Job Market Paper

Empirical Evidence on International Monetary Spillovers

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This paper estimates the effects of U.S. monetary policy shocks in a selection of other economies in the Americas. Across a range of measures of U.S. policy shocks, U.S. monetary contractions are followed by reductions in economic activity in Chile, Colombia, Mexico and Canada. For each measure of U.S. shocks, the size and timing of the response of foreign output is similar to the size and timing of the response of U.S. output to U.S. monetary shocks. Expenditure-switching channels appear unlikely candidates for explaining the transmission of U.S. shocks to foreign output. Instead, transmission appears to work through financial channels: foreign central banks raise interest rates and contract money supplies in response to a U.S. monetary contraction, and there is some evidence for large movements in prices of commodities such as coffee, copper, lumber, and oil.

Key Words: monetary policy shocks, international monetary spillovers

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1. INTRODUCTION

This paper studies how economic developments in the United States affect economic outcomes in other countries. The relevance of this research increases with the ever-growing exposure of different countries to each other's economies through trade and capital flows. My research addresses the issues of why economic activity is volatile and why activity is positively correlated across countries. I approach these issues focusing on the potential role of U.S. monetary policy as a driving force.

It has long been held that "when America sneezes, the rest of the world catches a cold."[1] Central banks around the world often refer to the effect that economic activity in the United States has on their own economies.[2] They often emphasize the role of the United States as a market for the home country's exports. A contraction in the United States normally leads to a reduction in foreign countries' exports.

Developments in U.S. monetary policy could affect outcomes in other countries via exchange rates. With floating exchange rates, a monetary contraction in the United States might appreciate the U.S. dollar and stimulate other countries' export sectors. Alternatively, when capital is mobile, a fixed exchange rate means that movements in interest rates in the anchor country must be followed by similar movements in the country that is fixing its exchange rate. More generally, to the extent that a central bank values a stable exchange rate, it will tend to mimic interest rate movements abroad even if the exchange rate is not explicitly fixed.

While there are many conceivable sources of shocks originating in the United States that might affect other countries, I focus on one main shock. I study the effect of shocks to U.S. monetary policy on real economic activity in Canada, Chile, Colombia, and Mexico from 1966 to 1996. These countries are interesting to study for a variety of reasons. First, the Latin American debt crisis in the 1980s is often attributed to high interest rates in the United States. Second, these are the countries in the Americas that have the longest, most reliable series of monthly output data. Third, the extent to which they are linked with the United States through trade varies greatly: over 70% of Mexican and Canadian exports were destined for the United States between

[1] Nearly fifty years ago, Salant (1959) referred to this phrase as a "hackneyed formula" (p. 322).

[2] For example, the Bank of Canada (2007) argues that "the slowing U.S. economy has had a moderating effect on economic growth in Canada" (p. 5). The Bank of England (2007) noted that "the news of the world economy in the month pointed to continued growth in the United Kingdom's major overseas markets" (p. 3). The Reserve Bank of Australia (2007) notes that "Growth of the Australian economy has for some time been assisted by favourable international conditions. ... [S]lower growth in the United States [is] expected to be more than offset by stronger growth in China and other major economies" (p. 1).

1966 and 1996; around 40% of Colombian exports and less than 20% of Chilean exports went to the United States. Fourth, they represent a variety of monetary regimes: Canada is famous for its floating exchange rate, Colombia had a managed currency for most of the period, while Chile imposed significant capital controls. The facts that the period of analysis is from 1966 to 1996 and the countries I study are all in the Americas mean the results may not apply to other places and other times. In spite of this, quantifying the role of U.S. monetary policy shocks in generating economic volatility and comovement in these countries during this period remains an interesting task.

There is a large empirical literature studying the domestic effects of U.S. monetary policy shocks, surveyed by Christiano, Eichenbaum and Evans (1999). This literature attempts to find some measure of monetary policy shocks to overcome the omitted variables bias that inevitably arises when the federal funds rate (or some quantitative measure, such as non-borrowed reserves or the money stock) is used as the measure of monetary policy. The measure of shocks must exclude the variation in the policy instrument that is due to the central bank's systematic response to, or anticipation of, economic activity. If it does not, the reverse causation is likely to induce significant biases.

Similar issues arise in estimating the impact of U.S. monetary policy on output in foreign countries. While the Federal Reserve may not respond directly to the Mexican economy, common shocks may affect both Mexican and U.S. output. If the Federal Reserve responds to these shocks, then the change in the federal funds rate, for example, is not an exogenous measure of policy even for estimating the effect of U.S. monetary policy shocks on Mexican output.

The response of central banks in the aftermath of the September 11, 2001, attacks on the World Trade Center clearly illustrates this point. On September 17, the Federal Reserve reduced the target for the federal funds rate by 50 basis points, citing the potential for the terrorist attacks to have "adverse effects on asset prices and the performance of the economy" (Board of Governors of the Federal Reserve System, 2001). Around the same time, the central banks of Canada, England, Australia, and other countries cited a prospective weakening of economic activity as they lowered their own official interest rates.[3] When regressing Canadian output growth on the change in the federal funds rate, events such as those in September 2001 could lead to the mistaken conclusion that a fall in interest rates in the United States causes output to be low in Canada. Estimates of the effect of changes in the federal funds rate on Canadian output would contain a positive bias.

[3]See Bank of Canada (2001), Bank of England (2001), and Reserve Bank of Australia (2001).

Whether estimating the effect of U.S. monetary policy shocks on U.S. output or foreign output, changes in the federal funds rate motivated by common shocks must be excluded.

Common shocks are not the only possible cause of endogeneity when estimating the effect of U.S. monetary policy shocks on foreign output. There may be movements in the federal funds rate that are unrelated to economic developments in the United States but are correlated with determinants of growth in other countries. For example, suppose the Federal Reserve adjusted the federal funds rate in response to a foreign financial crisis that was not expected to affect U.S. output. Such a movement in the funds rate would be valid to use in estimating the effect of U.S. monetary policy shocks on U.S. output. However, it would not be valid to use in estimating the effect of U.S. monetary shocks on foreign output.

My identifying assumption is that the Federal Reserve does not adjust the federal funds rate in response to idiosyncratic foreign events. This assumption implies that measures of monetary policy shocks that are exogenous when estimating the effect of U.S. monetary policy shocks on U.S. output are also exogenous when estimating the effect of U.S. monetary policy shocks on foreign output. I provide some narrative evidence in support of my assumption in Section 2. I show that if the assumption fails, the estimated responses of foreign output will likely include a positive bias.

In estimating the foreign effects of U.S. monetary policy shocks, I consider three different measures of monetary policy shocks . First, I construct a series of shocks based on the recursively identified vector autoregression (VAR) in Christiano, Eichenbaum and Evans (1996). This CEE-style monetary policy shock is the residual from regressing the change in the federal funds rate on lagged values of other variables in the VAR and contemporaneous values of those variables ordered before the change in the federal funds rate.[4]

Bernanke and Mihov (1998) also estimate a VAR, but allow for changes over time in the way the VAR is identified. The identification schemes Bernanke and Mihov propose are based on assumptions about how the market for reserves is equilibrated. This is intended to capture some changes in the Federal Reserve's operating procedure over time, such as the shift to quasi-targeting of the money stock that occurred under Paul Volcker.

The third measure of U.S. monetary policy shocks I use is from Romer and Romer (2004). Romer and Romer regress the intended change in the federal funds rate, as agreed to at Federal

[4]The variables are industrial production growth, price inflation, commodity price inflation, the change in the federal funds rate, and the growth rates of non-borrowed reserves and the money stock.

Open Market Committee (FOMC) meetings, on the Federal Reserve's own forecasts for output growth, inflation and unemployment. Their shock series is the residual from this regression.

Previous literature on the international effects of U.S. monetary policy shocks has used a range of empirical strategies. Eichenbaum and Evans (1995) is an influential paper that estimates a recursively identified VAR incorporating a block of foreign data.[5] Their analysis, like much other work in the field, emphasizes the dynamic response of exchange rates to monetary policy shocks. They find that a shock that raises the federal funds rate around 60 basis points appreciates the U.S. dollar by around one percent against other major currencies such as the Japanese Yen, German Deutschemark, the Italian Lira, the French Franc, and the U.K. Pound.[6] Bluedorn and Bowdler (2006) use the Romer and Romer (2004) measure of monetary policy shocks, but retain the focus on G7 economies. For these countries, they find that a 100 basis point increase in the federal funds rate reduces industrial production in other countries between one percent and three percent. Canova (2005) uses a VAR approach to study the transmission of U.S. shocks to Latin American economies, identifying his VAR with restrictions inspired by the DSGE literature. He finds that U.S. monetary policy shocks account for less than ten percent of output variability in Mexico and Chile, two countries I also study.

I study the effects of U.S. monetary policy shocks on foreign output. I find foreign output falls significantly following a contraction in U.S. monetary policy. For a given measure of U.S. monetary policy shocks, the estimated impulse response functions for foreign output are generally similar in size and timing to the response of U.S. output to the same shock measure. The results regarding the size and timing of the response of output depend on which measure of monetary policy is used. However, the patterns in the response of U.S. output to the different shock series generally carry over to the response of foreign output to U.S. shocks. The CEE-style shocks lead to smaller responses than the Bernanke-Mihov shocks, and the Bernanke-Mihov shocks generally lead to smaller responses than the Romer and Romer shocks in both the U.S. and foreign countries.

I analyze the quantitative significance of the effects of U.S. monetary shocks on foreign output. I consider how much effect U.S. shocks have had on output volatility and comovement across this set of countries during the period in question. I find that the fraction of variation in

[5] Eichenbaum and Evans analyze both the federal funds rate and non-borrowed reserves as instruments of monetary policy. They also consider the Romer and Romer (1989) index of monetary policy.

[6] Clarida and Galí (1994) use long-run restrictions to identify their VAR. They argue that U.S. monetary policy shocks explain a large fraction of exchange rate variability for certain exchange rates, but less for others. Faust, Rogers, Swanson and Wright (2003) and Faust and Rogers (2003) use high-frequency data (from changes in the federal funds rate and federal funds futures rates around FOMC meeting dates) to measure monetary policy shocks.

the year-on-year growth of output due to U.S. monetary policy shocks ranges between 20% and 40% for foreign countries, compared with 30% to 50% for the United States, depending on the measure of shocks used. The correlation of year-on-year growth rates between the United States and other countries in my study is between 0.15 and 0.6. Without U.S. monetary policy shocks, the correlation would be between 0.1 and 0.3.

Finally, I investigate how U.S. monetary shocks are transmitted to foreign output. I present evidence concerning the effect of U.S. monetary policy on trade flows, commodity prices, exchange rates, money, and interest rates. The evidence is inconsistent with expenditure-switching theories for two reasons. First, monetary contractions in the United States lead to reductions in activity abroad, not expansions. Second, if expenditure switching is dominant, a U.S. monetary contraction implies that foreign countries will export more to the United States and import less from it. However, for the four foreign countries in my study, imports from all sources fall by more than imports from the United States. In addition, these countries export less.

One reason expenditure-switching effects do not occur may be that foreign central banks tend to follow the policy of the Federal Reserve. Consistent with this view, I show that the real money stock in each country falls in response to a U.S. monetary contraction. There is also some evidence that interest rates rise in foreign countries in response to a rise in U.S. interest rates.

The four foreign countries I study have significant exposure to fluctuations in commodity prices. I find evidence that the prices of their most important export commodities fall significantly after U.S. monetary contractions. To the extent that changes in the terms of trade affect overall economic activity, this is another possible channel through which U.S. monetary policy shocks may affect output in foreign economies.

The paper is organized as follows. Section 2 presents the empirical strategy. Section 3 presents the main empirical results concerning the effect of U.S. monetary policy shocks on foreign output. Section 4 discusses the mechanisms through which these shocks are transmitted to output in other countries.

2. EMPIRICAL APPROACH

The main goal of this paper is to estimate the dynamic effects of a shock to U.S. monetary policy on the level of economic activity in foreign countries. A range of theories predicts that impulses in U.S. monetary policy will influence production in other countries. This influence could be mediated by trade channels, commodity price movements, the response of foreign central banks to the Federal Reserve, or some other channel. Among different theories, there is even disagreement over whether a U.S. monetary contraction should stimulate or contract activity abroad.

Accurate estimates of the effects of monetary policy shocks depend on appropriate measures of monetary policy. This section discusses the identification strategy and measures of monetary policy in more detail before turning to the empirical specification and data.

