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Spillovers Across NAFTA

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Abstract

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This paper examines linkages across North America by estimating the size of spillovers from the major regions of the world—the United States, euro area, Japan, and the rest of the world—to Canada and Mexico, and decomposing the impact of these spillovers into trade, commodity price, and financial market channels. For Canada, a one percent shock to U.S. real GDP shifts Canadian real GDP by some ¾ of a percentage point in the same direction—with financial spillovers more important than trade in recent decades. Thus, a large proportion of the reduction in Canadian output volatility since the 1980s can be accounted for by the "Great Moderation" in U.S. growth. Before 1996, domestic volatility in Mexico swamped the contribution of external factors to the business cycle. After 1996, the response of Mexican GDP is 1½ times the size of the U.S. shock—"when the U.S. sneezes, Mexico catches a cold". These spillovers are transmitted through both trade and financial channels.

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I. INTRODUCTION

The last two decades have witnessed an acceleration in globalization, as trade and cross-border holdings of financial assets have grown more quickly than economic activity in most regions of the world. In North America, free trade agreements implemented between Canada and the United States (CUSFTA) in 1989 and both those countries and Mexico (NAFTA) in 1994 preceded an especially dramatic rise in interconnectedness, despite the high degree of integration that was already prevailing.

From 1988 through 2000, U.S.-Canada trade expanded from 37 percent of Canadian GDP to 65 percent, before falling back some recently (Figure 1). Cross-border holdings of financial assets went from 53 percent of Canadian GDP in 1988 to over 90 percent in 2006. Mexico-U.S. trade jumped from 23 percent of Mexican GDP in 1993 to over 40 percent in recent years. Some of the increase was a result of the 1994/95 economic crisis, but the implementation of NAFTA also hastened a rising trend, as Mexico-U.S. trade had been less than 10 percent of Mexican GDP before 1980. Financial integration has also advanced, with cross-border holdings nearing 50 percent of Mexican GDP, up from 25 percent in 1990.

The rapid tightening in integration between the United States and its NAFTA partners provides an opportunity to examine business cycle synchronization and spillovers of economic activity across countries in an environment of increasing globalization. The question is one of empirics, as economic theory provides no clear answer to the effects of either higher trade intensity or tighter financial linkages on output comovement.[1]

The main challenge in determining the source of spillovers across countries is to identify the size and provenance of shocks to each economy. Business cycle comovement could come from similar responses to common shocks, domestic factors that are correlated over the sample period but are unrelated across countries, or true spillovers—the response of growth in one country to conditions emanating from another.

Given the long history of substantial international business cycle fluctuations, the importance of common or global factors in national output fluctuations is widely recognized (see, for example, Bordo and Helbling, 2004). Consequently, a large body of literature has sought to measure the contribution of common factors to national business cycle fluctuations. In recent studies, dynamic factor models have been the preferred approach since these models reduce common variations across individual countries to a small number of significant but unrelated factors (see Gerlach, 1988, Gregory, Head, and Raynauld, 1997, Kose, Otrok, and Whiteman, 2003, and Stock and Watson, 2005).

[1] See Calderón, Chong, and Stein (2007) or Kose, Prasad, and Terrones (2004) for discussions of the impact of integration on business cycle comovement.

The common factors in such studies, however, are typically difficult to interpret, because basic factor model decompositions are atheoretical and lack a structural identification scheme. The common factor could reflect global shocks, spillovers from one country to others, or idiosyncratic shocks that happen to be correlated across countries.[2] This type of analysis leaves unanswered questions such as whether or not U.S. shocks account for a significant share of common output fluctuations.[3]

This paper uses an approach introduced in Bayoumi and Swiston (2007) to solve this identification issue. We construct an aggregate of smaller countries as a proxy for global shocks, which we call "the rest of the world". The rest of the world contains a set of countries that is varied in terms of both geography and industrial structure. Given the diversity of the constituent countries, any shock to this aggregate is a strong candidate for a global disturbance. Spillovers from the rest of the world to other regions can be regarded as a reasonable measure of the impact of global shocks, provided that none of the individual economies involved are likely to have significant direct effects on the economies under analysis.

This method is able to accurately identify the effects on Canada and Mexico of global shocks and of those emanating from other regions. We find that a positive shock of one percentage point to U.S. GDP growth brings about a ¾ percentage point rise in Canadian growth, with little variation across subsamples. For Mexico, the response since 1996 is 1½ percentage points; previous periods are dominated by idiosyncratic domestic factors. Neither country is highly sensitive to shocks from the euro area or Japan, while global shocks have been increasing in importance for both countries in recent decades.

