenous variables together.

In the advanced model, I allow for lags in both exogenous variables in each country. I ran the regressions with each as an exogenous variable alone, and then with the two variables together as exogenous. For the results and discussion, I concentrate on the regressions in both the exchange rate and terms of trade models for which both the Federal Funds Rate and quantitative easing are lagged. Full estimation results are available upon request.

In viewing the results of all eleven countries, it is natural to try to see any similarities across countries and to try to determine why spillovers and responses to changes in U.S. monetary policy were greater in some countries than in others. I will posit several possible reasons to explain why there was a collection of countries with high significance, a collection of countries with intermediate significance, and a collection of countries with very low to no significance. In this case, I look at the significance of the coefficients on the Federal Funds Rate and quantitative easing variables and their lags in classifying the significance level of the countries.

For the sake of brevity, I discuss only the results concerning Brazil, India, and Mexico. [6] These countries had the largest number of significant coefficients, and present a very interesting story.

In Brazil's exchange rate model with percentage change in exchange rate as the dependent variable, the Federal Funds Rate was significant in periods zero, two, six, and eight and quantitative easing was significant in periods zero, six, and seven. In the same model with change in overnight interbank lending rate as the dependent variable, the Federal Funds Rate was significant in periods one, four, six, nine, ten, and twelve and quantitative easing was significant

[6] I ran regressions for all eleven countries – Bolivia, Brazil, Chile, India, Malaysia, Mexico, Pakistan, Peru, Philippines, South Korea, and Venezuela – but am focusing mainly on the most significant results. All regression results are available in the appendix or in the accompanying electronic file. Brazil had 18 significant coefficients, and both India and Mexico had 11 significant coefficients. All other countries had 7 or fewer significant coefficients, and one – the Philippines – had no significant coefficients.

in periods four, seven, and nine. In the terms of trade model, the only significance was for the third and fourth lags of quantitative easing when percentage change in terms of trade was the dependent variable.

In the exchange rate model for India, the Federal Funds Rate was significant in periods one and five when percentage change in exchange rate was the dependent variable, and in periods two and nine when change in overnight interbank lending rate was the dependent variable. In the terms of trade model, the Federal Funds Rate was significant in period four, and quantitative easing was significant in periods three, four, ten, and eleven when percentage change in terms of trade was the dependent variable. With change in overnight lending rate as the dependent variable, the second and ninth lags of the Federal Funds Rate were the only significant coefficients.

Lastly, in the exchange rate model for Mexico with percentage change in exchange rate as the dependent variable, the Federal Funds Rate was significant in periods zero, one, three, and four and quantitative easing was significant only in the sixth period. With change in overnight interbank lending rate as the dependent variable, the Federal Funds Rate was significant in periods one, three, nine, and ten. And in the terms of trade model with percentage change in terms of trade as the dependent variable, quantitative easing was significant in the third and fourth periods.

Table 3.

Brazil Regression Results

	Exchange Rate as Dependent			***Interest Rate as Dependent (with ER)***			***Terms of Trade as Dependent***			***Interest Rate as Dependent (with TT)***		
Federal Funds Rate Lags	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**
0	**-5.153375**	**1.94899**	**-2.64**	**0.5940783**	**0.28172**	**2.11**	1.906365	2.65734	0.72	-0.035794	0.35916	-0.1
1	1.019547	2.43063	0.42	**-1.181414**	**0.35134**	**-3.36**	-2.604065	3.23607	-0.8	-0.0845017	0.43738	-0.19
2	**5.885563**	**2.22085**	**2.65**	0.3925986	0.32102	1.22	1.11427	3.22366	0.35	-0.1656658	0.4357	-0.38
3	3.510995	2.03618	1.72	-0.3053186	0.29432	-1.04	-0.172022	3.14613	-0.05	-0.4610608	0.42522	-1.08
4	-3.997934	2.07876	-1.92	**1.426161**	**0.30048**	**4.75**	-3.018529	3.10663	-0.97	0.4446397	0.41989	1.06
5	-1.78532	2.13156	-0.84	-0.1697829	0.30811	-0.55	0.4859992	3.08169	0.16	0.1942127	0.41651	0.47
6	**4.886544**	**1.98817**	**2.46**	**-0.8894834**	**0.28738**	**-3.1**	-0.8657248	3.04421	-0.28	-0.2849132	0.41145	-0.69
7	-3.845922	2.02617	-1.9	-0.1244469	0.29288	-0.42	1.480414	2.57461	0.58	0.1139147	0.34798	0.33
8	**-4.46441**	**2.15473**	**-2.07**	0.0506475	0.31146	0.16						
9	-2.173697	2.19431	-0.99	**1.27361**	**0.31718**	**4.02**						
10	1.170699	2.26032	0.52	**-0.6705177**	**0.32672**	**-2.05**						
11	-1.413721	2.13424	-0.66	-0.1228432	0.3085	-0.4						
12	**-3.964865**	**1.87511**	**-2.11**	**-0.5968045**	**0.27104**	**-2.2**						
Quantitative Easing Lags												
0	**-0.0358803**	**0.01337**	**-2.68**	-0.0014718	0.00193	-0.76	0.0156748	0.02281	0.69	-0.0005239	0.00308	-0.17
1	0.0079184	0.01712	0.46	-0.000794	0.00247	-0.32	0.0027506	0.03092	0.09	-0.002481	0.00418	-0.59
2	-0.0260118	0.01816	-1.43	0.0010743	0.00263	0.41	-0.0145986	0.03094	-0.47	0.0027135	0.00418	0.65
3	0.0248667	0.01899	1.31	0.0027835	0.00275	1.01	**-0.1318206**	**0.03094**	**-4.26**	-0.0006377	0.00418	-0.15
4	-0.011502	0.01852	-0.62	-0.0026836	0.00268	-1	**0.1334478**	**0.03269**	**4.08**	0.0015042	0.00442	0.34
5	0.0076352	0.0184	0.41	-0.0007774	0.00266	-0.29	0.0101146	0.03286	0.31	-0.0007805	0.00444	-0.18
6	**0.039407**	**0.01766**	**2.23**	-0.0010761	0.00255	-0.42	-0.0049529	0.03088	-0.16	-0.0009915	0.00417	-0.24
7	**-0.0376223**	**0.01791**	**-2.1**	**0.0062168**	**0.00259**	**2.4**	0.0067188	0.02255	0.3	0.0011941	0.00305	0.39
8	-0.0311619	0.01814	-1.72	-0.0021189	0.00262	-0.81						
9	0.0177077	0.01849	0.96	**-0.0054423**	**0.00267**	**-2.04**						
10	0.0201101	0.01852	1.09	0.0040744	0.00268	1.52						
11	-0.0235909	0.01846	-1.28	-0.0015409	0.00267	-0.58						
12	0.0277422	0.01432	1.94	0.001418	0.00207	0.68						

Note: The above results are for when Federal Funds Rate and Quantitative Easing are exogenous variables together.

Table 4.