2.1. Identification Strategy

Consistent estimation of the effects of monetary policy shocks requires that the monetary shocks be uncorrelated with omitted determinants of output growth. To think about the nature of the identification problem, consider equations (1) and (2). For simplicity, these equations omit any dynamic effects of monetary policy shocks. These equations describe output growth in two countries, the United States (Δy^{US}) and Mexico (Δy^{MEX}), as functions of the change in the federal funds rate (ΔFF^{US}). The many omitted determinants of output are summarized by the ϵ's:

$$\Delta y_t^{US} = \beta^{US} \Delta FF_t^{US} + \epsilon_t^{US}, \qquad \epsilon_t^{US} = \epsilon_t^W + \tilde{\epsilon}_t^{US}, \tag{1}$$

$$\Delta y_t^{MEX} = \beta^{MEX} \Delta FF_t^{US} + \epsilon_t^{MEX}, \qquad \epsilon_t^{MEX} = \epsilon_t^W + \tilde{\epsilon}_t^{MEX}. \tag{2}$$

The idiosyncratic shock for each country is uncorrelated with the idiosyncratic shock for the other country and with the world shock (ϵ_t^W). Even apart from both being affected by the federal funds rate, output in the United States and Mexico may be correlated due to commonly-experienced world shocks.

The Federal Reserve adjusts the federal funds rate in response to determinants of economic activity (such as ϵ_t^W) and in response to other concerns (ϵ_t^{FF}):

$$\Delta FF_t^{US} = \delta^W \epsilon_t^W + \tilde{\delta}^{US} \tilde{\epsilon}_t^{US} + \tilde{\delta}^{MEX} \tilde{\epsilon}_t^{MEX} + \epsilon_t^{FF}. \tag{3}$$

The Federal Reserve's systematic response to events that affect the economy is parameterized by $\{\delta, \tilde{\delta}^{MEX}, \tilde{\delta}^{US}\}$. The change in the federal funds rate will be correlated with the error term in the output equations if these δ coefficients are not zero.

Under these assumptions, least squares estimates of β^{US} and β^{MEX} are both potentially inconsistent:

$$\hat{\beta}^{US} \rightarrow_p \beta^{US} + \frac{\delta^W var(\epsilon_t^W) + \tilde{\delta}^{US} var(\tilde{\epsilon}_t^{US})}{var(\Delta FF_t^{US})} \tag{4}$$

$$\hat{\beta}^{MEX} \rightarrow_p \beta^{MEX} + \frac{\delta^W var(\epsilon_t^W) + \tilde{\delta}^{MEX} var(\tilde{\epsilon}_t^{MEX})}{var(\Delta FF_t^{US})}. \tag{5}$$

The usual arguments about the Federal Reserve's response to economic outcomes imply that each coefficient $\{\delta, \tilde{\delta}^{MEX}, \tilde{\delta}^{US}\}$ is positive. Therefore estimates of β^{US} and β^{MEX} contain an asymptotically positive bias. Note that the inconsistency arises from two distinct sources. First, the Federal Reserve responds to the common shock. Second, the Federal Reserve may respond to idiosyncratic shocks.

The literature on estimating the effect of U.S. monetary policy shocks on U.S. output attempts to purge ΔFF of the components that are a response to factors affecting U.S. output. In this setup, the ideal measure of shocks is $m_t \equiv \tilde{\delta}^{MEX} \tilde{\epsilon}_t^{MEX} + \epsilon_t^{FF}$, which contains all the variation in the change in the federal funds rate that is uncorrelated with ϵ_t^{US}. If $\tilde{\delta}^{MEX} = 0$, then the shock that is appropriate for estimating the effect of U.S. monetary shocks on U.S. output will also produce consistent estimates of the effect of U.S. monetary policy shocks on Mexican output. The key identifying assumption of my paper is that $\tilde{\delta}^{MEX} = 0$. This assumption justifies my use of measures of monetary policy that have been used to estimate the effect of U.S. monetary policy shocks on U.S. output.

There are several reasons why my identifying assumption may be invalid. One is that the Federal Reserve might respond to foreign financial crises, such as that in Mexico in 1994. A financial crisis overseas is likely to reduce foreign output, corresponding to low value of $\tilde{\epsilon}_t^{MEX}$. If the Federal Reserve typically lowers interest rates in such crises (that is, if $\tilde{\delta}^{MEX} > 0$), we would observe a low value for the monetary shock, m_t. Thus low values of m_t and Δy_t^{MEX} may be associated in the data, even though the relationship is not causal but is due to an omitted third factor. This would induce a positive bias in estimates of β^{MEX}.

In practice, the Federal Reserve does not appear to often lower interest rates when a financial crisis breaks out abroad. In the Mexican situation in 1994, the Federal Reserve's preferred approach was to make a loan to the Bank of Mexico, rather than alter interest rates.[7] In addition, DeLong and Eichengreen (2002) report that the extent of the U.S. government's non-monetary policy response was based partly upon analysis of the effects on employment in each U.S. state if the Mexican economy were to collapse. The larger the effects on the U.S. economy, the larger the response would be. This is precisely the kind of action that the literature on the effect of U.S.

[7] The transcript of a Federal Reserve Board of Governors phone conference makes this clear. See Board of Governors of the Federal Reserve System (1994).

monetary policy shocks needs to exclude when measuring monetary policy. If these papers have succeeded in the task they set themselves, then there is no additional problem in my analysis.

Rivlin (1998) discusses the role of the Federal Reserve in the aftermath of the Asian financial crisis. She notes that in the initial stages of the crisis, less attention was paid to the turbulence in Asia. Over time, the weakness in Asian economies reduced demand for U.S. exports. She states that "The Federal Reserve, recognizing that the balance of risks has shifted from overheating to cooling off, has cut short term interest rates twice." Rivlin emphasizes that the Federal Reserve's monetary policy response was due to the perceived effect of the crisis on the U.S. economy.[8] Had there been no effect on the U.S. economy, the Federal Reserve would not have acted.

Yellen (2007), in discussing the outlook for the U.S. economy from the perspective of a central banker, refers to future weakness of foreign economic activity. The context for her discussion of activity abroad is concern about economic growth in the United States. If activity is weak internationally, then this will affect U.S. output. This further suggests that the reason the Federal Reserve worries about global economic activity is because of its possible effects on the U.S. economy.

In spite of these arguments, suppose the Federal Reserve actually does respond to foreign financial crises and economic weakness and that it does so more than would be justified by the likely impact of the crisis on U.S. output. Since I find that increases in U.S. interest rates lower output abroad, endogeneity concerns related to financial crises work against finding a statistically significant effect of U.S. shocks on foreign output. That is, Federal Reserve responses to financial crises are likely to generate a positive bias in the impulse response function. Correcting for this bias would make the estimated responses even more negative.

An alternative reason my identification strategy could fail is that there are common trends in monetary policy among different countries. Given that so many countries went through the Great Inflation simultaneously (documented in Ciccarelli and Mojon, 2005, and Scrimgeour, 2007), one might suspect that there was a common monetary cause that determined these outcomes.[9]

[8]Rivlin also discusses the response of European central bankers. They also were not prepared to respond when the crisis seemed unlikely to affect their own economies: "the initial storm warnings from Asia were also first dismissed by many Europeans as far away and not their problem." Meyer (1998) gives the same interpretation as Rivlin. In his opinion, "the spillover from Asia [would] importantly shape the U.S. outlook for 1998. A slowdown of such a magnitude could be expected to substitute for some or all of the monetary tightening that otherwise might have been justified."

[9]A particular version of this hypothesis is that the United States provides leadership in monetary policy. If U.S. monetary policy influences other countries' policies, but not vice versa, then this paper's estimates still represent the effect of U.S. monetary shocks. However, if the U.S. policymakers get their ideas from elsewhere, then the estimates in this paper include the effect of monetary policy shocks originating in the country that is the intellectual leader.

In all three shock series I use there is a slight tendency for the monetary shock to be negative (expansionary) in the 1970s and positive elsewhere. If other countries' monetary policies have similar tendencies, and if it is this small long-run variation in monetary policy that helps identify the effect of shocks on output, then the effect of commonly held ideas could be wrongly attributed to U.S. monetary policy shocks in my framework. However, the long-run variation is a minor contributor to the overall variance of the monetary policy shock measures. Therefore, it is unlikely that these trend movements in the shock series are important for identifying the coefficient estimates.

2.2. Measures of U.S. Monetary Policy Shocks

A large literature has attempted to estimate the domestic effects of monetary policy shocks in the United States. Since Bernanke and Blinder (1992), most studies focus on the federal funds rate as the Federal Reserve's instrument. As a baseline, I report impulse responses when the change in the federal funds rate measures monetary policy shocks. However, in view of the likely problems with using the federal funds rate this way, I use three series that represent different approaches to measuring monetary policy shocks in the literature. All three measures of monetary policy cover 1966 to 1996. Figure 1 presents the cumulated values of the different shock series, normalized to have the same mean and variance. First, the CEE-style shock is from the federal funds rate equation in a recursively-identified vector autoregression, based on Christiano et al. (1996).[10] Christiano, Eichenbaum and Evans use quarterly data. Since this paper uses monthly data, I estimate a similar VAR at a monthly frequency, substituting industrial production for gross domestic product. This monetary policy shock measure is the residual from regressing the change in the federal funds rate on twelve lags of each of the output variable, producer prices, commodity prices, money supply, non-borrowed reserves and total reserves, as well as contemporaneous values of variables such as output and prices.

Bernanke and Mihov (1998) have a related vector autoregression approach, but give more attention to the workings of the market for reserves. They explore the implications of different assumptions about supply and demand for borrowed and non-borrowed reserves for the appropriate identifying restrictions in a structural VAR. They emphasize the changing nature of the Federal Reserve's operating procedures (for example, the quasi-targeting of the money stock under Volcker), and estimate a model with regime-switches. An implication of their work is that the

[10] They also examine a measure of monetary policy shocks that uses non-borrowed reserves as the instrument of monetary policy.

Christiano, Eichenbaum and Evans identification strategy is more appropriate at some times than others. I use the series of monetary policy shocks identified in the regime-switching model and refer to it as the Bernanke-Mihov shock.

Neither Bernanke and Mihov nor Christiano, Eichenbaum and Evans account explicitly for expectations about economic activity and inflation in the future. The range of variables they use in their VAR does not provide all the information the FOMC uses for forecasting. This becomes a problem if the FOMC responds to information outside the VAR. Some movements of the funds rate could appear to be exogenous in the VAR, whereas they are actually due to the Federal Reserve's deliberate response to economic developments.

The third measure of monetary policy shocks – from Romer and Romer (2004) – makes a more direct attempt to model the Federal Reserve's systematic behavior and accounts for explicitly for expectations. Romer and Romer construct a measure of the Federal Reserve's intended funds rate, based on the minutes of FOMC meetings. They regress the intended changes in the federal funds rate on recent data and internal forecasts for variables such as GDP and unemployment. The Romer and Romer shock is the residual from this regression.

Endogeneity in the measure of monetary policy biases the estimated effect of U.S. monetary policy shocks. If the shocks do not adequately measure the exogenous component of monetary policy, then a similar problem may be inherited in my analysis. Since the three measures are constructed differently, they may be differentially susceptible to this critique. An endogenous measure of monetary policy is normally thought to generate a positive bias in the effects of contractionary monetary policy shocks on output since interest rates often rise when the economy is growing quickly and expected to continue growing quickly.

2.3. Specification

I estimate the overall effect of U.S. monetary policy shocks on foreign output using a single-equation, dynamic, linear model

$$\Delta y_t^c = \mu^c + \sum_{k=1}^{K} \alpha_k^c \Delta y_{t-k}^c + \sum_{l=1}^{L} \beta_l^c m_{t-l} + \epsilon_t^c, \tag{6}$$

where Δy^c is the growth rate of production in country c and m is a measure of monetary policy shocks. Equation (6) is similar to the output equation in a VAR. It contains both lags of the dependent variable and of another variable, in this case a measure of monetary policy. The difference from a VAR is that it does not include lags of other variables such as inflation or commodity prices. Sims (1998) emphasizes that the coefficients on lags of other variables in a typical VAR equation are generally small, so omitting other variables should not have a large effect on the results.

In most cases discussed in this paper, K is 24 – two years worth of lagged output growth included on the right-hand side – and L is 36. The long lag length of output growth and the money shock mimic the influence of other intermediate factors. For example, if the money shock actually affected investment plans with a lag of one month and investment plans affected output with a lag of one month, it would appear as if the money shock affects output with a lag of two months. Section 3 discusses the sensitivity of the results to variation in K and L.

For most of the analysis, the regression equation above is estimated separately, country by country. For presentation purposes, it is sometimes convenient to stack the data and restrict the autoregressive and distributed lag coefficients to have the same values in different countries. Some results are based on estimating

$$\Delta y_t^c = \mu^c + \sum_{k=1}^{K} \alpha_k \Delta y_{t-k}^c + \sum_{l=1}^{L} \beta_l m_{t-l} + \epsilon_t^c \tag{7}$$

with pooled data. This implies an single impulse response function for all foreign countries.

Before estimating the effects on output, I scale each monetary policy shock series by the least-squares coefficient from regressing the change in the federal funds rate on the shock. This ensures that a one unit change in each shock has the same implications for the change in the federal funds rate. Specifically, impulse response functions are responses to a shock that implies a 100 basis point increase in the federal funds rate.[11]

In addition to impulse response functions, section 3 also includes a variance decomposition exercise to assess the output volatility is due to U.S. monetary shocks. I also analyze how much comovement between production in different countries is induced by U.S. monetary policy shocks.