We also use this identification scheme to identify the major channels through which spillovers are propagated—trade, commodity prices, and financial markets. Trade and financial market linkages both contribute to U.S. spillovers, with the latter becoming increasingly important for both countries. For Canada, financial markets transmit about a quarter of spillovers from the U.S. before 1989 and more than a half since then, while the contribution of trade has declined modestly, from 50 to 40 percent. Trade accounted for 60 percent of U.S. spillovers to Mexico over the 1970-2007 period, but has decreased to 40 percent since 1996, mirrored by a rise in the contribution of financial spillovers to 60 percent from 40 percent.

[2] See, for example, Canova and Dellas (1993). There are other problems as well. For example, if countries respond differently to some common shock, say, for example, because of differences in economic structure, the estimated common factors may or may not capture the effects of these common shocks, depending on the stringency of the restrictions on the dynamic structure of the underlying model.

[3] Stock and Watson (2005) allow for lagged spillovers of country-specific shocks, but this still leaves contemporaneous shocks unidentified.

II. Identifying Spillovers in a Vector Autoregression

As explained above, examining the dynamic response of growth across countries in a vector autoregression (VAR) presents a problem in identifying the size and location of shocks to growth. In order to estimate impulse response functions, the errors across individual equations are typically orthogonalized using a Cholesky decomposition, which assumes that all of the correlations between errors are assigned to the equation that is earliest in the ordering. For example, in a 3-variable VAR, all of the correlation between the residuals in the first equation and the second and third ones is assigned to the first, while any remaining correlation between the errors in the second and third equations is assigned to the second. This approach works well if there is a relatively clear ordering for the Cholesky decomposition, but such strong assumptions are unlikely to hold in a VAR containing growth across countries.

This paper uses a quasi-Bayesian approach to identification within a VAR framework, introduced in Bayoumi and Swiston (2007).[4] They average results across a number of "plausible" Cholesky orderings, which acts as a mechanism for assigning priors to the direction of causality. The probability that spillovers originate in country A as opposed to country B is equal to the proportion of Cholesky orderings in which A is ahead of B. These probabilities are then modified by the variance-covariance matrix of the errors in the VAR to arrive at an estimate of the magnitude of spillovers between the two countries. Note that this updating depends only on the parameters of the variance-covariance matrix and not on the full probability distribution, which is used in traditional Bayesian methods.[5]

The underlying approach can be illustrated using a two variable VAR. Consider the matrix A that transforms the estimated errors e from such a VAR into orthogonalized errors ε. Mathematically, $\varepsilon = A\,e$. For the two possible Cholesky decompositions, the matrix A is:

$$A = \begin{pmatrix} 1 & -\dfrac{\sigma_{12}}{\sigma_{11}} \\ 0 & 1 \end{pmatrix} or \begin{pmatrix} 1 & 0 \\ -\dfrac{\sigma_{12}}{\sigma_{22}} & 1 \end{pmatrix} \tag{1}$$

where σ_{ij} is the relevant entry in the estimated variance-covariance matrix of the equation errors (for example, σ_{11} is the variance of the error on the first variable in the first equation). The zeros in the lower left cell of the first matrix and the upper right cell of the second

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[4] The discussion here closely follows that paper.

[5] For approaches that use Bayesian techniques to update forecasts across models see Sala-i-Martin, Doppelhofer, and Miller (2004) and Leamer (1978). See Wright (2003) for a discussion and application of Leamer's Bayesian model averaging technique.

indicate that in each of these decompositions contemporaneous feedback between the two variables flows in only in one direction.

By putting weight on both decompositions, however, this procedure allows contemporaneous spillovers in both directions. The user assigns a weight of α to the first Cholesky decomposition and $(1-\alpha)$ to the second. The matrix that orthogonalizes the equation errors becomes:

$$A = \begin{pmatrix} 1 & -\alpha \dfrac{\sigma_{12}}{\sigma_{11}} \\ -(1-\alpha)\dfrac{\sigma_{12}}{\sigma_{22}} & 1 \end{pmatrix} \tag{2}$$

While the weight α defines the prior probability on the source of contemporaneous correlation between the two error terms, this prior is modified by the estimated parameters of the variance-covariance matrix of errors $(\sigma_{11}, \sigma_{12}, and\, \sigma_{22})$. Mathematically,

$$\frac{a_{12}}{a_{21}} = \frac{\alpha}{(1-\alpha)} \frac{\sigma_{22}}{\sigma_{11}} \tag{3}$$

where a_{ij} is the relevant entry of the matrix A. The relative importance assigned to each possible direction of causation, and thus the estimated magnitude of spillovers, depends on both the prior (α) and on the variances of the equation errors $(\sigma_{11}\ \&\ \sigma_{22})$, which are not affected by the ordering of the variables. This updating of the priors by the distribution of the error terms turns out to be important in interpreting the results, as discussed below.

The intuition of this example can be generalized to the n-variable case, with the complication that adding variables to the VAR makes it more difficult to define the errors in each equation (the *e*'s), as account has to be taken of correlations with errors from a greater number of equations. But, once this has been done, the rest of the logic of this two-variable case holds.