India Regression Results

	Exchange Rate as Dependent			***Interest Rate as Dependent (with ER)***			***Terms of Trade as Dependent***			***Interest Rate as Dependent (with TT)***		
Federal Funds Rate Lags	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**
0	-0.5346136	0.74724	-0.72	0.4053199	1.40519	0.29	0.6814625	1.08266	0.63	-0.9469813	1.60479	-0.59
1	**2.256208**	**0.81802**	**2.76**	-2.899083	1.53828	-1.88	0.4316844	1.18547	0.36	-1.528929	1.75718	-0.87
2	-0.9236161	0.84286	-1.1	**3.45463**	**1.58501**	**2.18**	0.1668188	1.17334	0.14	**5.369984**	**1.7392**	**3.09**
3	-1.113413	0.85045	-1.31	-3.116042	1.59928	-1.95	-0.8280942	1.19837	-0.69	-3.17229	1.77631	-1.79
4	-0.4436837	0.86211	-0.51	1.249336	1.6212	0.77	**-2.388159**	**1.19563**	**-2**	-0.8561094	1.77224	-0.48
5	**-2.42655**	**0.849**	**-2.86**	-1.506106	1.59655	-0.94	0.4630332	1.19803	0.39	-1.166257	1.7758	-0.66
6	1.5571	0.8616	1.81	0.9267375	1.62024	0.57	0.9302595	1.192	0.78	-0.6248564	1.76687	-0.35
7	-0.6382413	0.86649	-0.74	1.861139	1.62944	1.14	1.344653	1.17317	1.15	1.991163	1.73895	1.15
8	-0.4004568	0.86044	-0.47	-1.237593	1.61807	-0.76	-0.1382971	1.18638	-0.12	-1.353276	1.75853	-0.77
9	0.3859341	0.86713	0.45	**4.675953**	**1.63064**	**2.87**	-2.008675	1.19506	-1.68	**3.965539**	**1.7714**	**2.24**
10	0.9811111	0.801	1.22	-1.060713	1.50629	-0.7	1.305112	1.18697	1.1	-0.5266787	1.75941	-0.3
11							-1.860901	1.08275	-1.72	0.9665563	1.60492	0.6
Quantitative Easing Lags												
0	0.0109028	0.01098	0.99	0.00319	0.02065	0.15	0.0113532	0.01544	0.74	0.0117597	0.02288	0.51
1	-0.0241604	0.01554	-1.55	0.0018408	0.02923	0.06	-0.0075845	0.02167	-0.35	-0.0053112	0.03213	-0.17
2	-0.0013609	0.01569	-0.09	0.002747	0.02951	0.09	-0.0028065	0.02188	-0.13	-0.0028154	0.03243	-0.09
3	0.0074892	0.01483	0.51	-0.0139221	0.02789	-0.5	**-0.1725562**	**0.02168**	**-7.96**	-0.0173127	0.03214	-0.54
4	0.005161	0.014	0.37	-0.0073437	0.02633	-0.28	**0.1582516**	**0.02236**	**7.08**	-0.0087261	0.03315	-0.26
5	-0.0115399	0.014	-0.82	0.0126178	0.02633	0.48	0.0255426	0.02225	1.15	0.0101442	0.03298	0.31
6	0.0233582	0.01399	1.67	0.0057624	0.02631	0.22	0.0192804	0.02225	0.87	0.0004616	0.03298	0.01
7	-0.0248726	0.01449	-1.72	0.0009013	0.02725	0.03	-0.0204869	0.02166	-0.95	0.0205089	0.0321	0.64
8	0.0081115	0.01717	0.47	0.0194453	0.03229	0.6	-0.0059102	0.02423	-0.24	0.0252012	0.03592	0.7
9	-0.0054495	0.01885	-0.29	-0.0028437	0.03546	-0.08	0.0350803	0.02659	1.32	-0.0119931	0.03941	-0.3
10	0.006236	0.01381	0.45	-0.0112522	0.02597	-0.43	**-0.1387683**	**0.02669**	**-5.2**	-0.0088036	0.03956	-0.22
11							**0.1121341**	**0.01945**	**5.77**	-0.0034724	0.02883	-0.12

Note: The above results are for when Federal Funds Rate and Quantitative Easing are exogenous variables together.

Table 5.

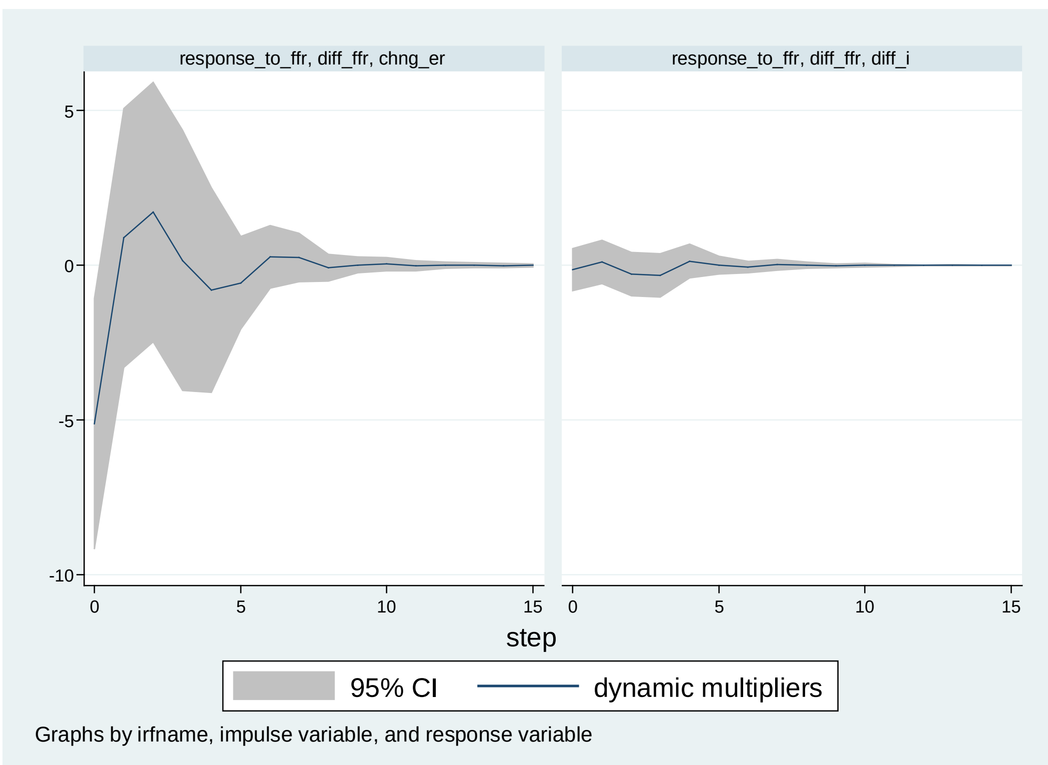
Mexico Regression Results

	Exchange Rate as Dependent			***Interest Rate as Dependent (with ER)***			***Terms of Trade as Dependent***			***Interest Rate as Dependent (with TT)***		
Federal Funds Rate Lags	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**	**Coefficient**	**St. Error**	**Z-Score**
0	**-5.142203**	**1.76954**	**-2.91**	-0.4109808	1.66814	-0.25	0.6967362	1.5658	0.44	-0.3766385	1.04459	-0.36
1	**5.876004**	**2.01949**	**2.91**	**7.202199**	**1.90376**	**3.78**	-0.1501296	1.83628	-0.08	1.171099	1.22504	0.96
2	3.089628	2.01339	1.53	-2.965425	1.89802	-1.56	0.1872487	1.84599	0.1	-0.5850164	1.23152	-0.48
3	**-6.333806**	**1.94596**	**-3.25**	**-3.607567**	**1.83445**	**-1.97**	-0.290846	1.84197	-0.16	-0.4946345	1.22883	-0.4
4	**4.996186**	**1.96741**	**2.54**	3.603564	1.85466	1.94	-1.195638	1.57762	-0.76	1.327504	1.05247	1.26
5	-0.2997762	1.9688	-0.15	-1.336197	1.85598	-0.72						
6	0.5135375	1.97224	0.26	0.5197847	1.85922	0.28						
7	1.517048	1.95301	0.78	-0.4232991	1.8411	-0.23						
8	-1.559436	1.99635	-0.78	-0.1438789	1.88195	-0.08						
9	-0.0277804	1.9603	-0.01	**-4.21055**	**1.84796**	**-2.28**						
10	-2.085624	1.76466	-1.18	**6.614836**	**1.66354**	**3.98**						
Quantitative Easing Lags												
0	0.0053288	0.01664	0.32	0.0047131	0.01569	0.3	0.0101177	0.01481	0.68	0.0036071	0.00988	0.37
1	-0.0353894	0.02205	-1.61	-0.0098386	0.02078	-0.47	0.0011571	0.02165	0.05	-0.005059	0.01444	-0.35
2	0.0107486	0.02274	0.47	0.0003096	0.02144	0.01	-0.0074813	0.02306	-0.32	-0.0019127	0.01538	-0.12
3	0.0328366	0.02375	1.38	0.0298403	0.02239	1.33	**-0.1110128**	**0.0217**	**-5.12**	0.0037951	0.01448	0.26
4	-0.0261356	0.02323	-1.12	-0.0001102	0.0219	-0.01	**0.116631**	**0.01477**	**7.9**	-0.0001683	0.00985	-0.02
5	-0.0127009	0.02335	-0.54	-0.0135281	0.02201	-0.61						
6	0.0483767	0.02335	2.07	-0.0088164	0.02202	-0.4						
7	-0.0114358	0.02402	-0.48	0.0145034	0.02264	0.64						
8	-0.0393853	0.02381	-1.65	-0.0290124	0.02245	-1.29						
9	0.0095571	0.02434	0.39	0.0039903	0.02294	0.17						
10	0.0091357	0.01838	0.5	0.0171511	0.01732	0.99						