In section 4, I discuss how U.S. monetary shocks affect a range of other variables that might facilitate the transmission of U.S. shocks to foreign output. Among the variables I study are some interest rates and exchange rates. Since these are often determined in financial markets, it seems likely that they will respond most quickly to the monetary policy shocks, perhaps even within the month the shock occurs.[12] For this reason, I estimate impulse responses for money stocks, interest

[11]Impulse responses and standard errors are produced with a Monte Carlo procedure. A parameter vector is drawn from a normal distribution with mean equal to the estimated parameter vector and variance equal to the estimated variance-covariance matrix. From this parameter vector I compute an impulse response function. The reported impulse response function is the average from 1,000 such simulations.

[12]In recursive VARs, such variables are often ordered after the variable representing monetary policy, meaning that the monetary policy shock can have contemporaneous effects on the money supply and exchange rate.

rates, and exchange rates including the contemporaneous value of the monetary policy shock in the regression.

2.4. Data

I take data on industrial or manufacturing production from the International Monetary Fund's International Financial Statistics. I use these production data because they are monthly. Further descriptions of data sources are in Appendix A. The production data are seasonally adjusting prior to estimating equation (6), using the Census Bureau's X-12-ARIMA method (see Findley et al., 1998). The X-12-ARIMA method allows for a seasonal pattern that evolves over time. The method used to adjust the data for seasonality has only minor effects on the estimated impulse responses and coefficients.

In addition to the United States, the countries included in the study are Canada, Chile, Colombia, and Mexico. These countries are chosen from among countries in the Americas because they have relatively long time series on industrial or manufacturing production. The production data for Canada and the United States cover the full sample of monetary policy shocks – 1966 to 1996. The Mexican data start in 1970, while the Colombian series begins in 1980. I use Chilean data starting in 1976, though earlier data are available. The early 1970s were particularly turbulent years for the Chilean macroeconomy, and I have chosen to exclude data from then.

Table 1 presents some descriptive statistics for the monthly growth rate of production data for the five countries, and Figure 2 plots the data. U.S. industrial production grew at an annual rate of 3% on average, similar to the others, with Mexican growth being somewhat higher. The volatility of growth rates is much higher in the Latin American countries than in Canada or the United States. It is possible that measurement error generates a significant fraction of the measured volatility of the Latin American economies. In spite of this, it is likely that much of the additional volatility is fundamental to the industrial structures in these countries.

Despite the pervasiveness of high frequency variability in the monthly data, there is still a positive correlation of production in each other country with production in the United States. The idiosyncratic volatility is less prevalent in annual data. For annual growth rates there is a correlation of 0.72 between the United States and Canada. Output in Chile and Colombia is somewhat less correlated with the United States than Canadian output is. Surprisingly, the correlation of Mexican output with output in the United States is lower on an annual basis than on a monthly basis.

Whether the high frequency variability is due to fluctuations in activity or due to measurement error affects the appropriate interpretation of the results. It might be that these fluctuations in the data reflect underlying economic activity but that the autoregressive specification does not accurately represent the dynamics. Instead, these fluctuations may be more faithfully described by a moving average process. If so, then the autoregression estimated would lead to overestimates of the fraction of volatility due to monetary policy shocks. This happens because the autoregressive model produces an estimate of the residual variance that is too low. By contrast, if measurement error is the cause of the volatility, then the variance decompositions may understate the contribution of U.S. monetary policy shocks to foreign output variability. This occurs because the estimated residual variance is higher than the true variance, since the data contain measurement error.

To illustrate some of the effects that measurement error might have on the results, suppose that the data are generated by

$$\Delta y_t^* = \alpha_1 \Delta y_{t-1}^* + \beta_1 m_{t-1} + \beta_2 m_{t-2} + \epsilon_t. \tag{8}$$

We observe $y_t = y_t^* + u_t$, where u_t is white noise measurement error. If we use least squares to estimate $(\alpha_1, \beta_1, \beta_2)$, the limiting values of the parameters are

$$\begin{pmatrix} \hat{\alpha}_1 \\ \hat{\beta}_1 \\ \hat{\beta}_2 \end{pmatrix} \to_p \begin{pmatrix} \alpha_1 - \frac{(1+2\alpha_1)V_u}{V_{\Delta y} - \beta_1^2 V_m} \\ \beta_1 \\ \beta_2 + \frac{\beta_1(1+2\alpha_1)V_u}{V_{\Delta y} - \beta_1^2 V_m} \end{pmatrix} \tag{9}$$

where V_x is the variance of x for $x \in \{u, \Delta y, m\}$.

The asymptotic bias in $\hat{\alpha}_1$ is a combination of an attenuation bias and a negative bias. Note that the estimate is consistent if $\alpha_1 = -\frac{1}{2}$. Otherwise, $\hat{\alpha}_1$ is biased toward $-\frac{1}{2}$. While $\hat{\beta}_1$ is consistent, $\hat{\beta}_2$ is inconsistent. The asymptotic bias of $\hat{\beta}_2$ depends on both α_1 and β_1. When $\alpha_1 > -\frac{1}{2}$ and $\beta_1 < 0$, there is a negative asymptotic bias in $\hat{\beta}_2$.

In principle, it is possible to estimate the parameters in the model above by maximum likelihood, incorporating the moving average component in the residual. This remains a task for future research.

3. FOREIGN OUTPUT RESPONSES TO U.S. MONETARY POLICY SHOCKS

This section presents the main empirical findings on the effect of U.S. monetary policy shocks on output in foreign countries. It starts with an analysis of the impulse responses of output. Following that is a discussion of the variance decomposition and a covariance decomposition determining the effect of U.S. monetary shocks on international output comovement.

3.1. Impulse Response Functions of Output

Figure 3 presents the responses of production in the United States and the four foreign countries to all three measures of shocks, as well as to the change in the federal funds rate. Figure 3(f) gives the impulse responses from pooling the data in the foreign countries. These impulse response functions show the percentage deviation of output from its trend following a U.S. monetary policy shock that raises the federal funds rate by 100 basis points. Table 2 gives the size and month of the maximum estimated effect of these shocks on production.

According to these results, U.S. monetary contractions reduce output, both in the United States and abroad. Output in each country falls in response to a contraction in U.S. monetary policy, regardless of how the shock is measured.[13] The size of the estimated effects depends on both the measure of shocks used and the country.

There is some variation in the estimated impulse responses across measures of monetary policy. The response of output to U.S. monetary policy shocks is generally greatest when the Romer and Romer measure is used. The Bernanke-Mihov series usually implies somewhat smaller responses, while the CEE-style series implies still smaller responses. This is true across the five countries.

If the measures of monetary policy shocks contain measurement error, then we would expect these impulse responses to be attenuated. If the measurement error is independent across measures there might be some advantage to combining the information in the different measures. For example, we could used principal components or factor analysis to estimate such a shock. Such a shock might be able to reduce the impact of measurement error. However, the estimated response of U.S. output using one of these synthetic shocks is similar in magnitude to the response to the Bernanke-Mihov shock. It is larger than the response to the CEE-style shocks, but smaller than the response to the Romer and Romer shocks. This suggests that independent measurement error is not the problem, or that the measurement error is much larger for some series than for others.

Figure 3(b) shows the response of Canadian production to U.S. monetary policy shocks. What is most striking about this plot is its broad similarity to the impulse response function for U.S. output. The responses of Canadian and U.S. production are similar in magnitude and

[13] In some cases there is an initial increase in output after a contraction, followed by a larger reduction in output. Also, Mexican output increases persistently following an increase in the federal funds rate.

timing. The maximum reduction in Canadian production following a 100 basis point contraction is between 2.71% and 4.95% depending on which shock measure is used. The range for the United States is 1.60% to 4.36%. The timing of the maximum responses is also similar. In general, the peak response occurs around 28 months after the shock. (The lag of the peak response of U.S. production to the Bernanke-Mihov shock is estimated to be fifteen months. However, the response at 28 months is similar to the response at fifteen months in this case.)

For the three other countries, as already noted, U.S. monetary policy tightening precedes a contraction in output. These output contractions are large. According to the Bernanke-Mihov and Romer and Romer shocks, a 100 basis point increase in the federal funds rate reduces output in Chile, Colombia and Mexico on the order of 4% to 8%. This is larger than the response of output in the United States. For all these countries the response to the CEE-style shock is smaller, just as in the United States.

As with the United States, the response of output is gradual, with the peak effect usually occurring after two years. The response of output seems more persistent than in the United States, where output reverts toward trend.

The plots in Figure 3 do not show the standard errors for the impulse responses, though these are important in interpreting the results. The t-statistics for the impulse responses at the maximum response are generally above two. However, this statistic does not have a t-distribution since it is computed for the maximum response. An alternative approach to assessing the precision of the estimates is to test the null hypothesis that the impulse response function is zero in all periods up to a certain horizon. (A natural horizon would be 48 months, which is the number of periods for which the impulse response function is calculated and reported.) For the United States, Colombia and Mexico, the typical outcome from such a test on the estimates represented in Figure 3 is a failure to reject the null hypothesis at conventional levels of significance. Unfortunately, the test does not have great power to discriminate between the null hypothesis and alternative hypotheses in which U.S. monetary policy shocks have very large effects on output. For Canada and Chile, the test confidently rejects the hypothesis that there is no effect of U.S. monetary policy shocks on production.

Figure 3(f) shows the estimated impulse response function when foreign production data are pooled and the countries are restricted to have the same coefficients. This restriction is unlikely to be valid, but it generates a single impulse response function so is easy to report and is a convenient way of summarizing the information in the individual countries' impulse responses. In accordance with the response of output in individual countries, the pooled response shows a more persistent response of output in foreign countries than in the United States. The more persistent response of foreign output to the U.S. monetary policy shock is in contrast to the generally higher persistence of output growth in the United States.

An interesting question is whether the responses for the United States are significantly different from responses for other countries. To test this requires allowing for the fact that the estimated impulse response functions may be correlated across countries because the innovations may be correlated across equations (as in equations (1) and (2)). I run a series of pairwise seemingly unrelated regressions for the production in the United States and production in each other country, allowing for contemporaneous correlation of residuals across equations. The parameters from these regressions yield impulse response functions that account for correlation. With a 5% significance level, we fail to reject the null hypothesis that the impulse response functions in the United States and the other country are identical out to 48 months after the shock.

3.2. Lag Specification

The responses I find for other countries are larger than many previous studies. One reason for this is the selection of countries I study. Most previous work focuses on the G7. I include three Latin American economies, which turn out to have larger responses. In the case of Canada, though, there is still a difference. Some of these differences are because I estimate a single equation, and some because I allow a long lag specification.

Bluedorn and Bowdler (2006) study the effect of U.S. monetary policy shocks on G7 countries. They use the Romer and Romer shocks, so comparing the findings here with theirs can reveal differences not due to the measure of monetary shocks. The one country that is in both Bluedorn and Bowdler's study and this one is Canada. Bluedorn and Bowdler find the peak response of Canadian industrial production to a 100 basis point monetary policy shock to be less than 2%. This is substantially smaller than the 4.95% in my results. Romer and Romer (2004) estimate a VAR as well as the single-equation specification and find that this reduces the size of the estimated response by around one third, which is not enough to explain the discrepancy with my result.

The rest of the difference appears to come from the lag length Bowdler and Bluedorn use. The number of lags of the monetary policy shock included has an important effect on the impulse responses. Smaller values of L generate smaller impulse responses. Reducing L from 36 to twelve brings the maximum response of U.S. output down to around 3%, while the maximum response of Canadian output falls from around 5% to around 3.3%. (Reducing L from 36 to twelve has larger effects on the estimated responses in other countries.) Since Bluedorn and Bowdler's VAR has twelve lags, their impulse response functions are smaller than those presented in this paper.[14] So the discrepancy between my finding and Bluedorn and Bowdler's is approximately half due to estimating a single equation, and half due to allowing more lags of the monetary policy shock to enter the regression equation. The association of more lags in the estimating equation with larger responses of production holds for the Bernanke-Mihov and CEE-style shocks as well.

Including more lags of the monetary policy shock in the estimated equation leads to larger estimated effects of U.S. monetary shocks on foreign output. But should all those lags be included? The same issue arises when Hamilton and Herrera (2004) debate the conclusions of Bernanke, Gertler and Waston (1997) about the effect of oil price shocks on the macroeconomy. Hamilton and Herrera criticize the short lag length Bernanke, Gertler and Waston use in their study. Hamilton and Herrera use likelihood ratio tests to discriminate between alternative lag specifications. Bernanke, Gertler and Watson use the Akaike information criterion, which favors fewer lags. Bluedorn and Bowdler use enough lags to whiten the residuals in the regression equations.

Including too many lags may increase the variance of the estimator, but including too few lags may bias the estimator because relevant variables are omitted. Therefore the choice of lag length involves a tradeoff between bias and variance of the estimator. Noting a range of options for choosing between different lag structures and the effect that different lags specifications have on the results, I leave aside a more complete analysis of lag selection in this context for future work.