It is also possible to calculate how uncertainty across Cholesky orderings adds to the variance around the impulse response functions, over and above the standard error associated with the parameter uncertainty of the VAR. Sticking with the 2-variable example, let $\bar{x}_t$ represent the average impulse response for period *t* across the two decompositions (so that $\bar{x}_t = \alpha \bar{x}_{1t} + (1-\alpha)\bar{x}_{2t}$). The variance of the impulse response function can be written:

$$\begin{aligned} E(x_{ijt} - \bar{x}_t)^2 = {} & \alpha^2 E(x_{1jt} - \bar{x}_{1t})^2 + 2\alpha(1-\alpha)E(x_{1jt} - \bar{x}_{1t})(x_{2jt} - \bar{x}_{2t}) + (1-\alpha)^2 E(x_{2jt} - \bar{x}_{2t})^2 \\ & + \alpha^2 E(\bar{x}_{1t} - \bar{x}_t)^2 + (1-\alpha)^2 E(\bar{x}_{2t} - \bar{x}_t)^2 \end{aligned} \tag{4}$$

where subscript i on the left-hand side indicates the different orderings (1 and 2). Variation across orderings produces the two terms in the second line of (4), which we call specification uncertainty. Subscript j indexes the individual observations represented in the sample from which the standard errors are calculated. This generates the three terms in the first line of (4), reflecting the familiar uncertainty associated with each individual identification scheme, coming from the imprecision with which the coefficients of the VAR are estimated (recall that the coefficient estimates are independent of the choice of ordering).

Given that the individual identification schemes differ only in their assumptions about the ordering of the variables, the errors across individual orderings are likely to be highly correlated. Accordingly, we assume that the correlation across different orderings is unity. Under this assumption, the first line of (4) can be approximated by taking the weighted average of the variances of each of the decompositions. The second line of (4) reflects the uncertainty due to variation in the response across orderings and is simply the variance of the response across these decompositions.

Hence, the uncertainty associated with identification can be approximated by simply adding the variance of the impulse responses across identification schemes to the variance associated with parameter uncertainty. Given our assumption of a perfect correlation of errors associated with parameter uncertainty across orderings, this is an upper limit for the true value of this variance. This procedure can again be generalized to the n-variable case.

III. Where do Shocks to Canada and Mexico Originate?

This section uses a VAR containing quarterly real GDP growth, with four lags, to isolate the geographic sources of disturbances to growth in Canada and Mexico.[6] Estimation starts in 1970, beginning with the availability of estimates for the euro area from Fagan, Henry, and Mestre (2005). The data extend through the second quarter of 2007. Results are also presented for subsamples corresponding with periods of greater integration with the United States. For Canada, the sample break date is set at 1989, when the CUSFTA came into effect. The sample break date for Mexico is 1996—two years after the implementation of NAFTA, in order to exclude the effects of the Tequila crisis of 1994-5.

The regions included are the United States, the euro area, Japan, and the rest of the world aggregate, comprising the GDP of several smaller countries. It includes eight industrial countries—Australia, Canada, Denmark, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom—and four emerging markets—Korea, Mexico, South Africa, and Taiwan. In all, the rest of world aggregate contains eleven countries, as Canada or Mexico

[6] While conventional tests indicated a shorter number of lags (which varied across specifications) four lags were chosen, as, in addition to being a natural choice for quarterly data, it is consistent with the specifications used in Stock and Watson (2005) and Perez, Osborn, and Artis (2006).

are dropped when the country is under analysis. The rest of world growth rate is formed by weighting each country's growth rate by its GDP at purchasing power parity.[7]

The priors on the correlation of Canadian and Mexican VAR residuals are formed by averaging results across the following eight orderings for the Cholesky decomposition:

1. US, EA, JP, ROW;
2. US, JP, EA, ROW;
3. US, EA, ROW, JP;
4. US, JP, ROW, EA;
5. ROW, US, EA, JP;
6. ROW, US, JP, EA;
7. EA, ROW, JP, US;
8. JP, ROW, EA, US.

In numerical terms, the above priors give, for example, a fifty percent probability that the correlation between Canadian, U.S. and rest of world shocks is driven by the U.S., and fifty percent that it is driven by the rest of the world. The other probabilities are 75:25 U.S.-euro area and U.S.-Japan, and 50:50 euro area-Japan, rest of world-euro area, and rest of world-Japan. In all cases, Canada or Mexico is ordered last, assuming that any contemporaneous correlation between their residuals and those of the major regions is driven by the larger economies. Given this "small country" assumption, results are not shown for the impact of Canada or Mexico on the other regions.[8]

A. The Evolution of Domestic Shocks and Correlations Over Time

The residuals from the VAR described above (which do not vary with the Cholesky ordering) give a picture of the variance of domestic shocks, and the degree to which they are correlated with disturbances in other countries. As shown in Table 1, Canada's shocks have experienced a sizable reduction across subsamples. The five-fold decline in the magnitude of domestic shocks is paralleled only in the United States, while the volatility of euro area and rest of the world shocks is two to three times lower in the second half of the sample, and fifty percent lower for Japan. These results, on a different sample period, are consistent with the findings of Stock and Watson (2005) and International Monetary Fund (2007a), while Perez, Osborn, and Artis (2006) find a more pronounced drop in European than Canadian or U.S. shocks.[9]

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[7] The countries included are based on availability of quarterly real GDP dating back to 1970. Results were similar using only the small industrial countries, and for equally-weighted aggregates.