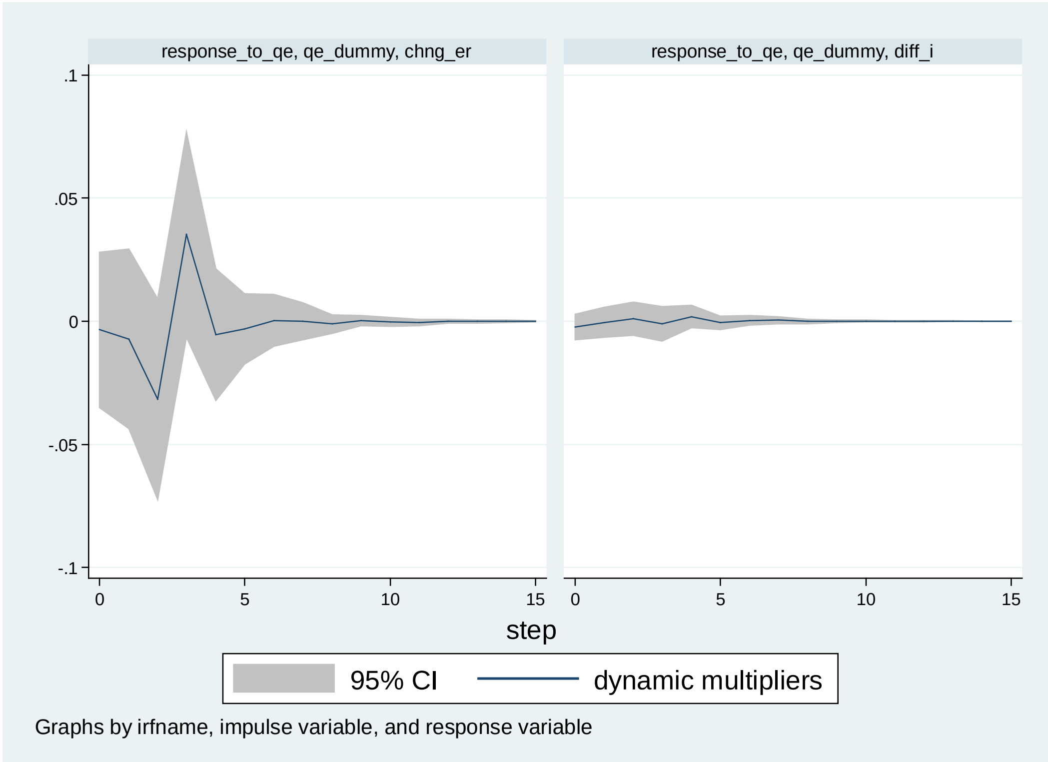
Note: The above results are for when Federal Funds Rate and Quantitative Easing are exogenous variables together.

One very interesting aspect of my results is that the signs of the coefficient estimates of both the Federal Funds Rate and quantitative easing were alternating positive and negative. This suggests some sort of multi-period adjustment process for both changes in exchange rates as well as the monetary policy response of the foreign central bank. The figures below represent the impulse response functions for Brazil, India, and Mexico when the Federal Funds Rate is shocked (top) and when quantitative easing is shocked (bottom). The graph on the left of each figure has the percentage change in exchange rate as the variable responding to the shock, whereas the graph on the right of each figure has the change in overnight interbank lending rate as the responding variable.[7]

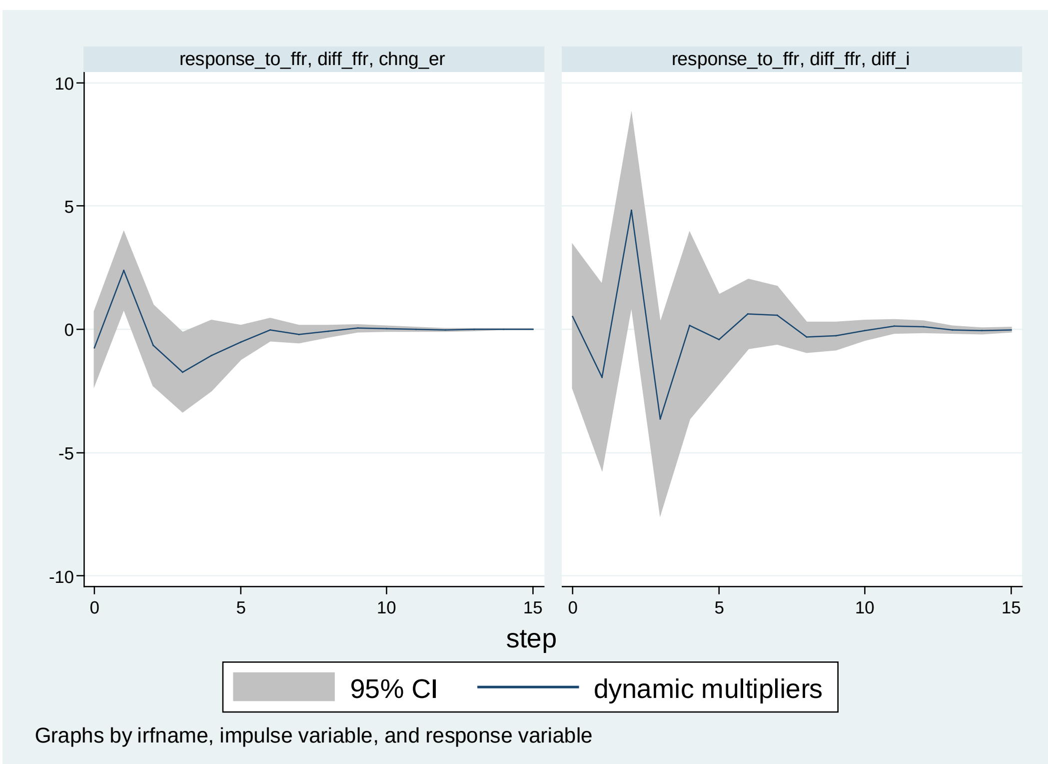
Brazil:



[7] These impulse response functions were created by limiting the lag lengths of all variables (exchange rate, overnight interbank lending rate, Federal Funds Rate, and quantitative easing) to only 4 time periods. This adjustment is appropriate given the insignificance of several middle range coefficients which increased the volatility in the impulse response functions. Reducing the model to containing only 4 lags keeps down the amount of 'false' volatility that is inherent in statistically insignificant coefficient estimates.


response_to_qe, qe_dummy, chng_er
response_to_qe, qe_dummy, diff_i
.1
.05
0
-.05
-.1
0
5
10
15
step
95% CI
dynamic multipliers
Graphs by irfname, impulse variable, and response variable