3.3. Volatility Due to U.S. Shocks

While the impulse response function describes the effect of a particular shock, it is interesting to know what contribution U.S. monetary policy shocks have made to overall output variability. Cochrane (1994) investigates the importance of different shocks in accounting for output variability in VARs. His conclusions have become the received wisdom. He reports that "Monetary policy shocks account for at most 20% of the variation in output" (p. 296).

Christiano et al. (1999) present variance decompositions for a range of VAR models, some of which agree with Cochrane's statement. However, when the federal funds rate is used as the policy instrument in the VAR, the monetary policy shock explains around 40% of the variability

[14] The results are relatively insensitive to the choice of K, the number of lags of output growth.

of output eight to twelve quarters ahead. When quantitative measures, such as $M1$, are used as the policy instrument, the variance decomposition assigns less importance to monetary policy shocks in explaining output variability. In the international context, Cushman and Zha (1997) argue that international shocks explain 75% of the variability of Canadian variables, while Canova (2005) argues that U.S. monetary policy shocks explain less than 10% of the variability of output in Mexico and Chile.

I use the parameter estimates from the previous section, along with assumptions that monetary policy shocks and other shocks are serially uncorrelated, to compute a theoretical variance for output growth. I compute this variance in two scenarios: when monetary policy shocks have their historical variance, and when their variance is set to zero.[15] I do this for the month-on-month growth rate of output and for the year-on-year growth rate. The monthly growth rate captures high frequency variation in output, while the yearly growth rate reflects business cycle variation. Table 3 shows the percentage reduction in output volatility that would come from shutting off U.S. monetary policy shocks entirely.

For production in the United States, monetary policy shocks explain around 20% of the short-term variability and from 31% to 57% of the business cycle variability in output growth. This is somewhat higher than the the conclusion in Cochrane's paper, though it is roughly in line with Christiano, Eichenbaum and Evans.[16] The previous section showed that the Romer and Romer shocks imply larger responses of output to a given movement in the funds rate than the other shocks imply. That result is echoed in Table 3, which shows that the Romer and Romer shocks explain a larger fraction of the variation in output.

According to Table 3, U.S. monetary policy shocks also explain a significant fraction of output volatility in other countries too. The figures for Canada are similar to the United States. The variance decomposition suggests that around half the variability of yearly growth in Chilean output has been due to U.S. monetary policy shocks. This is much larger than Canova finds, possibly because his sample begins in several years later.

These variance decompositions may not provide a reliable indication of how much future variability in output will be due to monetary policy shocks. During the period I study there is a reduction in the variance of each measure of monetary policy shocks. For example, the variance of

[15] For each country, I use use the variance of the monetary policy shock from the same period for which I estimate the regression equation.

[16] The measure of output used in the variance decomposition matters. This is evident here in the destinction between monthly growth and yearly growth, and is also discussed in Cochrane's paper.

the Romer and Romer shock series after 1982 is around one-fifth the variance over the full sample. If this persists, we might expect monetary policy shocks to explain one-sixth, rather than one-half, of U.S. output variability in future.

Another important consideration is the effect that the long lag specification has on the variance decomposition. An argument in favor of including many lags is that it should not bias the estimated impulse response functions, merely reduce the precision with which they are estimated. By contrast, the variance decomposition is likely to be distorted by including too many lags. In the case of Colombia in particular, the sample of output data covers only seventeen years, but I estimate dozens of parameters, greatly reducing the number of degrees of freedom. One way to deal with the problem is to reduce the number of lags included. Another approach would be to impose some structure on the coefficients estimated. For example, we could insist that $\{\hat{\beta}_1, ..., \hat{\beta}_6\}$ are equal and $\{\hat{\beta}_7, ..., \hat{\beta}_{12}\}$ are equal, and so on. This restriction does not greatly reduce the fraction of Colombian output variability due to U.S. monetary policy shocks, though one might think it should if the model were being overfit.

3.4. Explaining Comovement

One possible reason for comovement of output across countries is common response to a monetary policy shock in the United States. Of course, there are many other reasons for output in different places to move together, summarized by ϵ_t^W in equations (1) and (2). The results in this section reflect only the importance of U.S. monetary policy shocks in driving comovement.

Table 4 shows the theoretical correlation of annual production growth rates in other countries with growth in the United States when there are no monetary policy shocks. For comparison, the table also shows the actual correlation as computed in Table 1.[17]

The results suggest that at the annual frequency, U.S. monetary policy shocks have contributed greatly to the comovement of output in different countries. While Canadian output growth and U.S. growth had an actual correlation of 0.72, they would have had a correlation of around 0.3 if there had been no monetary policy shocks. Similarly, the correlation of output growth in Colombia and Chile with U.S. output would have been much lower over this period had there been

[17]The method used to compute the counterfactual correlation is similar to the method used for the variance decomposition. It suggests a theoretical correlation between U.S. and foreign output in the presence of monetary policy shocks. Since this varies somewhat across different measures of shocks, the table only reports the actual correlation computed from the data.

no monetary policy shocks. Similar to Canova's finding, the table suggests that these monetary policy shocks may have lowered the comovement of output in Mexico and the United States.

The top panel in the table provides information on the effect of U.S. monetary policy shocks on monthly output correlations. The results can be easily summarized here: there is only a small impact. Correlations of month-on-month output growth in the United States and abroad are marginally lower without monetary policy shocks. For example, the counterfactual correlation of Canadian production growth with the United States is between 0.25 and 0.3, relatively close to the actual correlation of 0.39. The impact of monetary policy shocks on comovement becomes more apparent at lower frequencies.

4. TRANSMISSION OF U.S. SHOCKS TO FOREIGN OUTPUT

This paper has shown that monetary policy shocks in the United States appear to have large effects on production in other countries. There are several plausible channels through which monetary policy shocks in the United States might affect the economies of other countries.

If a foreign country does not change its interest rates in response to a U.S. monetary contraction, the value of its currency should fall relative to the U.S. dollar. This depreciation should imply the usual expenditure-switching effects.[18]

If the foreign central bank does adjust its interest rates, we would expect consumption and investment to change as in the basic closed-economy model. There may be additional effects that operate through open economy channels too, especially if there are differences in the amount by which the foreign central bank and the Federal Reserve alter their respective interest rates. The Dornbusch model suggests that if the foreign central bank increases its interest rates less than the Federal Reserve, then the dollar should appreciate against the foreign currency, stimulating the foreign country's traded goods sector.

U.S. monetary policy shocks might affect commodity prices that are important to foreign economies. For example, the fall in U.S. expenditure due to a contractionary monetary policy shock could lower commodity prices. Frankel (2006) also gives a supply-side explanation for how monetary policy might affect commodity prices.[19]

[18]Expenditure-switching effects were perceived to be important in the 1930s when countries left the gold standard and depreciated their currencies. This was thought to stimulate a country's exports and reduce imports, bringing prosperity at the expense of other countries. Eichengreen (1992) counters this beggar-thy-neighbor interpretation of departures from the gold standard, arguing that "Nothing could be more contrary to the evidence" (p. 21).

[19]How variations in commodity prices affect production is an open question. Producers in other countries might substitute away from producing these commodities, perhaps into non-measured production or out of production

This section presents some evidence concerning the effect of U.S. monetary policy shocks on trade flows, foreign monetary policy and commodity prices.

Identifying the transmission channels is not trivial. For example, showing that U.S. monetary policy contractions affect both foreign output and investment is not enough to prove that the effect on output occurs through the effect on investment. The effect on investment could be due to the fall in output. In addition, the endogeneity of investment in a regression of output on investment cannot be resolved by using the monetary policy shock as an instrument since it is plausibly an influence on other variables that contribute to output.

Implicitly or explicitly, other studies of the transmission mechanism make identifying assumptions. For example, Kim (2001) uses a VAR approach to study the transmission of U.S. monetary policy to other G7 nations. His paper experiments with a range of schemes to identify the effect transmission mechanisms.

4.1. Trade Responses

This section analyzes trade data taken from the International Financial Statistics and Direction of Trade databases. The International Financial Statistics database records total exports and imports for each country, while the Direction of Trade database records bilateral trade flows, all in nominal U.S. dollars. It is particularly interesting to study the bilateral trade flows, since previous studies appear not to have used these data. I have deflated trade flows using a price index from the United States. U.S. exports and imports are deflated by U.S. export price index and U.S. import price index respectively. For the other countries, I deflate exports – whether bilateral or total – by the U.S. import price index and imports by the U.S. export price index. IFS generally lacks country specific data on import and export price indices and exports and imports in local currency. Since the composition of U.S. imports and exports from each other country are not identical, this is obviously not an ideal approach to deflating trade flows.

Figure 4 shows how different measures of trade flows respond to U.S. monetary contractions. Figures 4(a) and 4(b) show estimated responses of U.S. exports and imports to U.S. monetary policy shocks. Figures 4(c) and 4(d) show the estimated responses of exports and imports for the four other countries. Figures 4(e) and 4(f) report the responses of bilateral export and import flows between the four foreign economies and the United States.

altogether. It is also conceivable that this channel could raise manufacturing production if productive inputs move from the commodity sector to the manufacturing sector.

Note that both exports and imports for the United States decline in response to a contractionary shock. If the beggar-thy-neighbor view were correct, then we might expect to see exports fall and imports rise, or at least to see exports fall more than imports. In fact, the point estimates for the impulse responses show that U.S. imports fall more than exports in response to the contractionary U.S. monetary shock.

The contrast between total exports and imports is more stark for other countries. In response to a contractionary monetary policy shock in the United States, foreign exports do not respond much, but imports fall substantially. The reduction is around 8% after two years, and it stays at that lower level for some time. Exports fall by around 3% but return to trend quite quickly.

These results would provide some support for the beggar-thy-neighbor view, except that the overall response of output is not what that theory would predict. What is really striking is the similarity between the response of exports and imports in the United States and in the other four countries. The large reduction in imports and the small reduction in exports would both be consistent with strong aggregate demand effects (expenditure reduction) rather than substitution effects (expenditure switching) induced by the shock.

The results for bilateral trade flows reinforce this conclusion. Exports to the United States rise initially, but fall subsequently. While imports from the United States do not exhibit a strong response to the monetary shock, total imports into Canada, Chile, Colombia and Mexico fall substantially. This is more consistent with a reduction in each country's expenditure on foreign goods than an expenditure-switching effect from U.S. goods to other countries' goods.

4.2. Interest Rates, Exchange Rates and Money

A plausible explanation for the large impulse responses estimated for production is that foreign central banks respond to the Federal Reserve's actions. If the Federal Reserve raises interest rates, and the foreign central bank moves to a more contractionary monetary policy, this could lead to a reduction in output in the foreign economy.[20]

Figure 5 shows the estimated responses of short-term interest rates in the United States, Canada, and Colombia to a U.S. monetary contraction in the United States. The figure does not show estimated responses for Chile and Mexico for two reasons. First, in Chile and Mexico,

[20]In an interesting paper that is related to some of these issues, di Giovanni, McCrary and von Wachter (2005) estimate the direct effects of domestic monetary policy on domestic output. They attempt to work around the usual endogeneity bias by using the German interest rate as an instrument for interest rates in other European economies. It seems likely that German monetary authorities could be responding to common demand shocks that other central banks would respond to also, potentially invalidating their identification strategy.

interest rates have been volatile at times because of periods of high inflation and financial crises. Second, financial markets have often been regulated and data on interest rates are not so readily available for early parts of the sample. Where data are available, estimates of the response of Chilean or Mexican interest rates to U.S. monetary policy shocks are generally very imprecise. Data on the Colombian central bank's discount rate are available and are used in Figure 5(c). Until 1986 the discount rate was adjusted infrequently and in large steps, while after 1986 the discount rate evolved more smoothly.

The estimated responses of interest rates depend in interesting ways on the measure of monetary policy shocks considered. A 100 basis point Romer and Romer shock increases the federal funds rate by over 200 basis points at short horizons.[21] At longer horizons, the estimated response is negative, probably because of a reduction in inflation due to the monetary contraction. On average, the Romer shocks were somewhat negative during the 1970s while interest rates were generally rising over the course of the decade. In contrast, the Volcker experiment featured generally positive shocks followed eventually by substantial reductions in nominal interest rates. By contrast, the CEE-style shock and the Bernanke-Mihov shock suggest much less persistent deviations of interest rates from trend. In the case of the Bernanke-Mihov shock, the short-term interest rate returns to trend around six months after the shock occurs.

The larger response of interest rates to the Romer and Romer shock suggests a reason why output appears to fall more in response to these shocks. The size of the shocks fed into the impulse response function is calibrated to correspond to a 100 basis point rise in the federal funds rate. In practice, the monetary tightening is larger and more sustained for a given Romer and Romer shock, so it makes sense that the output response is larger too.