[8] Canada or Mexico could theoretically impact other regions through the lagged impact of their shocks, but we found that the impact was not statistically significant. For more detail on the size of shocks and IRFs across the major regions, see Bayoumi and Swiston (2007).

[9] However, their sample breaks in 1979, which is before the break in U.S. volatility estimated by Stock and Watson (2003) and McConnell and Perez-Quiros (2000), among others. They also include the United Kingdom

(continued…)

The correlation of Canadian shocks with impulses elsewhere has also fallen in recent decades—from 0.38 to 0.30 for the United States and from 0.30 to 0.18 for the rest of the world. Meanwhile, the correlation with euro area and Japanese shocks have turned from slightly positive to slightly negative. These lower correlations combine with the smaller magnitude of external shocks to cause an even greater proportionate reduction in the covariance of Canadian shocks with those elsewhere. Thus, both domestic and external factors have contributed to a decline in the volatility of the Canadian economy.

For Mexico, the most striking fact is that the variance of domestic shocks through 1995 is more than twice as large as any of the major economies of the world (Table 2). This reflects the high degree of domestic volatility, as Mexico experienced three recessions from 1980 through 1995, in which output declined by an average of over 7 percent from peak to trough. By contrast, output in the United States fell by an average of slightly over 2 percent in the three recessions during this period. Mexican shocks decline by a factor of four since 1996.

The correlation of Mexico's shocks with those elsewhere is broadly stable across sample periods, except in the case of the United States, where it triples after 1996. This offsets some of the reduced size of U.S. shocks and keeps the covariance between the two shocks at two-thirds its pre-1995 level. For other regions, the covariances fall by at least a factor of three. In all, external developments were propitious for the Mexican cycle in this period, while domestic stability was the most important factor in the reduced volatility of the economy.

B. Size of Spillovers to Canada

Figure 2 contains impulse response functions (IRFs) showing the impact on Canadian GDP of shocks to the United States, euro area, Japan, and rest of world for the 1970-2007 period. The left-hand column includes the average response across the eight Cholesky orderings given above, with ± two standard error bands that only account for coefficient uncertainty, and an additional set of bands incorporating the specification uncertainty discussed above. The right-hand column compares the average to the IRFs for Cholesky orderings 1, 5, and 7, thus testing the robustness of the results to the extreme assumptions that any contemporaneous correlation between the shocks of various regions is dominated by the United States, rest of world, or euro area, respectively.[10]

Spillovers from the United States are large and statistically significant drivers of the Canadian business cycle. Canada's initial response to a typical U.S. shock is ¼ percentage point and rises to almost a full percentage point after two years. With innovations to U.S. GDP averaging over one percentage point in this period, the response of Canadian growth is

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in the European aggregate. As shown by Stock and Watson (2005) and Perez, Osborn, and Artis (2006), the decline in domestic shocks there has exceeded that in the other major economies of Europe.

[10] Full results for these orderings including standard errors are available upon request.

fully 75 to 80 percent as large as the original shock. This lines up with the findings of a number of other authors, including Stock and Watson (2005); Perez, Osborn, and Artis (2006); and, with different methodologies, Perez, Osborn, and Sensier (2007); and Ambler, Cardia, and Zimmermann (2004).[11] There is almost no influence on Canada of shocks to the euro area or Japan. Canada's response to rest of world growth is just below ½ percentage point. Although the initial impact of global shocks is on par with that from U.S. shocks, their effects accumulate less over time than U.S. spillovers do.

The estimated response of the Canadian economy to U.S. shocks is remarkably robust to uncertainty across the Cholesky orderings, as evidenced by the narrow gap between the two sets of standard error bands in the left-hand column of Figure 2, and by the lack of variation across responses in the graph in the right-hand column. Variation across orderings is most noticeable in the response of Canadian GDP to global shocks. Spillovers are higher when the rest of the world is ordered before the United States and are statistically significant, but are only statistically significant for one quarter when the United States is given primacy in the ordering. Even though the correlation between euro area and global shocks is just as high as that between U.S. and global shocks, the effects of rest of world spillovers are not sensitive to the relative position of the euro area.