India:


response_to_ffr, diff_ffr, chng_er
response_to_ffr, diff_ffr, diff_i
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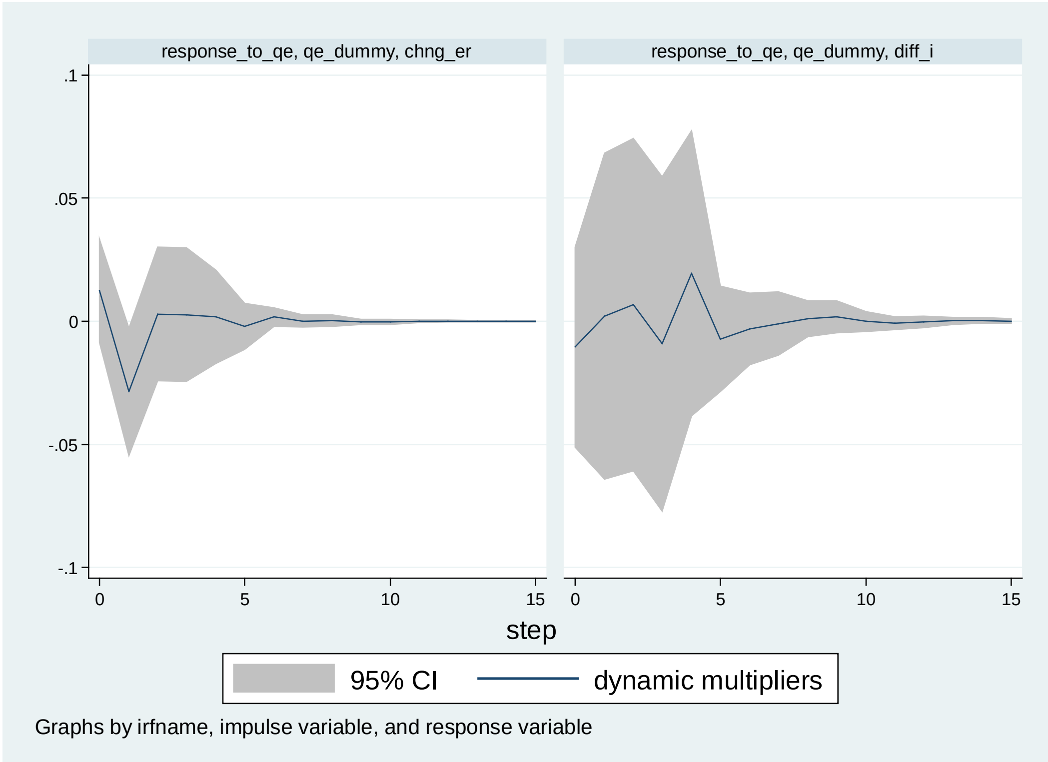
step
95% CI
dynamic multipliers
Graphs by irfname, impulse variable, and response variable


response_to_qe, qe_dummy, chng_er
response_to_qe, qe_dummy, diff_i
.1
.05
0
-.05
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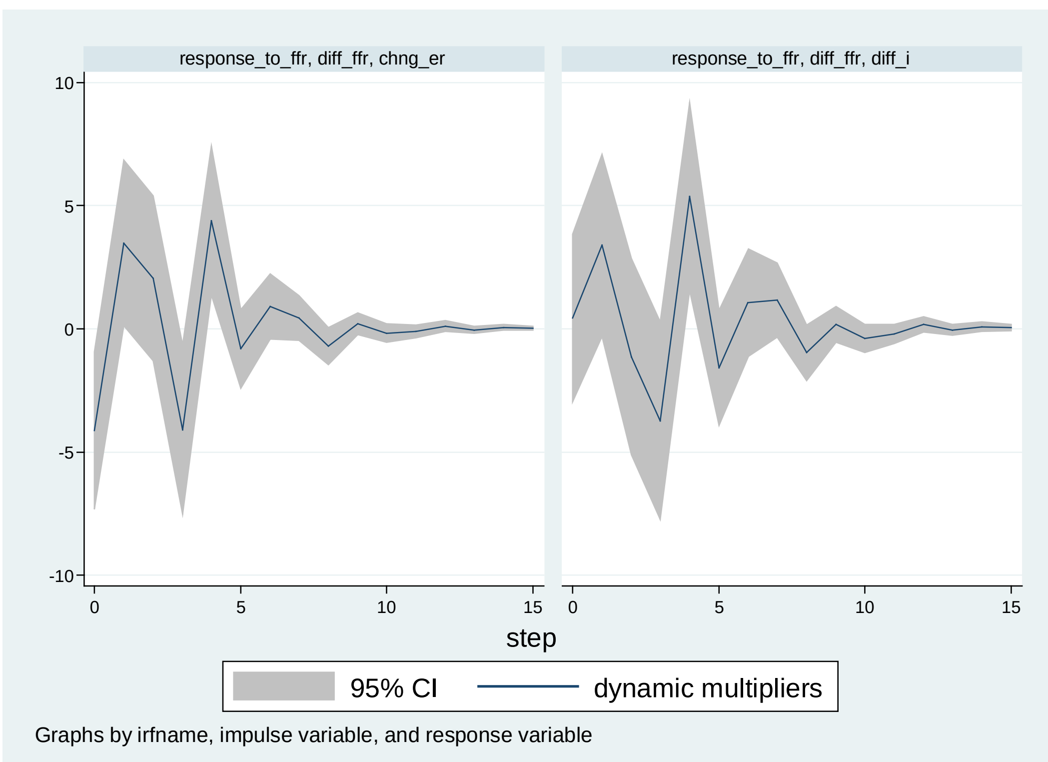
10
15
step
95% CI
dynamic multipliers
Graphs by irfname, impulse variable, and response variable

Mexico:


response_to_ffr, diff_ffr, chng_er
response_to_ffr, diff_ffr, diff_i
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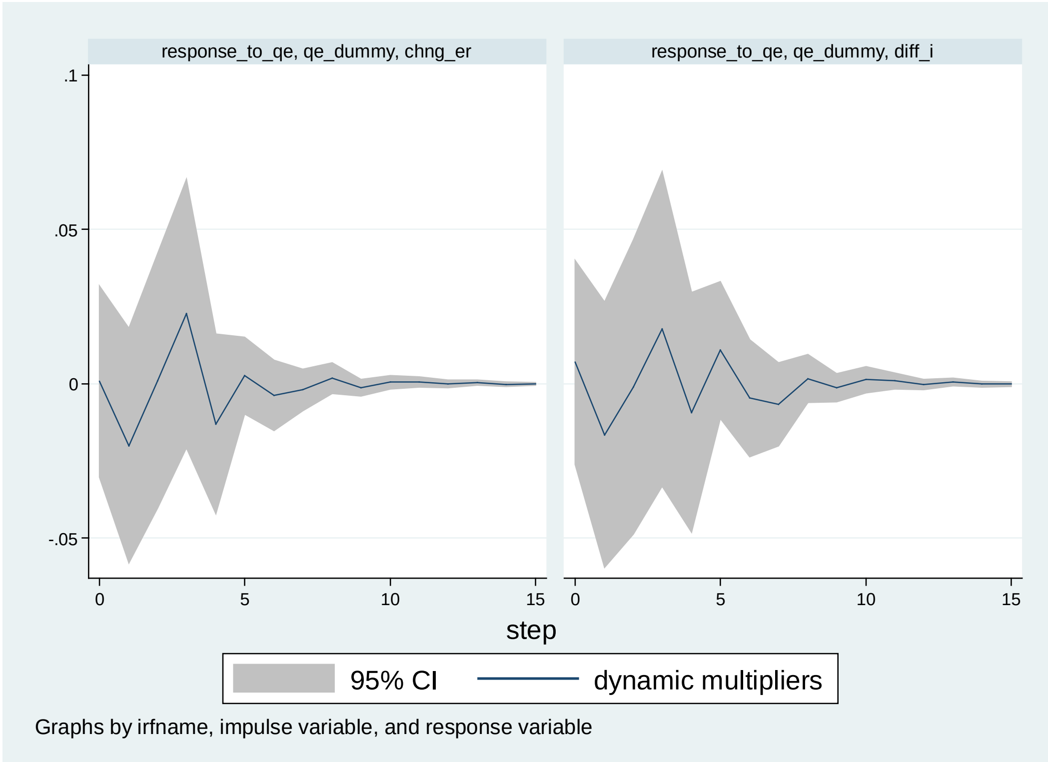
95% CI
dynamic multipliers
Graphs by irfname, impulse variable, and response variable



The above figures show that the magnitude of the reactions is greater with a Federal Funds Rate shock than with a quantitative easing shock. There also seems to be a cyclical adjustment process, with alternating positive and negative responses, followed by stabilization around the steady state about 10 time periods later. In the case of Brazil, the change in the exchange rate reacts significantly more than does the change in interest rate; however, in both India and Mexico, the opposite is true, with the larger responses coming from the domestic monetary policy adjustment. Overall, Mexico was the country with the largest responses in terms of magnitude, and it was also the country that took the longest to revert to its steady state values.

The figures for Brazil indicate that the exchange rate falls in the time period of the shock for both Federal Funds Rate and quantitative easing shocks. On the other hand, the monetary policy response is positive in response to both shocks in the first time period. Following the initial time period of the shock (for both cases of the Federal Funds Rate and quantitative easing), the rate of change in the exchange rate fluctuates around zero percent growth until about seven time periods following the shock, when the rate of change in the exchange rate stabilizes at about zero percent. The foreign central bank also responds with slight fluctuations in the rate at which it lends for approximately five time periods around an overall change in the interest rate of zero percent.