Responses of interest rates in Canada are quantitatively similar to the United States. Again, the Romer and Romer shock suggests larger responses of interest rates, with the overnight money rate increasing around 200 basis points after a standard shock.

As with Canada, interest rates in Colombia appear to rise after a contractionary shock to monetary policy in the United States. The magnitude of the increase in Colombian interest rates is much smaller, increasing 50 basis points rather than 200 basis points in the wake of a U.S. shock of 100 basis points. The standard errors for the estimated responses are large, probably because

[21] Recall that the size of the shock is chosen to correspond to a 100 basis point increase in the federal funds rate during the quarter of the shock.

the first half of the sample features an interest rate that is mostly constant with occasional large movements.

The similarity between the U.S. and Canadian interest rate responses to a monetary policy shocks suggests that the Bank of Canada's strategy generally involved moving its interest rates in line with U.S. interest rates, even though it had a floating exchange rate after May 1970. Indeed John Crow, who was Governor of the Bank of Canada from 1987 to 1994, says as much in his memoir. In discussing the Canadian response to the Volcker disinflation, Crow (2002, pp. 152-153) states:

> At the start of the 1980s, the Bank's monetary policy was to all intents forced by events outside our borders – namely, the great America disinflation led by the Federal Reserve's Paul Volcker. ...
>
> Confronted itself with the fallout from the U.S. decision to confront inflation, the Bank of Canada decided to try to hang on to the U.S. dollar exchange value for our currency. This meant, in practice, at least matching U.S. rate increases.
>
> Calls for a halt to the process [of tight monetary policy] became louder and more widespread. A popular accompanying slogan was for Canada to have a "made-in-Canada" monetary policy, and in effect, try to take whatever monetary medicine the United States would dish out by allowing our dollar to depreciate further. Thereby, it was hoped to avoid the pain of such high Canadian interest rates.

Crow's point is echoed by Greider (1987) who cites (on p. 414) two reasons for foreign output to fall after a tightening of U.S. monetary policy:

> When the richest market in the world, the American economy, declined, exporters around the world lost their best customer. Moreover, the central banks of other industrial nations raised their interest rates too, supporting Volcker's initiative against inflation and depressing their own domestic economies. When the locomotive pulled the world's economy forcefully in one direction, the rest of the train followed.

Greider implicitly rates the expenditure-reduction effect as more important than the expenditure-switching effect, and he emphasizes the comovement of monetary policy actions.

Figure 6 shows the response of real M1, deflated by the Consumer Price Index. The responses are most stark in the United States and Canada, where the money stock falls substantially in response to the Romer and Romer shock as well as the CEE-style shock, consistent with a large monetary contraction. The subsequent rebound in the real money stock could be due to the eventually lower nominal interest rates that reduce the opportunity cost of holding money. The Bernanke-Mihov shocks suggest much smaller and less persistent effects of monetary policy shocks on the money stock.

The impulse response functions suggest that the real money stock contracts in the three Latin American economies as well. This provides some further support for the notion that foreign central banks tend to follow the lead of the Federal Reserve. The effects are imprecisely estimated. The point estimates are generally larger in magnitude than in the United States, but with larger standard errors. It is worth noting a couple of unusual results. For Chile, the Romer and Romer shocks suggest massive reductions in the real money stock in response to a 100 basis point increase in U.S. interest rates. Similarly for Mexico, the Bernanke-Mihov shocks suggest large reductions in the money supply – on the order of 25%. Uncovering the precise reasons for these anomalous results is a task for further research.

Figure 7 presents the response of bilateral exchange rates to a U.S. monetary contraction. The response of the Canadian dollar exchange rate is small and relatively precisely estimated. This is ironic since the Canadian dollar is famous for floating, while the other currencies were more obviously managed for long periods of time.[22] The responses of the three other currencies (the pesos of Chile, Colombia and Mexico) are all imprecisely estimated. There is not strong evidence that the exchange rate moves greatly following a U.S. monetary policy shock. This is consistent with the lack of evidence in favor of expenditure-switching effects.

4.3. Commodity Prices

Many accounts of the international macroeconomic turmoil of the 1970s blame rising inflation and sluggish output growth on sharp increases in commodity prices. Lustig (1998) argues that the Mexican economy grew slowly during the 1980s because of "adverse external conditions – that is, scarce external credit, unfavorable terms of trade, and high real world interest rates – that prevailed since 1982" (p. 4). Corbo and Fischer (1994) argue that "[t]he [Chilean] recession of 1975 had three major causes. The first was the large drop in the terms of trade, with copper prices falling by about 45 percent in real terms ... and the price of oil rising by a factor of three" (p. 35).[23] In both Chile and Mexico the terms of trade are dominated by movements in commodity prices, since Chilean exports were dominated by copper and Mexican exports by oil at the times in question.[24]

[22]This finding is in line with Bluedorn and Bowdler, who find smaller responses of the Canadian dollar exchange rate than of other exchange rates.

[23]The other two causes they refer to are domestic stabilization and some problems related to the removal of price controls.

[24]Kehoe and Ruhl (2007) show that terms of trade shocks are not the same as productivity shocks, though this intuition is common. Terms of trade changes and productivity changes both affect real consumption. By contrast, while productivity affects real output, changes in the terms of trade do not affect real output in the same way. A fall

Barsky and Kilian (2001, 2004) argue that the high commodity prices in the 1970s were due to loose monetary policy. Could U.S. monetary contractions reduce foreign output by lowering commodity prices? Frankel (2006) discusses a model of commodity prices in which commodities are storable. Storage makes commodities assets, so the return on commodities should be related to rates of return on other assets. High interest rates require high returns on commodity prices, which means lower commodity prices at present, given future prices.

In addition to the dynamic mechanism, static aspects of the economy could impact commodity prices. If demand for a commodity falls after a monetary contraction and supply of the commodity is inelastic, then price movements could be large.[25] In the case of lumber, Myneni, Dorfman and Ames (1994) note that 50% of Canadian softwood lumber production was exported to the United States during the early 1990s. They point out that lumber demand depends on housing starts, which are highly cyclical. Myneni et al. observe that housing starts in the United States fell by 46.8% between 1978 and 1982, a period that includes substantial tightening of monetary policy in the United States. Stock and Watson (1999) show that residential investment is strongly procyclical. They show that the cyclical component of residential investment in the United States is six times more variable than the cyclical component of GDP.

Frankel argues that monetary policy has empirically important effects on commodity prices. However, his least squares regressions of commodity prices on interest rates are likely to be plagued by omitted variables bias. For example, positive aggregate demand shocks probably induce interest rate rises and commodity price rises. Therefore, a least squares regression of commodity prices on interest rates is likely to produce a slope coefficient with a positive bias.

The measures of monetary policy shocks discussed in this paper aim to extract the component of interest rates that is due to the Federal Reserve's response to inflation. As such, they may help ameliorate the endogeneity concerns not addressed in Frankel's work.

Figure 8 presents impulse responses for prices of four significant commodities: lumber, copper, coffee, and oil. The commodity prices are real, having been deflated by the U.S. producer price index. The figure shows the response of each commodity price to each measure of monetary policy shocks.

in productivity reduces output. Terms of trade changes do not affect the constant price value of output unless they induce changes in quantities produced. The common perception, represented by Lustig and by Corbo and Fischer, that changes in the terms of trade affect output depends on such a mechanism.

[25] If demand drops because of a fall in income, then the reduction in price will be related to $\frac{\epsilon_y^d}{\epsilon_p^d+\epsilon_p^s}$, where ϵ's denote elasticities of demand or supply with respect to price or income.

These four commodities are selected by virtue of their central importance in at least one of the foreign economies under study. Lumber is a dominant commodity in Canada. Over most of the sample, oil was an important Mexican export. Mexico was a net exporter of oil in the early 1970s, but substantial discoveries during that decade, together with price increases, raised the fraction of exports accounted for by oil from 15% in 1976 to over 70% in 1981 (Lustig, 1998). Coffee has traditionally been the major export for Colombia. (Cárdenas, 2006, reports that coffee was 60% of nominal Colombian exports in 1980. Over time its importance has diminished significantly, making up less than 10% of Colombia's exports since 2000.) Copper has long been a major export for Chile, and is so central to the Chilean economy that control over copper resources has been a recurring political issue in Chile.

While there is some reason to believe that U.S. monetary policy shocks might affect commodity prices, Figure 8 is not entirely conclusive. In particular, different measures of monetary policy shocks have different implications for commodity prices. Figure 8(a) shows the response of lumber prices. After a Romer and Romer shock, lumber prices fall rapidly to be 25% lower than they would have been, absent the shock, after around one year. After this prices rebound to be near their trend three years after the shock. By contrast, the Bernanke-Mihov and CEE-style shocks suggest much smaller and more transitory lumber price responses. This could be related to the different persistence of the interest rate effects of each shock series.

The response of copper prices (Figure 8(b)) also depends on which measure of monetary policy shocks is used. The Romer and Romer shocks imply large, though more persistent, responses for copper prices than for lumber prices. Copper prices fall by around 10% in real terms following a 100 basis point Romer and Romer shock. The Bernanke-Mihov shock suggests a small initial impact, but this is short-lived, while the CEE-style shock predicts little movement in the copper price.

In Figure 8(c), the real price of coffee is shown to fall around 20% by two years after a 100 basis point Romer and Romer shock, but as with lumber prices, it recovers relatively substantially after that. In contrast to lumber prices, a 100 basis point Bernanke-Mihov contraction leads to sustained reductions in the price of coffee, though the reduction is smaller than for the Romer and Romer shock.

Of all the commodity price responses estimated, the response of oil prices is most imprecisely estimated. According to Figure 8(d), the price of oil falls around 6% in the year following a 100 basis point Bernanke-Mihov shock. The Romer and Romer shock contraction predicts a rise in the real price of oil over a 24 month horizon. The CEE-style shock also suggests that oil prices rise in response to a monetary contraction.

Overall, the evidence regarding commodity price effects of U.S. monetary policy shocks is mixed. The Romer and Romer shock series suggests relatively large responses in some cases. The other shock series offer limited support for the hypothesis that U.S. monetary policy shocks affect commodity prices. The disagreement of different shock measures is an interesting issue, and may be related to the persistence of interest rate responses.

An additional issue, at least for the Romer and Romer shock, is why different commodity prices respond differently. Maybe differential storability among commodities explains their varied responses to the monetary shock. If the price changes are essentially demand driven, then a relatively inelastic supply curve, such as is likely to characterize coffee in the short run, would produce large price changes. Other commodities, such as copper and oil, might have more elastic supply curves since the products can be stored more easily.

5. CONCLUSION

This paper produces empirical evidence relating to the epidemiological view of business cycles. In this view recessions are contagious, and other countries are often infected by the United States. I have studied the effect that U.S. monetary policy shocks have on the economies of a selection of other countries in the Americas.

I identified the effects of such shocks by assuming that the Federal Reserve does not respond to shocks that are idiosyncratic to other countries. On this basis, I used several measures of monetary policy shocks designed to remove the component of Federal Reserve policy that is a response to economic developments affecting the United States.

Overall, contractions in each of the three shock series lead to reductions in economic activity abroad. This suggests an important effect of U.S. monetary policy on economic outcomes in other countries. The impulse response functions show production responding more in each other country than in the United States. The variance decomposition exercise suggests that output would have been around one-third less volatile if U.S. monetary policy shocks were eliminated. In addition, comovement between output in different countries would have been lower.

The transmission of shocks in the United States to other countries does not appear to work through expenditure-switching channels. Most of the evidence on trade channels is more consistent with reductions in import demand due to lower income. The evidence is not consistent with the expenditure-switching hypothesis for two reasons. First, the response of foreign output to a U.S. monetary contraction is the wrong sign. Second, exports to the United States from the other countries examined do not increase persistently in response to a U.S. monetary contraction.

Evidence in this paper favors the view that monetary policy abroad tends to follow the lead of the United States. The strongest evidence is for Canada, despite the famous Canadian commitment to monetary independence. Canadian interest rates rise strongly after a U.S. monetary contraction. As in all other countries, the real money stock in Canada falls following such a shock.

The final point is contingent on which measure of monetary policy is used. The Bernanke-Mihov and Christiano, Eichenbaum, Evans-style shocks suggest little response of commodity prices to U.S. monetary policy shocks. By contrast, the response of several important commodity prices – coffee, lumber, copper and oil – to the Romer and Romer measure of U.S. monetary shocks is consistent with transmission of U.S. shocks via commodity prices. The prices of these important export commodities tend to fall significantly in the wake of a U.S. monetary contraction. To the extent that such price movements disrupt these economies, they could be a large part of the process by which U.S. monetary policy shocks have their impact on foreign output.

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TABLE 1.

Descriptive Statistics for Monthly Production Data Growth Rates

Country	Mean	Standard Deviation	First Autocorrelation	Correlation with U.S. Production	Correlation with U.S. (Annual)	Number of Observations
United States	0.22	0.82	0.25	1.00	1.00	372
Canada	0.24	1.26	-0.09	0.39	0.72	372
Chile	0.22	4.75	-0.34	0.16	0.52	252
Colombia	0.18	3.78	-0.52	0.20	0.38	203
Mexico	0.31	3.65	-0.53	0.23	0.14	323

TABLE 2.