The uncertainty over Canada's response to the rest of the world stems almost entirely from the high correlation between global and U.S. shocks in the volatile 1970s and early 1980s (Figure 3). For the 1970-1988 subsample, the impact of global shocks on Canadian GDP was statistically significant for the first two to three quarters only when the rest of the world was ordered ahead of the United States. The post-1988 results are insensitive to the ordering—the response is significant for one year after impact before fading. The finding of statistically significant spillovers from the rest of the world also validates the use of the aggregate as a proxy for global shocks, as none of these countries in themselves would be expected to have a significant effect on the Canadian economy. Spillovers from the euro area are close to zero in all periods, while for Japan there is the counterintuitive finding of significant negative spillovers since 1989, although the idiosyncratic behavior of the Japanese business cycle over this period may explain this result without implying causality.

Results by subsample indicate that spillovers from the United States are stable over time once the volatility of U.S. shocks is taken into account. The response of Canadian GDP has been nearly halved since CUSFTA implementation, from 1.1 to 0.6 percentage points (Figure 3). However, the entire reduction can be attributed to the decline in U.S. volatility, as the magnitude of U.S. shocks has fallen from 1.5 to 0.8 percentage points (Figure 4), while the 70 to 80 percent response of Canadian GDP to U.S. shocks has remained broadly stable before and after CUSFTA implementation. The size of the reduction in U.S. disturbances is

[11] Other estimates range from 0.5 (International Monetary Fund, 2007b and Klyuev, 2007) to 1.0 (Schmitt-Grohé, 1998) percentage points.

unique among the major regions, as shocks to the euro area and rest of world did not vary much across the subsamples, while the decline in Japanese shocks was less pronounced. Meanwhile, the magnitude of Canadian shocks has been steady at 0.6 to 0.8 percentage points over a one to two year horizon.

Rolling regressions confirm the stability of the Canadian response to U.S. shocks. We estimated the same eight VARs described above, over eleven year rolling windows. The bottom panel of Figure 4 shows the ±1 standard error bands of the impulse response function at an eight quarter horizon averaged across these VARs, with the estimation window ending in the period indicated on the x-axis. All shocks are normalized to one percentage point, and the full sample response across eight VARs, 0.84, is shown for comparison. There is no visible trend in the rolling estimates. They indicate a response above the full sample average in windows ending from 1991 to 2001, and below average spillovers before and after, but no statistically significant breaks, as even the ±1 standard error bands encompass the full sample response in all periods except one.

Lower output volatility in the United States explains the entire decrease in spillovers to Canada. This points to the importance of the great moderation in U.S. output in reducing volatility in Canada.The effects of increased integration, then, appear to be slight, or offset by still other factors, as the Canadian response as a proportion of U.S. shocks has been steady. Overall, variance decompositions attribute over 40 percent of the variability in Canadian growth to external factors, with the proportion rising to over 60 percent since 1989 (Table 3). Part of this rise can be attributed to the negative correlation with the Japanese business cycle and is probably spurious. At the same time, the importance of global shocks has more than doubled, with its increased share coming at the expense of the United States, euro area, and Canada.

C. Size of Spillovers to Mexico

Given that the variance of idiosyncratic shocks to the Mexican economy swamps that coming from abroad before the 1990s, this section briefly analyzes the full sample and 1970-1995 results before concentrating on the 1996-2007 period, when the identification of spillovers becomes more clear because the role of external factors in Mexican growth is more precisely estimated. However, even those estimates need to be interpreted with some caution, given that they only cover one full business cycle. In this section, the rest of world aggregate includes Canada and excludes Mexico.[12]

The full sample results in Figure 5 show that there was a moderate positive response of Mexican GDP to activity in the United States, euro area, and Japan over the full sample, with

[12] Including both Canada and Mexico as individual countries in the same VAR showed no significant spillovers between the two countries.

a zero average response to global shocks, perhaps because global oil shocks that were negative for the rest of the world had some positive elements for Mexico. There are no statistically significant spillovers for the average across eight orderings, although shocks from each of the first three regions are mildly significant when given primacy in the ordering. The right-hand column of Figure 5, with results for the 1970-1995 subsample, illustrates the difficulty of identifying the effects of external shocks in the presence of a high degree of domestic volatility, as the standard error bands are quite wide.

Moving to the post-crisis period, the response of Mexican growth to external fluctuations is more precisely estimated, despite the reduction in degrees of freedom coming from a smaller sample size (Figure 6). Since 1996, the typical one standard deviation shock to U.S. GDP has resulted in a 1¼ percentage point response of Mexican GDP. The impact starts small, at ⅓ percentage point, and builds over the first year and a half after impact to become more than 1½ times the size of the U.S. shock. The greater than one-for-one response is also found in Österholm and Zettelmeyer (2007) for GDP; Chiquiar and Ramos-Francia (2005) for manufacturing production; and Bergin, Feenstra, and Hanson (2007) for maquiladora assembly industries.