India’s impulse response functions suggest less variation than Brazil in the rate of change in the exchange rate, with an initial increase followed by a decrease that then stabilizes around zero percent change in response to the Federal Funds Rate shock (or an initial decrease followed by an increase that then stabilizes in response to the quantitative easing shock). There is more variation in the monetary policy response, with an alternating pattern of increases and decreases for closer to ten time periods following the Federal Funds Rate shock and five periods following the quantitative easing shock.

Lastly, Mexico had longer variation in both the exchange rate and monetary policy responses to both the Federal Funds Rate and quantitative easing shocks. Neither the rate of change in the exchange rate nor changes in monetary policy stabilized until around twelve time periods following the Federal Funds Rate shock, or about eight periods following the quantitative easing shock.

A common theme across all impulse responses for all countries is that both the Federal Funds Rate shocks and the quantitative easing shocks are transitory in nature and do not result in a new long-run steady state. The responses indicate that values revert back to their stable conditions after approximately 5-10 time periods. Thus, the effects of the shocks will die out over time, apparently due either to the intrinsic nature of the shocks or due to foreign central bank intervention.

7 Discussion

The vector auto-regression results indicate that few emerging economies had many statistically significant spillover effects from quantitative easing. There are two possible reasons for this: either I have a small sample problem, with fewer than 30 quantitative easing observations; or there are no significant spillover effects from quantitative easing.

Understanding both the results of the vector auto-regressions, as well as the implications of the results, provides an interesting task. It is consistent with the theory that the exchange rate, rather than terms of trade, provides the primary channel of transmission of spillover effects from U.S. monetary policy. According to that theory, monetary policy affects short-term interest rates, which in turn affect changes in the exchange rate. Thus, it is not surprising that the exchange rate model has much more significance than does the terms of trade model.[8] Only three countries, Bolivia, Chile, and the Philippines, had no significant coefficients in the exchange rate model. It is thus not surprising that those three countries exhibited the lowest spillovers and responses to changes in U.S. monetary policy.

As discussed in the theory section, there are several important differences across countries that may help explain the results, including bilateral trade integration, business cycle synchronization, the gravity model, and exchange rate regime classification.

[8] The lack of significance in the terms of trade model also refutes the claim held by many foreign central bankers that the U.S. employed quantitative easing as a backhanded trade policy designed to depreciate the U.S. dollar. If this fear was empirically verified by the data, then I would see the trade channel as a significant transmission device for spillover effects from quantitative easing shocks.

I ran separate regressions corresponding to the bilateral trade integration, business cycle synchronization, and gravity model theories.[9] Where relevant, I included the exchange rate regime dummy variable in each of the other regressions corresponding to the three theories. This was only applicable in the case of India, which experienced a managed floating exchange rate regime for some of the time period considered.

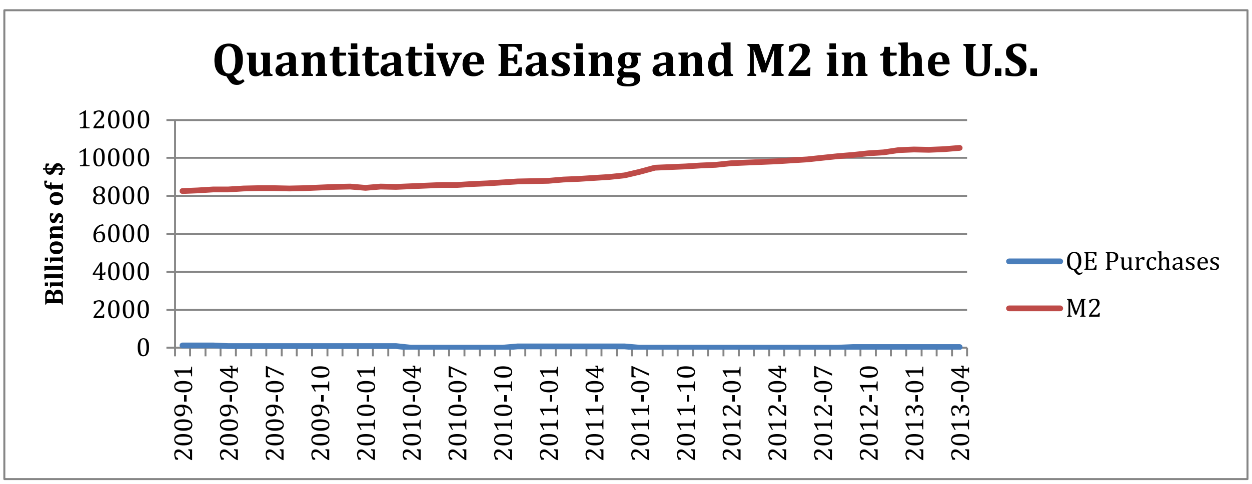
In the simplest of theories, Federal Funds Rate should have a positive coefficient. This would indicate that an increase in the Federal Funds Rate, corresponding to a U.S. monetary contraction, would lead to an appreciation in the dollar relative to foreign currency, and thus increase the exchange rate between Brazil and the U.S. However, the coefficient on the Federal Funds Rate is repeatedly negative, but only significant in the case of Brazil. This could be due to an argument posed in a Chicago Federal Reserve Bank letter, which was written to address concerns in the 1980s and 1990s regarding dollar depreciation following an increase in the Federal Funds Rate. The key principle lies in the distinction between anticipated and unanticipated monetary shocks. In general, unanticipated monetary policy shocks will yield the expected change in the value of the dollar – expansionary shocks lead to depreciation, contractionary shocks lead to appreciation. However, the anticipated monetary policy shocks cloud these results, and can lead to results that are contrary to simple theory, as I've found in my

[9] Data for these regressions included exchange rate, Federal Funds Rate, quantitative easing, foreign direct investment inflows and outflows, bilateral exports and imports, and GDP growth rates. All variables were monthly in frequency and covered the period 1990-2012. Exchange rate was included as percentage change, Federal Funds Rate as a period-to-period difference, quantitative easing as a dummy (which took a value of one if purchases were made in that month), bilateral imports and exports as percentage of total imports and exports, and FDI inflows and outflows as a percentage of GDP. Synchronization was measured as the standard deviation of the absolute value of the difference in GDP growth rates between the U.S. and each of Brazil, India, and Mexico. Exchange rate regimes were included as a dummy variable. The only instance of a regime that was not independent float was a managed floating regime in India. Thus, a managed float dummy is included in the regressions for India.

Exchange rates, Federal Funds Rate, and data on quantitative easing were all collected from the Federal Reserve Board. Foreign direct investment inflows and outflows were collected from the United Nations Conference on Trade and Development. Bilateral imports and exports were collected from the International Monetary Fund Direction of Trade Statistics. GDP growth rates were collected from the World Bank Databank. Lastly, exchange rate regimes were collected from The Chinese University of Hong Kong's database on historical exchange rate regimes.

regressions.[10] For example, when bond prices today are based on expected changes in future monetary policy, and an expansionary monetary policy change is announced, but less expansionary than expected, then the dollar may appreciate because the nominally expansionary policy is contractionary relative to market expectations.

Alternatively, an increase in quantitative easing purchases, corresponding to a U.S. monetary expansion, should lead to a depreciation of the dollar relative to foreign currency, leading to a decrease in the exchange rate. Therefore, quantitative easing should have a negative coefficient. The results indicate that the coefficient on quantitative easing is consistently negative, although pretty insignificant. This could be because quantitative easing increases the money supply in the U.S., but by such a small amount. As such, quantitative easing may not have any effect on the value of the dollar because it is in such small proportion to the other purchases that make up money supply. For example, in April 2013, quantitative easing purchases were $40 billion whereas M2 was $10525 billion. Thus, quantitative easing made up a mere .038% of total M2. The graphic below plots quantitative easing purchases and money supply (measured as M2) in the U.S. over the period 2009-2013. All data come from the Federal Reserve Board.