Impact of U.S. Monetary Policy Shocks on Output

	Maximum Response			Month of Max. Response		
Country	CEE-style	BM	Romer	CEE-style	BM	Romer
United States	-1.60	-2.41	-4.36	28	15	28
Canada	-2.71	-3.08	-4.95	28	28	26
Chile	-2.95	-8.04	-9.53	45	37	23
Colombia	-3.25	-4.47	-7.93	28	39	32
Mexico	-1.03	-3.99	-4.80	36	28	37

Notes: The first three columns of figures give the largest deviation of production from its baseline path in response to a 100 basis point monetary policy shock in the United States. The figures in the last three columns give the number of months after the impulse in which the maximum response occurred.

TABLE 3.

Variance Decomposition

	Month-on-month growth			Year-on-year growth		
Country	CEE-style	BM	Romer	CEE-style	BM	Romer
United States	0.16	0.22	0.29	0.32	0.31	0.57
Canada	0.25	0.27	0.20	0.26	0.31	0.41
Chile	0.36	0.46	0.29	0.40	0.50	0.62
Colombia	0.19	0.15	0.20	0.21	0.24	0.46
Mexico	0.07	0.15	0.09	0.12	0.17	0.22

Notes: The figures in the table give the percentage of output growth variance due to the U.S. monetary policy shock.

TABLE 4.

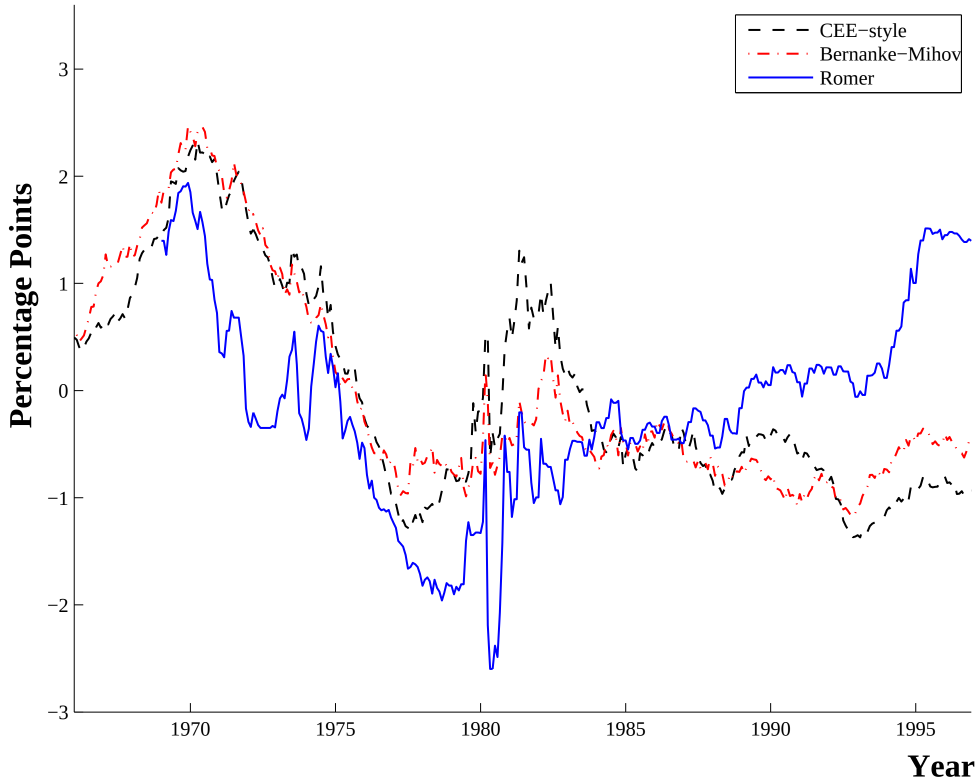
The Effect of U.S. Monetary Shocks on International Output Comovement

	Correlation of month-on-month output growth			
Country	Actual	Without CEE-style	Without BM	Without Romer
USA	1.00	1.00	1.00	1.00
Canada	0.39	0.30	0.25	0.28
Chile	0.16	0.15	0.14	0.11
Colombia	0.20	0.13	0.13	0.08
Mexico	0.23	0.19	0.16	0.19

	Correlation of year-on-year output growth			
Country	Actual	Without CEE-style	Without BM	Without Romer
USA	1.00	1.00	1.00	1.00
Canada	0.72	0.32	0.27	0.32
Chile	0.52	0.18	0.16	0.13
Colombia	0.38	0.13	0.13	0.07
Mexico	0.14	0.23	0.18	0.21

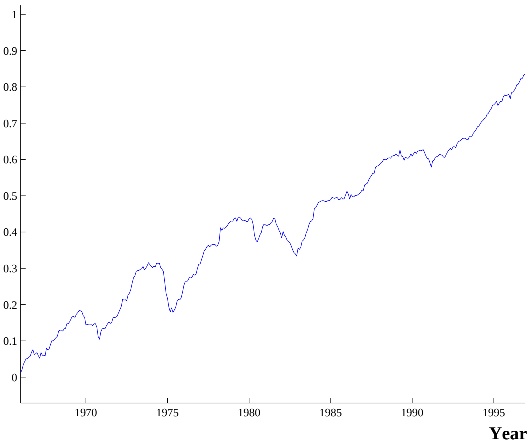
Notes: Figures in the table give the correlation of foreign growth rates with the United States growth rates. The "Actual" column is from Table 1. The counterfactual correlations are computed analytically in a manner analogous to that generating the statistics in Table 3.

FIGURE 1. Cumulated Values of U.S. Monetary Policy Shock Series

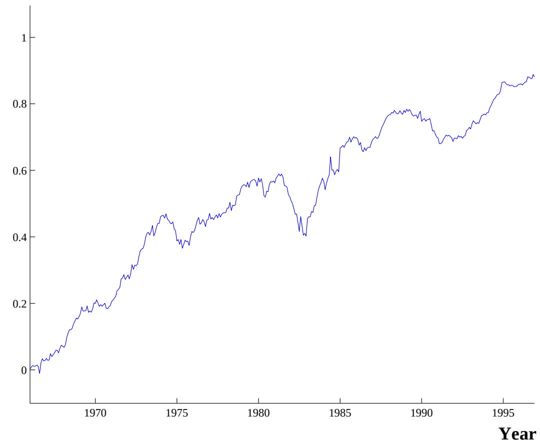


Notes: This graphs presents the cumulated values of the monetary policy shock series. The cumulated series have been studentized so they each have a mean of zero and a unit standard deviation.

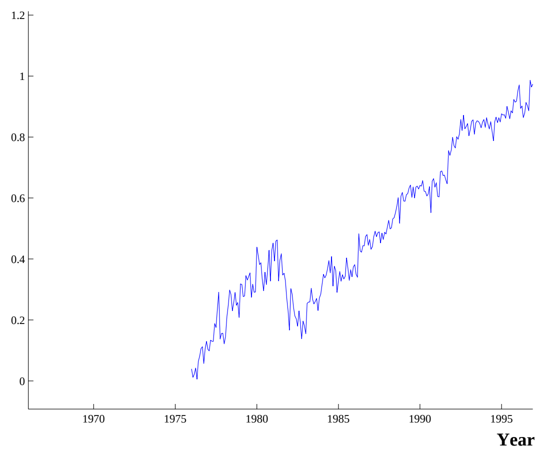
FIGURE 2. Data for Industrial and Manufacturing Production



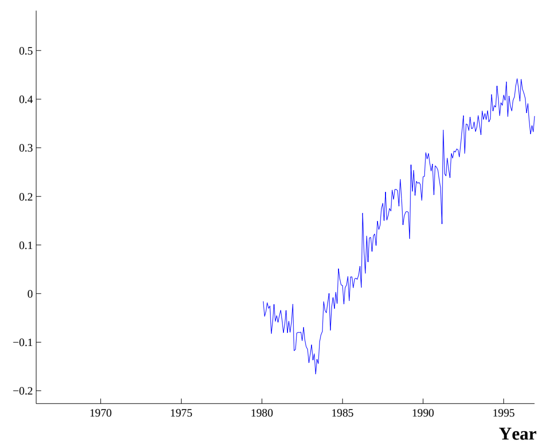
(a) United States.



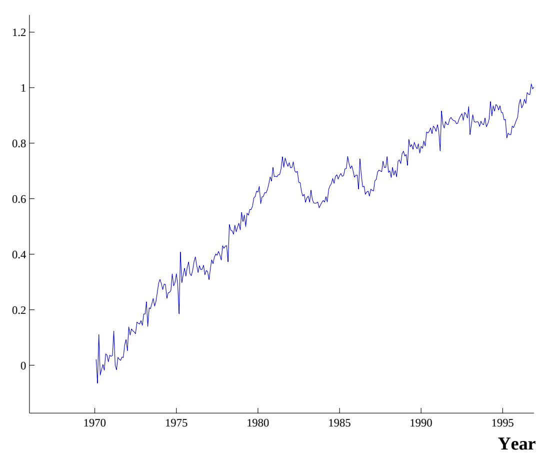
(b) Canada.



(c) Chile.



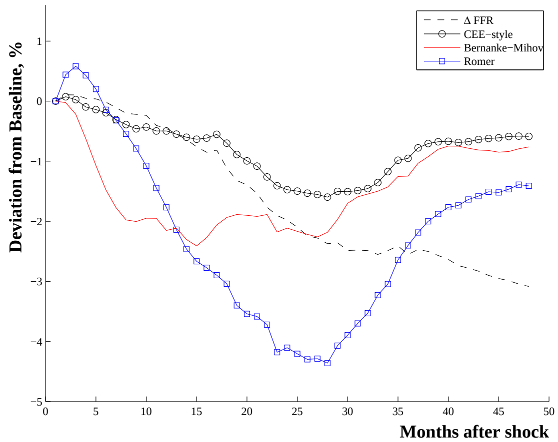
(d) Colombia.



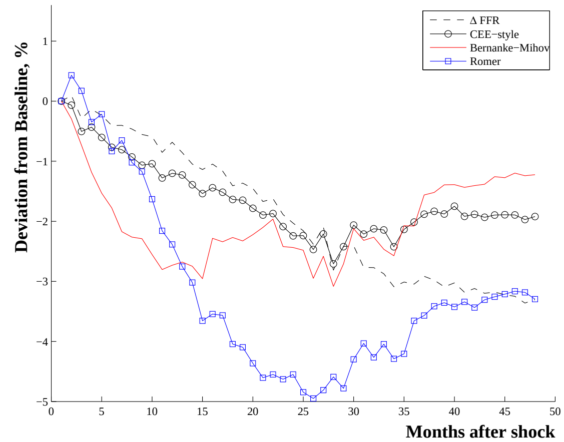
(e) Mexico.

Notes: These figures plot the log of industrial production (for the United States and Canada) or manufacturing production (for Chile, Colombia and Mexico). The data have been seasonally adjusted using the X-12-ARIMA method.

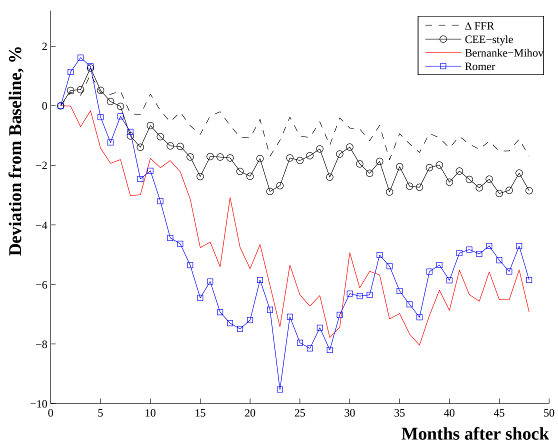
FIGURE 3. Impulse Responses of Production to U.S. Monetary Policy Shocks.



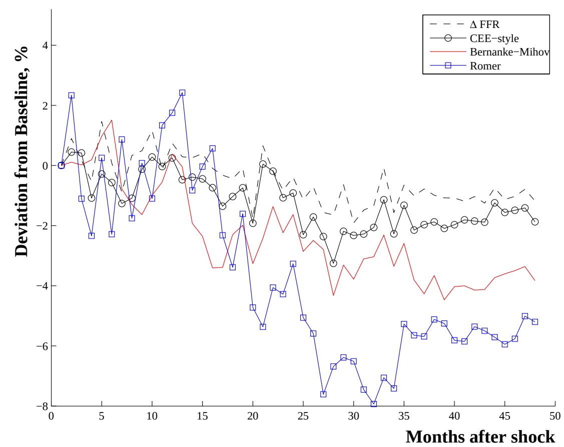
(a) United States.