In contrast to the increased spillovers from the United States, linkages to other regions remain low. The average response to the euro area and Japan is minimal, while the response to global disturbances peaks at ½ percentage point. The right-hand column of Figure 6 shows that, as for Canada, the point estimates for the euro area and rest of world are higher when they precede the United States in the Cholesky ordering, but the differences are minor. Mexico’s response to U.S. shocks is robust across all orderings, while euro area and rest of world spillovers are mildly significant in early quarters when their shocks are ordered first.

Figure 7 shows the shocks by subsample for each region, including standard errors for the later subsample to highlight the period since 1996. As seen in the Canada analysis, fluctuations in U.S. and Japanese GDP have fallen compared to earlier decades, while global and euro area shocks show less variation by subsample. The starkest change, though, is for shocks to Mexican GDP, which were an order of magnitude larger than those of any major economies from 1970-1995, but fell by a factor of four and have been smaller than U.S. and Japanese shocks since 1996. The third panel on the right shows the dramatic increase in Mexico’s response to U.S. shocks.

Rolling VARs confirm the upward shift in the sensitivity of the Mexican economy to U.S. shocks. The bottom panel of Figure 7 reports the response of Mexican GDP after eight quarters, ±1 standard error, to a one percentage point shock in the United States. The estimation window is eleven years, so that the final runs roughly match the post-crisis period. There is a definite upward break and narrowing of the standard errors once the 1994-95 crisis drops out of the sample, but the graph also highlights the brief period of time over which the result holds. Thus, the estimated post-NAFTA spillovers from the United States to Mexico are tentative, pending the confirmation of this stronger link with further data.

Variance decompositions also underscore the rising importance of external factors in driving the Mexican cycle (Table 4). For the full sample and period before 1996, variation in Mexican GDP is dominated by domestic factors. Since 1996, external factors have accounted for over sixty percent of Mexican fluctuations. Spillovers from the United States have been responsible for thirty percent, twice the share attributed to either the euro area or the rest of the world. This increased relative importance of U.S. spillovers is another piece of evidence that growing cross-border linkages have tightened business cycle comovements between the two countries.

IV. By What Channels are Spillovers Transmitted?

This section builds on the analysis of the geographic provenance of spillovers by estimating the linkages by which these spillovers are transmitted across borders. Three potential channels are considered—trade, commodity prices, and financial conditions. This procedure is more applicable to identifying spillovers across countries than the sources of fluctuations in a domestic economy, which can be driven by additional factors such as consumer confidence or fiscal policy. Therefore, no attempt is made to decompose the sources of Canadian or Mexican domestic shocks.

The five variable VAR in the previous section is augmented by adding each of the above channels as exogenous variables in separate VAR runs. The response of GDP to foreign activity in the augmented VAR can be thought of as the size of the spillover excluding the channel that is present as an exogenous variable. The individual channel's contribution to spillovers, then, equals the difference between this response and the one from the original VAR, as in equation (5):

$$c_{i,j} = r_i - r_{i,j} \tag{5}$$

where $c_{i,j}$ is the contribution of channel *j* in period *i*. The response from the VAR with only GDP is r_i and $r_{i,j}$ is the response of domestic GDP to foreign GDP shocks from the VAR with channel *j* included. The sum of the spillovers coming from the individual sources is not constrained to equal the overall spillover estimated in the base VAR, so it provides an alternative estimate of the size of spillovers that can be used to verify the main results.

For the full sample, all four major regions were included, while spillovers by subsample were decomposed using a VAR containing only the United States, rest of world, and Canada or Mexico (with the appropriate reductions in exogenous variables), to conserve degrees of freedom.

A. Measuring the Channels

To identify trade spillovers, we use the contribution of exports to real GDP growth. Since imports are a function of domestic demand, contemporaneous movements in a country's imports and its output are likely to capture domestic factors in addition to the effects of foreign activity on income. Fluctuations in exports, however, are mainly a function of foreign income and their contemporaneous correlation with domestic demand can be considered exogenous to home country factors. If the effects of shocks to foreign growth on domestic activity are accounted for by movements in domestic exports, then there is evidence of spillovers through trade. Similarly, if a shock to a major economy's exports affects its GDP, and in turn this feeds through into growth in another country, this is a trade spillover. This justifies including the export contributions of the major regions along with those of Canada or Mexico. The contribution for the rest of world aggregate is excluded, however, because these countries are proxying for global shocks, and thus it is not clear that their exports can be considered to be exogenous to the global economy.[13] The lag structure should be short to prevent reverse causality from GDP shocks to exports in future periods from contaminating the estimates. Therefore, the contemporaneous and only one lagged value are included, given evidence of some autocorrelation in the variable.[14]

Spillovers from financial channels are captured by including short-term interest rates (the yield on three-month government securities), long-term interest rates (the yield on ten-year government securities), and equity prices for the United States, euro area, and Japan.[15] The interest rates are expressed in levels, since yields approximate a random walk. Equity prices were deflated by the country's GDP deflator, then expressed in quarterly percent changes. Because of the possibility of collinearity among the three variables, they enter as a group in a single VAR rather than individually. The contemporaneous value and first lag of each variable is included, in order to be comparable with the trade channel and to allow for transmission lags. The effects of foreign financial conditions on home country growth, either directly through financing raised abroad, or indirectly through their impact on home country financial conditions, are encompassed in the estimate of the spillover to home country growth. Therefore, financial conditions are not included for Canada or Mexico.