[10] http://qa.chicagofed.org/digital_assets/publications/chicago_fed_letter/1994/cflaugust1994_84.pdf

In the results tables, Model 1 refers to the gravity model, with the inclusion of foreign direct investment inflows and outflows; Model 2 to bilateral trade integration, with bilateral imports and exports; and Model 3 to business cycle synchronization, with the standard deviation measure. Results for Brazil, India, and Mexico are displayed below.

Brazil

VARIABLES	(1) Exchange Rate	(2) Exchange Rate	(3) Exchange Rate
Federal Funds Rate	-4.946***	-5.056***	-5.285***
	(1.568)	(1.492)	(1.618)
Quantitative Easing	-0.00178	-0.0177**	-0.0127
	(0.00941)	(0.00888)	(0.00858)
FDI Inflows	0.00757**		
	(0.00323)		
FDI Outflows	0.00634		
	(0.00418)		
Bilateral Exports		-0.264***	
		(0.0804)	
Bilateral Imports		0.344***	
		(0.117)	
Synchronization			0.000652
			(0.00519)
Constant	-0.0259**	-0.0168	-0.000367
	(0.0110)	(0.0172)	(0.00551)
Observations	149	159	149
R-squared	0.123	0.143	0.085

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

The above results indicate that the Federal Funds Rate is highly significant across all models, and quantitative easing is only significant in the bilateral trade model, in the determination of exchange rates in Brazil.

In Model 1, foreign direct investment inflows are positive and significant, indicating that an increase in foreign direct investment inflows leads to a depreciation of the Brazilian Real, and thus an increase in the exchange rate between Brazil and the U.S.

Additionally, in Model 2 both exports and imports are significant. The negative coefficient on exports indicates that as the percentage of exports to the U.S. increases, the Brazilian Real appreciates relative to the dollar, resulting in a decrease in the exchange rate. Conversely, the positive coefficient on imports implies that as the percentage of imports from the U.S. increases, the Brazilian Real depreciates relative to the dollar, resulting in an increase in the exchange rate.

India

VARIABLES	(1) Exchange Rate	(2) Exchange Rate	(3) Exchange Rate
Federal Funds Rate	-0.203	-0.989	-0.656
	(0.690)	(0.642)	(0.655)
Quantitative Easing	-0.00867*	-0.00169	-0.00894*
	(0.00463)	(0.00498)	(0.00495)
Managed Float Regime	0.0179***	0.0117***	0.0133***
	(0.00439)	(0.00396)	(0.00370)
FDI Inflows	0.0144***		
	(0.00452)		
FDI Outflows	-0.0209***		
	(0.00619)		
Bilateral Exports		0.0415	
		(0.0379)	
Bilateral Imports		0.0133	
		(0.0704)	
Synchronization			0.00259
			(0.00177)
Constant	-0.00412	-0.00626	-0.000419
	(0.00291)	(0.00829)	(0.00228)
Observations	258	258	258
R-squared	0.108	0.073	0.076

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

India represents the only country that was not characterized solely by an independently floating regime for the duration of the time period. The managed floating regime was highly significant, indicating that where it differs from independent floating, exchange rate regime is very important.

In Model 1, the coefficients on both foreign direct investment inflows and outflows are highly significant. The positive coefficient on inflows follows the pattern detailed in the Brazil results. The negative coefficient on outflows indicates that an increase in outflows leads to an appreciation of the Indian Rupee, and thus a decrease in the exchange rate.

Mexico

VARIABLES	(1) Exchange Rate	(2) Exchange Rate	(3) Exchange Rate
Federal Funds Rate	-0.794	-0.799	-0.728
	(1.438)	(1.351)	(1.338)
Quantitative Easing	-0.00400	-0.00505	-0.00663
	(0.00991)	(0.00856)	(0.00807)
FDI Inflows	-0.00307		
	(0.00488)		
FDI Outflows	-0.0202**		
	(0.00777)		
Bilateral Exports		0.0127	
		(0.0567)	
Bilateral Imports		0.0333	
		(0.0260)	
Synchronization			0.00655***
			(0.00222)
Constant	0.0241*	-0.0257	0.00226
	(0.0142)	(0.0432)	(0.00330)
Observations	218	228	218
R-squared	0.041	0.020	0.047

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Model 1, only foreign direct investment outflows are significant and negative, which is aligned with the pattern outlined in the case of India.

In Model 3, business cycle synchronization is highly significant and positive, indicating that as the measure of synchronization increases – corresponding to less synchronization between the U.S. and Mexico – the exchange rate increases. This means that as the U.S. and Mexico become less synchronized, the exchange rate moves in favor of the U.S., with the Mexican Peso appreciating relative to the dollar.

The results of the ordinary least squares regressions indicate that different theories work better for different countries. Brazil is best explained by bilateral trade integration, India by both exchange rate regime and foreign direct investment in the form of the gravity model, and Mexico by business cycle synchronization.

The U.S. currently ranks as Brazil's second largest trading partner, and thus it is plausible that bilateral trade integration is the dominant explanatory theory in the case of spillovers in Brazil.[11] Interestingly, the U.S. ranks as Mexico's largest trading partner, yet bilateral trade integration is remarkably insignificant in the case of Mexico.[12]

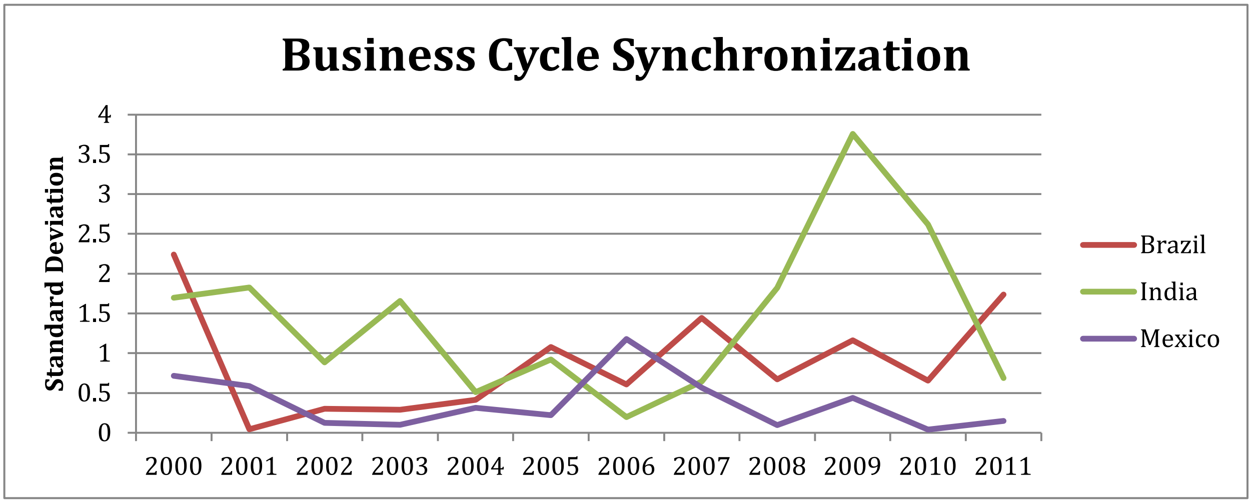
It is not at all surprising that exchange rate regime possesses significant explanatory power in regards to exchange rate fluctuations. Even though the distinction between independent float and managed float is not extreme, managed float is highly significant in the case of India.

It is not surprising that the foreign direct investment and the gravity model theories are so significant for India. India has low percentages of both inflows and outflows relative to Brazil and Mexico, yet the theory is more significant for India than for either of the other two countries. The table below calculates the average foreign direct investment inflows and outflows (as a percentage of GDP) for each of Brazil, India, and Mexico over the entire time period.

	Brazil	India	Mexico
FDI Inflows	2.77184205%	1.01438573%	2.69912652%
FDI Outflows	0.53053706%	0.41132274%	0.43039226%

[11] Prior to 2009, the U.S. was Brazil's largest trading partner. Between 2001 and 2012, China's trade relations with Brazil increased twelve fold. This is in accordance with the Banco Central do Brazil's Brazilian trade by area statistic (http://www.bcb.gov.br/?INDICATORS).
[12] http://mexico.usembassy.gov/eng/eataglance_trade.html

Business cycle synchronization is pretty accurate as a theory. Mexico is the most synchronized with the U.S., in that it has the lowest standard deviation of the difference in GDP growth rates. Thus, it makes sense that synchronization is so significant in the case of Mexico. The graphic below plots the standard deviation values for Brazil, India, and Mexico over the period 2000-2011.