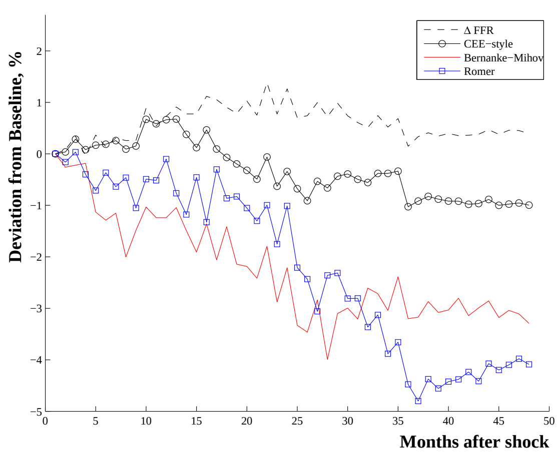
(b) Canada.



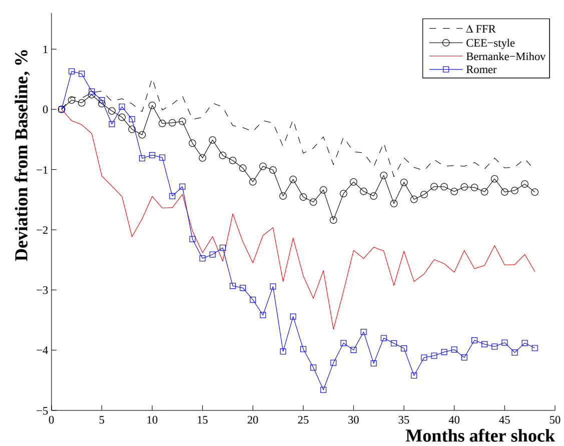
(c) Chile.



(d) Colombia.



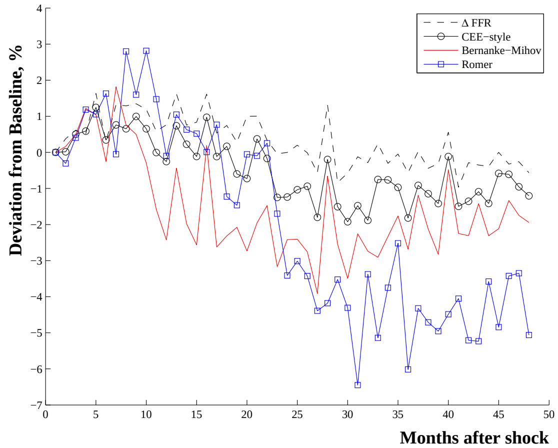
(e) Mexico.



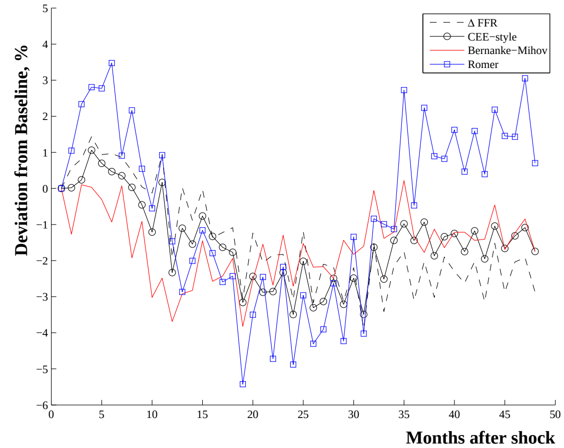
(f) Foreign Countries Pooled.

Notes: These graphs plot the response of production to shocks corresponding to a 100 basis point increase in the federal funds rate.

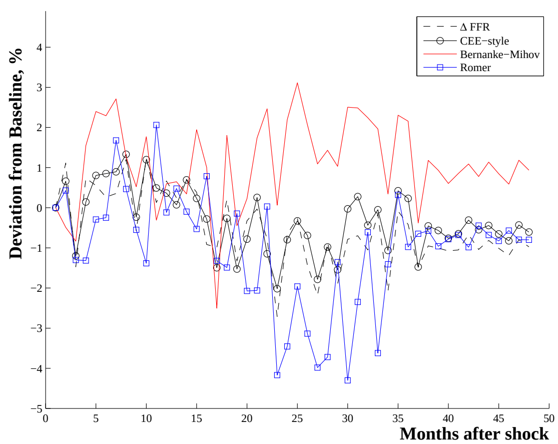
FIGURE 4. Impulse Response Functions for Exports and Imports



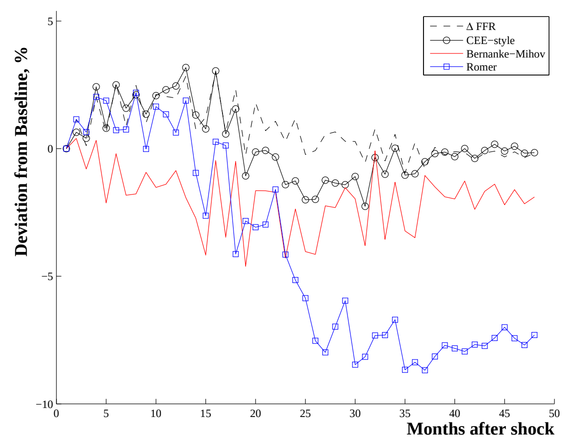
(a) Exports – U.S.A. to all destinations.



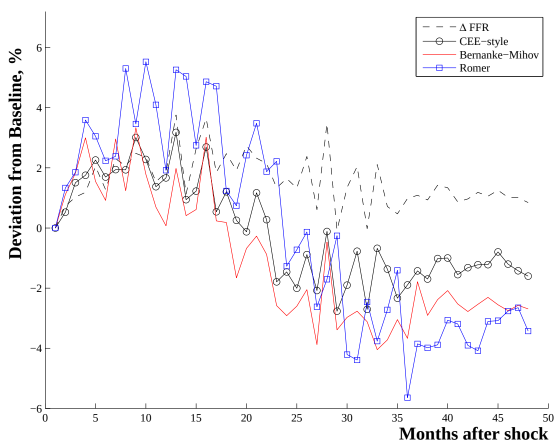
(b) Imports – U.S.A. from all sources.



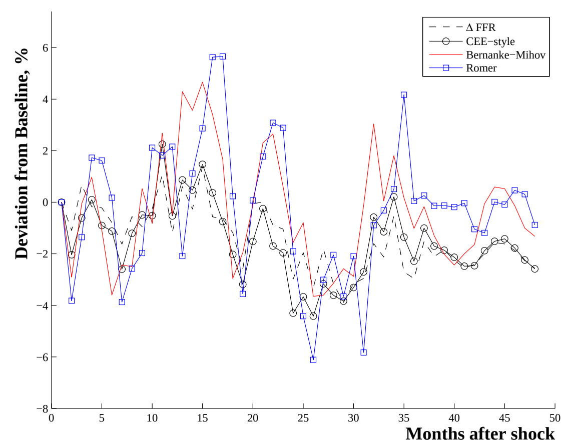
(c) Exports – Foreign Economies, Pooled.



(d) Imports – Foreign Economies, Pooled.



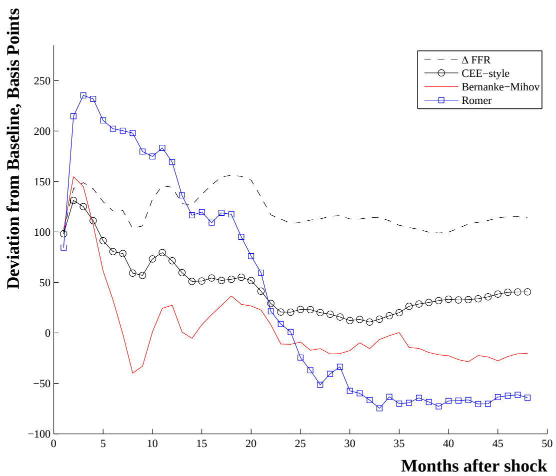
(e) Exports to U.S.A. – Foreign Economies, Pooled.



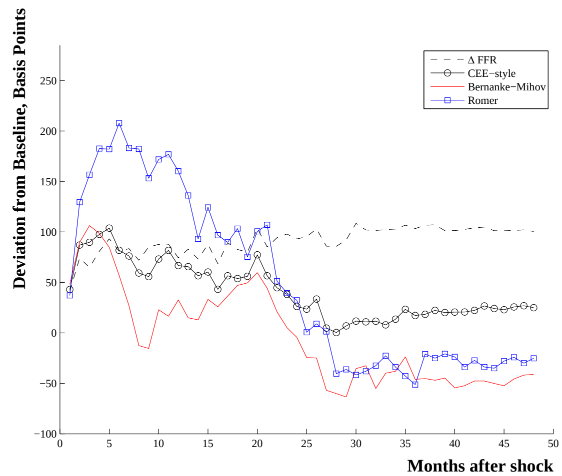
(f) Imports from U.S.A. – Foreign Economies, Pooled.

Notes: These graphs plot the response of real exports and imports to shocks corresponding to a 100 basis point increase in the federal funds rate.

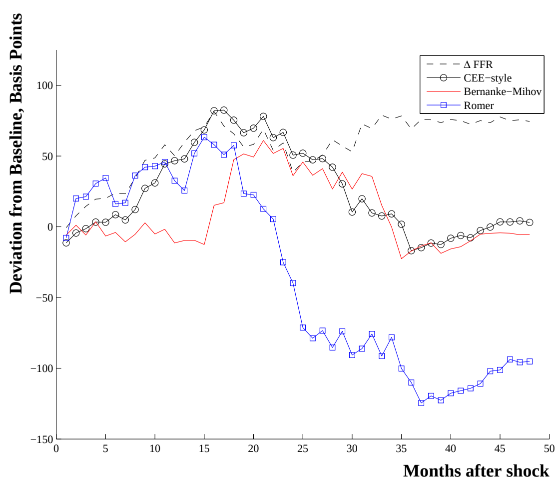
FIGURE 5. Impulse Response Functions for Short-Term Interest Rates.



(a) Federal Funds Rate.



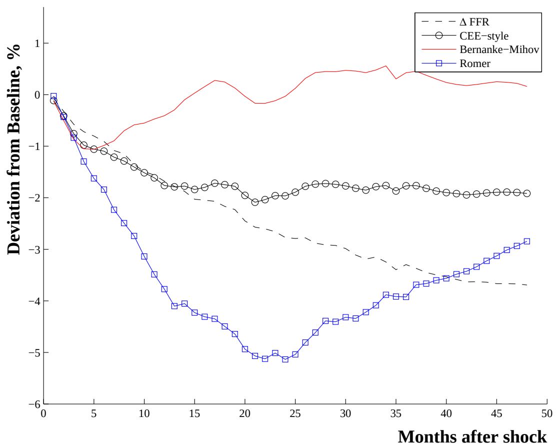
(b) Canadian Overnight Money Rate.



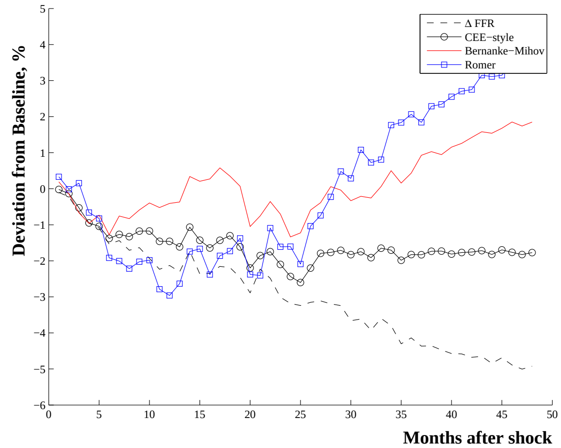
(c) Colombian Discount Rate.

Notes: These graphs plot the response of short-term nominal interest rates to shocks corresponding to a contemporaneous 100 basis point increase in the federal funds rate.

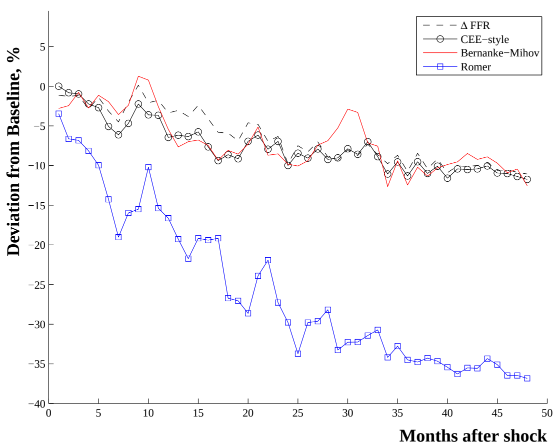
FIGURE 6. Impulse Response Functions for Real M1.