The commodity prices used are the APSP oil price and the non-energy component of the Goldman Sachs Commodity Index, a broad measure with weights based on global production. Because both express prices in U.S. dollars, they are converted into real terms

[13] Results including the export contribution for the rest of world aggregate are similar to those reported here and are available upon request.

[14] Estimation using zero lags showed only minor differences, while trade spillovers were smaller, on average, with four lags. Results for both specifications are available upon request.

[15] Rest of world financial conditions are not included. Given that the data already include the largest financial markets and those in other major economies are highly correlated with the regions included here, a rest of world financial conditions variable would be unlikely to add a significant amount of information. Bayoumi and Swiston (2007) found sizable financial spillovers from rest of world growth shocks even in the absence of a specific measure of the region's financial conditions.

using the U.S. GDP deflator, and entered into the VAR in quarterly percent changes. The contemporaneous value and four lags are used in order to allow for transmission lags.

B. Sources of Spillovers to Canada

The full sample results in Figure 8 show that both trade and financial linkages between the United States and Canada are strong. The two channels are responsible for the transmission of one third and one half, respectively of U.S. spillovers, with commodity prices contributing 15 percent. Klyuev (2007) uses a structural VAR and also finds that the effects on the Canadian economy from shocks to U.S. financial markets were larger than those from trade. Global shocks are more likely to affect Canada through the financial channel, which explains about half the spillover, compared to a third for trade and commodity prices together at their peak. The sum of spillovers across channels also verifies the estimate from the base VAR, except in the case of Japan.

The importance of U.S.-Canada financial linkages has increased over time, as they accounted for only a quarter of spillovers before 1988 but more than a half since 1989 (Figure 9). The contribution of commodities has fallen, with that of trade remaining diminishing slightly. The decomposition of Canada's response to the rest of the world shows more variation by subsample, due both to changes in the breakdown across channels and a less consistent overall response to the global GDP shock.

C. Sources of Spillovers to Mexico

Because of the lack of precision in the estimates of the magnitude of spillovers before 1995, the analysis on the sources of spillovers will focus on the full sample results and the period since 1996. For the full sample, the sum of spillovers across channels is broadly consistent with the direct estimate from the base VAR, except for the rest of the world, which shows sizable contributions from all three channels even though Mexico's response to global shocks is around zero (Figure 10). Sixty percent of spillovers from the United States came through trade and forty percent through financial conditions. Spillovers from the euro area were transmitted mostly through the financial channel while those from Japan were largely through trade. Despite Mexico's status as an oil exporter, commodity price shocks did not transmit much of the impact of growth shocks from these three regions. It could be the result of supply shocks, as the drag on foreign growth from higher commodity prices offsets the positive impact on Mexico's terms of trade, leaving Mexico's GDP response roughly balanced.

As the U.S. has become a more significant driver of the Mexican business cycle since 1996, the contributions to U.S. spillovers from both trade and financial conditions have increased. However, the relative importance has switched, as about sixty percent of U.S. shocks are now transmitted through financial variables and trade accounts for forty percent of spillovers. Österholm and Zettelmeyer (2007) also find that U.S. financial market fluctuations have a more powerful impact on Mexico than do commodity price shocks. Over a two year horizon, the decomposition of spillovers from the rest of the world assigns roughly equal weights to each of the three channels. The results for Mexico and Canada tell similar stories—the role of financial conditions in transmitting shocks from the United States has increased in importance in recent years.

V. Conclusions

This paper has examined both the size and sources of spillovers from the major regions of the world to Canada and Mexico. The methodology used here allows us to identify global shocks, to estimate spillovers from contemporaneous shocks across countries, and to evaluate the sensitivity of the results to changes in the assumptions made about the source of these contemporaneous shocks. We also decompose the estimated spillovers into contributions from trade, commodity price, and financial channels.

The Canadian business cycle is tightly linked with that of the United States throughout the last few decades. A one percent shock to U.S. GDP shifts Canadian growth by ¾ of a percent in the same direction, a response that is consistent across sample periods. Thus, the decline in U.S. volatility has played a significant role in the reduction in Canadian fluctuations in recent decades. Trade channels were the largest source of spillovers in the 1970s and 1980s, but, since inception of the Canada-United States Free Trade Agreement, financial shocks have become the prominent transmission mechanism. Shocks to the euro area and Japan do not have a significant impact on growth in Canada, while global shocks have exerted some influence on the Canadian economy since 1989, with the effects coming largely through trade. All of these estimates are robust to the assumptions made about the source of contemporaneous correlation between the growth shocks of the major regions.