In conclusion, the results of the regressions indicate that there isn't one dominant theory that can be applied across countries. However, there does appear to be one dominant theory per country. Thus, if foreign central bankers can learn which theory is dominant in their country, they can be better prepared to combat the spillover effects of U.S. monetary policy shocks.

There are some limitations with this study that should be addressed. Primarily, ordinary least squares may not be the best methodology for understanding the dynamic relationships between these theories and spillovers. I did not employ a methodology that allowed for lagged values of variables. Many time series macro-economic models indicate that the best predictor of a value in the current time period is the value in the previous time period.

Additionally, due to data availability, I used foreign direct investment as a proxy for global financial integration, which the literature suggests is an important factor in determining the strength of spillover effects. However, foreign direct investment is not a complete measure of global integration, as it does not include government asset and liability holdings or stock market equity and debt holdings.

Implications

Ultimately, I hope to gain an understanding of how spillover effects manifest themselves in terms of domestic effects within the responding country (i.e. the Latin American and South Asian countries). Investigating the real effects of monetary policy spillovers is a two-step process. Monetary policy spillovers originating from monetary policy shocks in the U.S. lead to exchange rate fluctuations, which in turn lead to changes in output and inflation in other countries. There are two primary theories that predict what the effects on output and inflation should be.

First, the demand-side theory posits that as the currency depreciates, the price of domestic goods falls, leading to increased international demand for domestic goods. This forces the domestic firms to export more, which leads to increased output. If output increases, so should inflation. Next, the supply-side theory predicts that as the currency depreciates, the input costs of domestic firms increases, leading those firms to reduce imports of those intermediate goods for production. This would lead to a fall in output, and a corresponding decrease in inflation.

With the exchange rate variable defined as foreign currency per U.S. dollar, a depreciation of the foreign currency would lead to an increase in the exchange rate. If the demand-side theory dominates, I expect to see positive coefficients for the exchange rate variable in both the output model and the inflation model. Conversely, if the supply-side theory dominates, I expect to see negative coefficients on exchange rates for both models.

The literature established that there are certain explanatory variables that are consistently used to estimate the real effects of exchange rate fluctuations.[13] Such variables include government spending, money supply, and energy price.

Government spending presents an interesting case, in that there are two opposing theories regarding what sign the variable should take. On the one hand, the crowding out hypothesis forecasts that as government spending increases, it will drive down or replace private sector spending and investment. This would lead to a fall in output – leading to a decrease in inflation – and a corresponding negative coefficient on government spending in both models. On the other hand, the crowding in hypothesis posits that as government spending increases, the increased demand facilitated by the government leads to increased private demand for new output sources (i.e. factories), which in turn increases spending by the private sector. This would result in increases in output and inflation, which would be reflected by positive coefficients on government spending in both models.

Money supply is very straightforward, in that as money supply increases, output and inflation should both increase. This would produce a positive coefficient on money supply in both models. Lastly, as energy price increases, it seems plausible that output would decrease – due to an increase in the cost of production – and thus inflation would fall as well. This would yield a negative coefficient on energy price in both models.

I ran regressions corresponding to separate models for output and prices.[14] The results for Brazil, India, and Mexico are below.

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[13] I considered four key studies in shaping my analysis of the real effects of monetary policy spillovers: Kandil and Mirzaie (2005), Kandil (2008), Kamin and Rogers (2000), and Kandil and Mirzaie (2003). Each of these studies looked at the effects of exchange rate fluctuations on output and prices. Many studies considered both developed and developing countries and distinguished between the demand-side and supply-side theories. No study came to a conclusion regarding which theory was overall dominant, although Kandil found evidence that the demand-side theory is dominant in developed countries whereas the supply-side theory is dominant in developing countries.

Brazil

VARIABLES	(1) Output	(2) Prices
Exchange Rate	0.000452	0.0635**
	(0.0359)	(0.0273)
Government Spending	0.329***	0.212**
	(0.0919)	(0.0699)
Money Supply	0.348**	0.340***
	(0.143)	(0.109)
Energy Price	0.0568*	0.00883
	(0.0279)	(0.0212)
Constant	0.716	-0.731
	(2.349)	(1.785)
Observations	16	16
R-squared	0.746	0.698

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Exchange rate is positive in both models, but only significant in the inflation model. This suggests that the demand side hypothesis dominates in Brazil. These results indicate that government spending is positive and significant. This shows that the crowding in hypothesis for both output and inflation dominates in Brazil. Additionally, money supply is positive and significant, which is aligned with the theory outlined in the theoretical framework section. However, askew from theory, energy price is positive, although not significant.

[14] I collected data on output, prices, exchange rates, government spending, money supply, and energy price. All variables were annual in frequency and covered the period 1980-2012. Output was measured as GDP, prices as the GDP deflator as an index, exchange rates as foreign currency per U.S. dollar, government spending in domestic currency, money supply in domestic currency, and energy price was an average of three spot prices: Dated Brent, West Texas Intermediate, and Dubai Fateh and was measured in U.S. dollars per barrel. Exchange rates were collected from the International Monetary Fund International Financial Statistics database. All other variables were collected from the International Monetary Fund World Economic Outlook.

India

VARIABLES	(1) Output	(2) Prices
Exchange Rate	-0.139***	0.144*
	(0.0418)	(0.0732)
Government Spending	-0.00825	0.115
	(0.0428)	(0.0749)
Money Supply	0.303***	0.246*
	(0.0778)	(0.136)
Energy Price	0.0261*	0.00718
	(0.0148)	(0.0259)
Constant	1.920	0.154
	(1.269)	(2.220)
Observations	24	24
R-squared	0.703	0.439

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Interestingly, in the case of India, exchange rate is negative for output and positive for inflation, although only significant for output. This indicates that the supply-side hypothesis dominates for output in India. Additionally, money supply is again positive, although only significant in the output model. The positive coefficient is what theory predicts. Energy price is also positive, but insignificant. Lastly, government spending is negative in output and positive in inflation, however both are insignificant.

Mexico

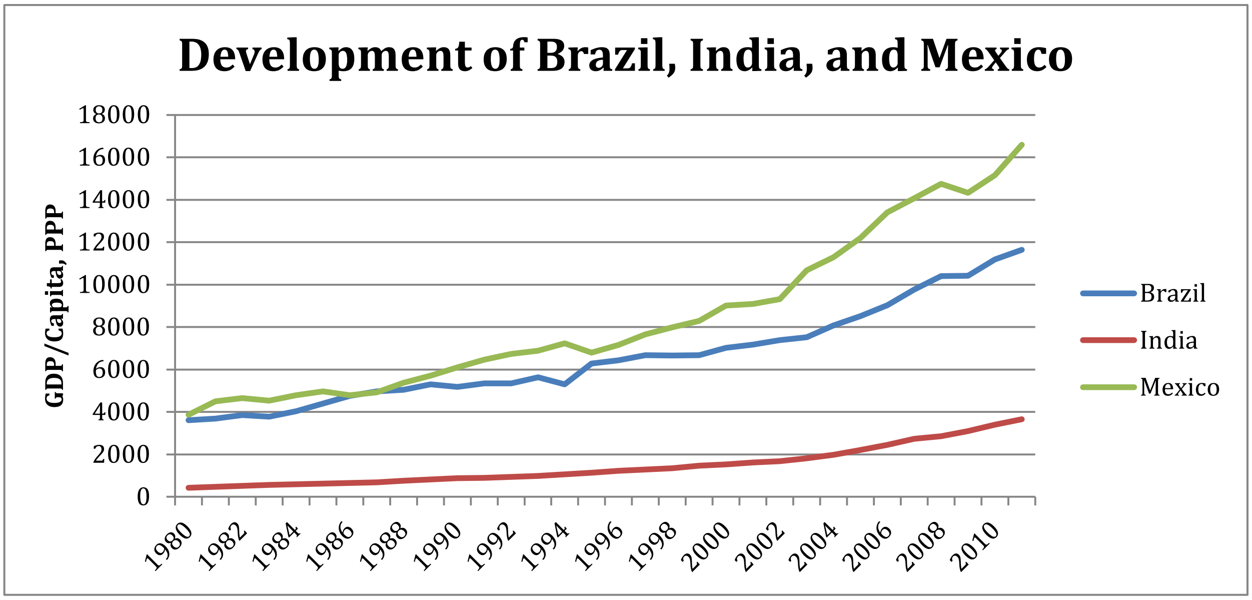
VARIABLES	(1) Output	(2) Prices
Exchange Rate	-0.151***	0.0750
	(0.0386)	(0.0853)
Government Spending	0.0776	0.327*
	(0.0706)	(0.156)
Money Supply	0.0802	0.240**
	(0.0498)	(0.110)
Energy Price	0.0360	0.00213
	(0.0282)	(0.0624)
Constant	1.048	1.898
	(0.920)	(2.033)
Observations	22	22
R-squared	0.649	0.726

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Exchange rate is negative and significant in the output model, and positive and insignificant in the inflation model, indicating that the supply-side hypothesis dominates for output in Mexico. Money supply is positive in both models, however only significant in the inflation model. Lastly, government spending and energy price are both positive in both models, although none of the coefficients are significant.