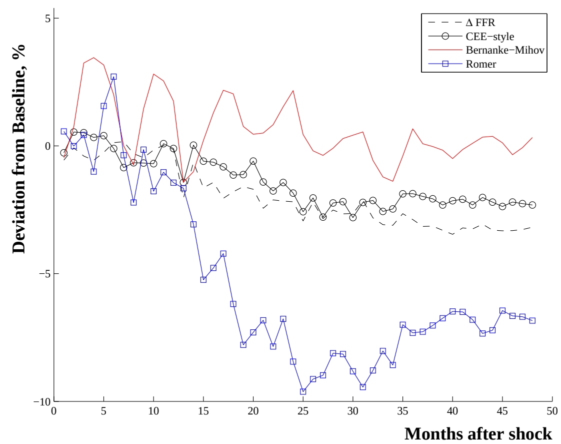
(a) United States.



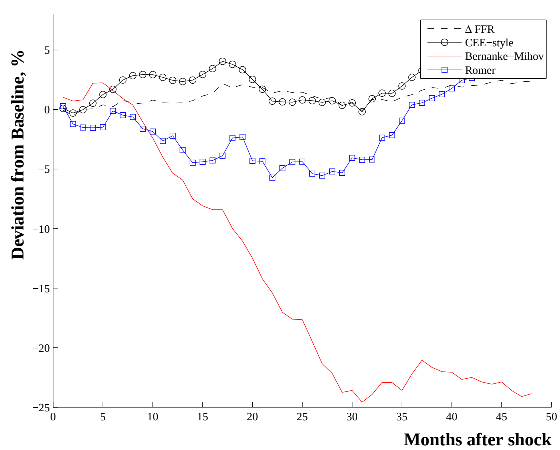
(b) Canada.



(c) Chile.



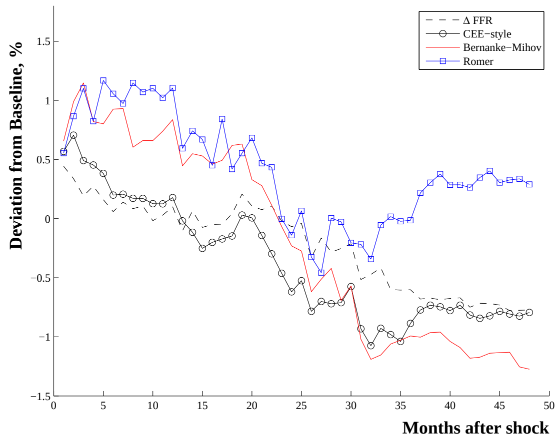
(d) Colombia.



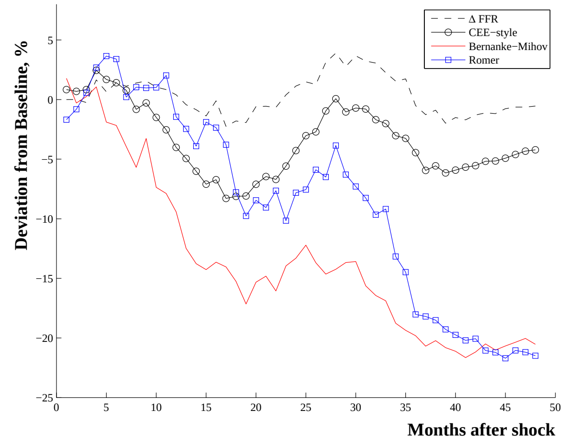
(e) Mexico.

Notes: These graphs plot the response of real M1 – M1 deflated by the consumer price index – to shocks corresponding to a 100 basis point increase in the federal funds rate.

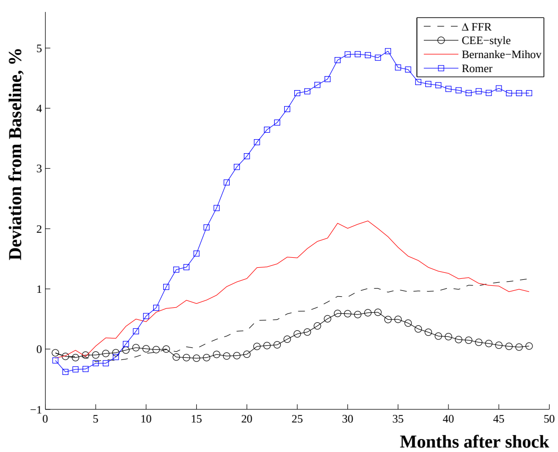
FIGURE 7. Impulse Response Functions for Exchange Rates.



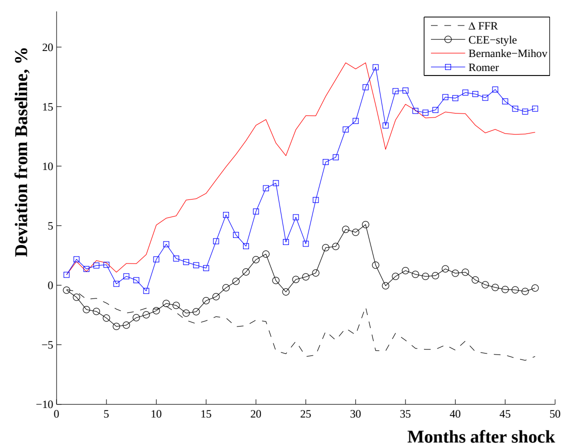
(a) Canada.



(b) Chile.



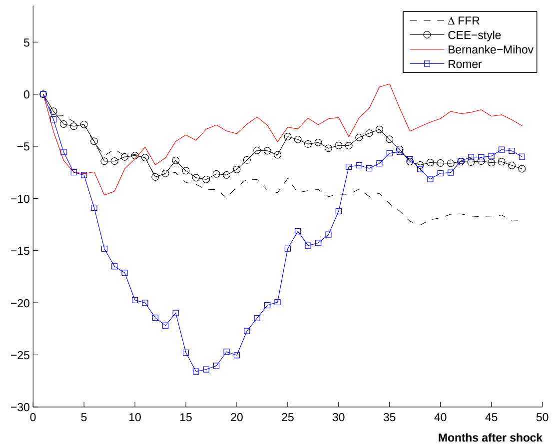
(c) Colombia.



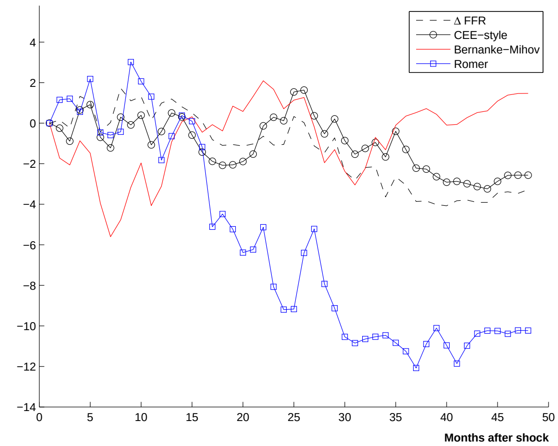
(d) Mexico.

Notes: These graphs plot the response of nominal exchange rates to shocks corresponding to a 100 basis point increase in the federal funds rate. The nominal exchange rate is defined so that an increase represents an appreciation of the U.S. dollar.

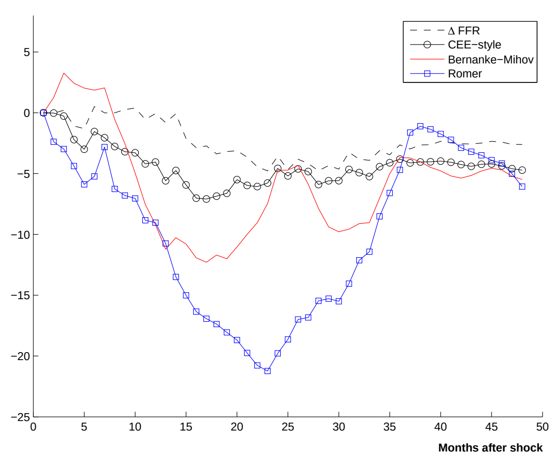
FIGURE 8. Impulse Responses of Commodity Prices.



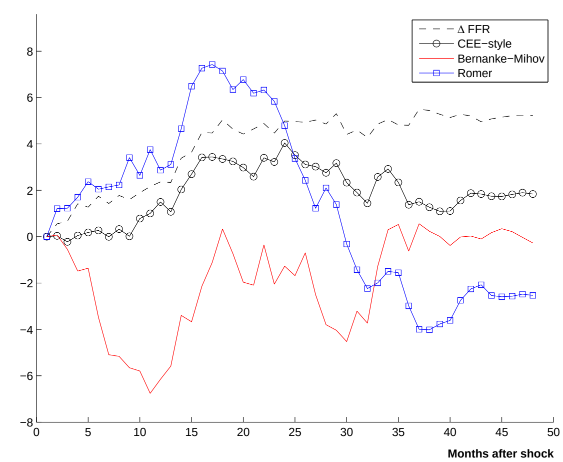
(a) Lumber.



(b) Copper.



(c) Coffee.



(d) Oil.

Notes: These graphs plot the response of real commodity prices to shocks corresponding to a 100 basis point increase in the federal funds rate.

APPENDIX A: DATA

Table A1 gives the sources for data used in the paper. As noted in section 2, there is some concern that the production data in particular may contain significant measurement error. As a check on the production data, sourced from International Financial Statistics I calculated a manufacturing production growth rate for Colombia from a national source covering Colombian historical statistics (Departamento Nacional de Planeación, 1998). The Colombian manufacturing production data are produced by DANE (Colombia's National Statistics Department). The data are based on a monthly survey of 1500 plants. For seasonally unadjusted data, the growth rate from the national source has a correlation of 0.97 with growth rate from the International Financial Statistics data. This suggests the IFS database includes the best quality data available.

While the IFS data are essentially identical to the national data, these data may still be a poor representation of underlying activity in the country in question. Construction of industrial production data in the United States and Colombia is similar, and is based on physical output, labor inputs and energy usage. Could it be that these methods are more suited to measuring output in the U.S.A. than Colombia? Or could it be that the methods are less accurate in Colombia (and elsewhere) than in the United States?

TABLE A1.

Data Sources

Series	Database	Code
U.S. Industrial Production	IFS	11166...ZF...
Canada Industrial Production	IFS	15666..CZF...
Chile Manufacturing Production	IFS	22866EY.ZF...
Colombia Manufacturing Production	IFS	23366EY.ZF...
Mexico Manufacturing Production	IFS	27366EY.ZF...
U.S. Exports	IFS	11170..DZF...
U.S. Imports	IFS	11171..DZF...
Canada Exports	IFS	15670..DZF...
Canada Imports	IFS	15671..DZF...
Chile Exports	IFS	22870..DZF...
Chile Imports	IFS	22871..DZF...
Colombia Exports	IFS	23370..DZF...
Colombia Imports	IFS	23371..DZF...
Mexico Exports	IFS	27370..DZF...
Mexico Imports	IFS	27371..DZF...
U.S. Exports to Canada	DOT	11170..DZF156
U.S. Exports to Chile	DOT	11170..DZF228
U.S. Exports to Colombia	DOT	11170..DZF233
U.S. Exports to Mexico	DOT	11170..DZF273
U.S. Imports from Canada	DOT	11171..DZF156
U.S. Imports from Chile	DOT	11171..DZF228
U.S. Imports from Colombia	DOT	11171..DZF233
U.S. Imports from Mexico	DOT	11171..DZF273
U.S. Export Price Index	IFS	11176...ZF...
U.S. Import Price Index	IFS	11176.X.ZF...
Oil Price	Global Financial Database	__WTC_D
Lumber Price	Global Financial Database	CMLBM
Coffee Price	Global Financial Database	CMKCMANM
Copper Price	Global Financial Database	__CU_NYD

TABLE A1—*Continued*

Series	Database	Code
Federal Funds Rate	FRED	DFF
Canada Overnight Interest Rate	Global Financial Database	IMCAND
Colombia Discount Rate	IFS	23360...ZF...
U.S. Non-borrowed Reserves	FRED	BOGNONBR
U.S. Total Reserves	FRED	TRARR
U.S. M1	IFS	11159MA.ZF...
Canada M1	IFS	15659MA.ZF...
Chile M1	IFS and *Boletin Mensual*	22859MA.ZF...
Colombia M1	IFS	23359MA.ZF...
Mexico M1	SourceOECD	none given
Canadian Dollar Exchange Rate	Global Financial Database	__CAD_D
Chilean Peso Exchange Rate	Global Financial Database	__CLP_D
Colombian Peso Exchange Rate	Global Financial Database	__CAP_D
Mexican Peso Exchange Rate	Global Financial Database	__MXN_D
U.S. Consumer Price Index	FRED	CPIAUCNS
Canada Consumer Price Index	Global Financial Database	CPCANM
Chile Consumer Price Index	Global Financial Database	CPCHLM
Colombia Consumer Price Index	Global Financial Database	CPCOLM
Mexico Consumer Price Index	Global Financial Database	CPMEXM
U.S. Producer Price Index	FRED	PPIACO

Notes: IFS is the International Monetary Fund's International Financial Statistics. DOT is the International Monetary Fund's Direction of Trade database. FRED is the Federal Reserve Economic Data maintained by the St Louis Federal Reserve Bank. *Boletin Mensual* is the the monthly bulletin of the Banco Central de Chile.