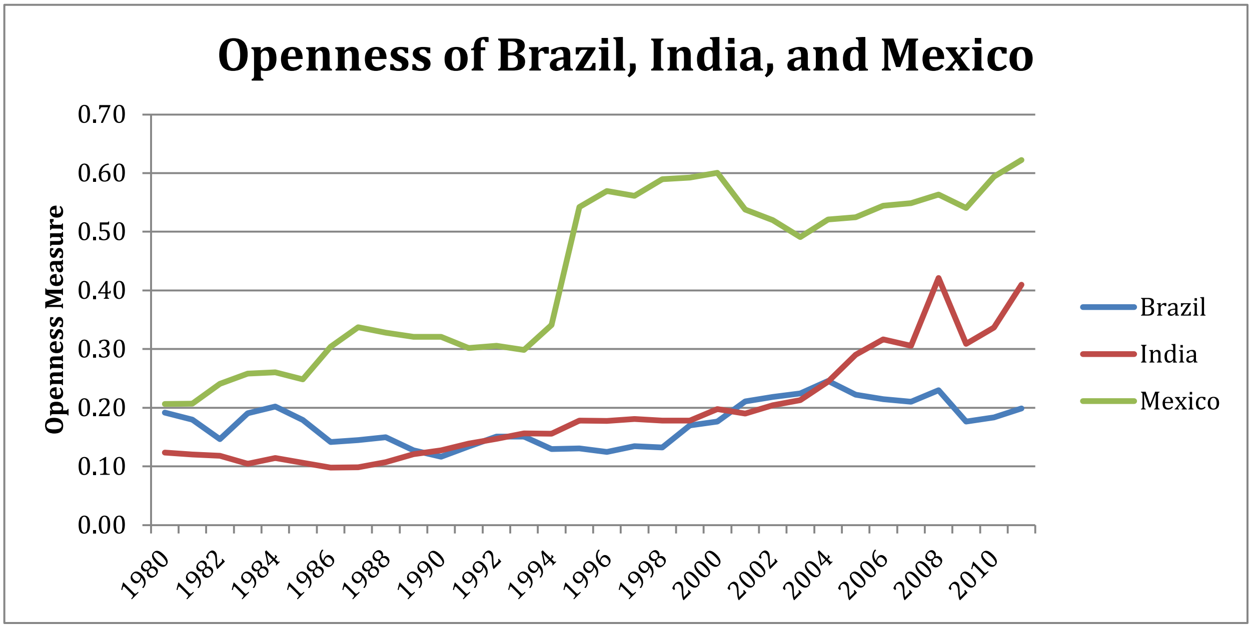
These results are mixed results regarding whether demand-side theory or supply-side theory is dominant. First off, in each country, exchange rate is only significant in one model but not the other. In Brazil, exchange rate is significant in the inflation model, whereas in both India and Mexico, exchange rate is significant in the output model. Additionally, the dominant theory in Brazil was the demand-side theory, whereas the dominant theory in both India and Mexico was the supply-side theory. Kandil (2008) suggested that the demand-side theory dominates in developed countries, whereas the supply-side theory dominates in developing countries. The graphic below charts the GDP per capita at purchasing power parity for Brazil, India, and

Mexico over the time period 1980-2011. All data is from the World Bank Data Bank. I use GDP per capita as a proxy for economic development.



This figure indicates that Mexico has consistently been above both Brazil and India in terms of GDP per capita. Thus, there are some lingering questions regarding why the inflation model was dominated by the demand-side hypothesis in Brazil. It is worth noting that GDP per capita is not a perfect measure of economic development, and that there may well be other development measures that would place Brazil ahead of India and Mexico.

The coefficients on exchange rates in both models are significantly higher for Mexico (in absolute value terms) than for India, which in turn are higher than Brazil. This follows from the logic that the more open an economy is, the more susceptible it will be to real effects from spillovers. I define openness as total trade as a percentage of GDP. The figure below plots openness for Brazil, India, and Mexico over the period 1980-2011. Data is from the International Monetary Fund International Financial Statistics data set.



This figure indicates that Mexico is vastly more open than both Brazil and India. Thus, it is fairly intuitive why Mexico's exchange rate fluctuations – as a result of monetary spillovers from the U.S. – cause a larger magnitude of output and price fluctuations. Brazil and India were fairly equal in terms of openness until approximately 2004, when India became much more open than Brazil. It follows the same logic that India has a larger magnitude of output and price fluctuations as a result of exchange rate shocks.

There are some limitations with the implementation of this study. First, due to data availability, the duration of the study is quite short. No country had more than 30 annual observations, and it is hard to draw significant conclusions from that few observations. Moving forward, I would like to add more countries and create a cross-sectional time-series model that can be used with fixed effects. This methodology would also allow me to investigate what factors lead to greater magnitudes of real effects (such as development and openness) across countries.

In addition, similarly to the explanatory theories model, the methodology did not allow for lagged values of the time-series variables. Thus, it may not be the best model to estimate the real effects, in terms of output and inflation, from exchange rate fluctuations emerging from monetary policy spillovers.

8 Conclusion

This study used vector auto-regressions to examine the responsiveness of eleven emerging economies in Latin America and South Asia over the period 1990-2012 to changes in U.S. monetary policy, measured as both the Federal Funds Rate and quantitative easing. I find that there is variation across the eleven countries regarding the responsiveness of foreign central banks to shocks of the Federal Funds Rate and quantitative easing. In particular, Brazil, India, and Mexico responded the most to changes in U.S. monetary policy, while Bolivia, Chile, and the Philippines responded the least to the same exogenous shocks.

Investigating the impulse response functions of Brazil, India, and Mexico yields the conclusion that there is a cyclical adjustment process to changes in U.S. monetary policy, with alternating positive and negative responses, settling at the steady state approximately ten time periods later. This seems to suggest some sort of overshooting in how foreign central banks respond to changes in U.S. monetary policy. The foreign central banks may want to consider more passive responses to changes in U.S. monetary policy, in an effort to reduce the friction of the adjustment process.

In applying different theories regarding bilateral relationships between the U.S. and each of the emerging economies, I offer possible but incomplete explanations for cross-country differences in spillovers and monetary policy responses to changes in U.S. monetary policies. No explanation was able to explain all results, although most were able to improve my understanding in many cases. Thus, I believe that these explanations, taken collectively, offer a better understanding than the vector auto-regression alone, of why there are differing degrees of responsiveness amongst my collection of Latin American and South Asian emerging economies.

The evidence is mixed regarding whether the demand-side or supply-side theories provide better explanations of the effects on output and inflation in the foreign countries from spillovers due to changes in U.S. monetary policy.

As touched upon in the previous section, there are significant limitations in this study. Even with these limitations, however, this study contributed to the preexisting literature on spillover effects of and foreign central bank responses to U.S. monetary policy shocks. The addition of quantitative easing as a separate monetary policy measure allowed me to see how the foreign central bank response differs according to the type of U.S. monetary policy chosen. This study also reinforced previous work in the area, primarily with the result that the currency channel is the primary driver of spillover effects, and that the trade channel is relatively insignificant.

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