For Canada, then, tighter integration with the United States has not had a noticeable impact on the size of spillovers, but the more rapid deepening of financial linkages is seen in their increased contribution to the transmission of shocks. One issue outside the scope of this paper is the role of Canadian macroeconomic policy in responding to U.S. fluctuations. If it has responded more vigorously to U.S. shocks in recent decades, this would offset some of the effects of tighter linkages on the size of spillovers.

The Mexican business cycle was dominated by idiosyncratic domestic factors from 1970 through 1995, as the variance of domestic shocks was more than twice as large as that of the major industrial economies. This volatility swamped any effects from international spillovers. With the stabilization of the Mexican economy since 1996, U.S. shocks have taken on a more influential role in driving the Mexican cycle. A one percentage point shock to U.S. growth leads to a change of 1½ percentage points in Mexican GDP—"when the U.S. sneezes, Mexico catches a cold." The U.S. economy has accounted for about one-third of the variation in Mexican GDP at business cycle frequencies since NAFTA implementation, and the spillovers have been transmitted through both trade and financial channels. There are no significant spillovers from the euro area or Japan, while the impact of global shocks is only mildly significant when it is assumed to be the source of all the contemporaneous correlation in shocks across regions.

It is difficult to disentangle the effects of NAFTA on spillovers to the Mexican economy from the general macroeconomic stabilization that has occurred over the past decade, as the agreement can be seen as either a cause or reflection of the country's commitment to a sound macroeconomic framework. Taken together, Mexico's integration into the global economy and domestic economic stability have caused its business cycle to become more closely linked to developments in the United States.

These results provide further evidence that higher levels of globalization have brought about increased synchronization of business cycles across countries and rising sensitivity to external shocks, as in Calderón, Chong, and Stein (2007) and Imbs (2006). They also underscore the importance of the great moderation in the United States for dampening economic fluctuations in other countries since the 1980s. Given the importance of financial linkages, at least some of this moderation can be attributed to a reduction in U.S. monetary policy shocks. The significant role of the financial channel in transmitting shocks also suggests that further research into the macroeconomic effects of financial market fluctuations is necessary. Finally, with the responses of Canadian and Mexican growth to U.S. shocks steady across sample periods, there is little evidence to support predictions of a decoupling of these economies from the U.S. cycle.

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Table 1. Canada: Correlations, Variances, and Covariances of VAR Residuals

Full sample: 1970Q1 to 2007Q2

	United States	Euro area	Japan	Rest of world	Canada	Variance of domestic shocks
		Covariance				
United States		0.07	0.13	0.15	0.21	0.57
Euro area	0.20		0.06	0.10	0.05	0.22
Japan	0.19	0.15		0.13	0.04	0.85
Rest of world	0.38	0.40	0.27		0.13	0.28
Canada	0.41	0.14	0.07	0.35		0.47

First half of sample: 1970Q1 to 1988Q4

	United States	Euro area	Japan	Rest of world	Canada	Variance of domestic shocks
		Covariance				
United States		0.11	0.31	0.27	0.34	1.08
Europe	0.19		0.07	0.14	0.08	0.30
Japan	0.31	0.14		0.18	0.14	0.93
Rest of world	0.40	0.39	0.29		0.16	0.42
Canada	0.38	0.18	0.17	0.30		0.75

Second half of sample: 1989Q1 to 2007Q2

	United States	Euro area	Japan	Rest of world	Canada	Variance of domestic shocks
		Covariance				
United States		0.02	-0.03	0.04	0.05	0.20
Euro area	0.12		0.08	0.04	-0.02	0.13
Japan	-0.09	0.30		0.06	-0.07	0.60
Rest of world	0.25	0.35	0.22		0.02	0.13
Canada	0.30	-0.12	-0.25	0.18		0.13

Correlation (below diagonal)

Source: IMF staff calculations.

Table 2. Mexico: Correlations, Variances, and Covariances of VAR Residuals

Full sample: 1970Q1 to 2007Q2

		United States	Euro area	Japan	Rest of world	Mexico	Variance of domestic shocks
			Covariance				
United States			0.09	0.13	0.15	0.16	0.57
Euro area	Correlation	0.25		0.07	0.10	0.14	0.23
Japan	Correlation	0.18	0.16		0.12	0.16	0.86
Rest of world	Correlation	0.40	0.40	0.26		0.07	0.25
Mexico	Correlation	0.17	0.23	0.14	0.12		1.61

First half of sample: 1970Q1 to 1995Q4

		United States	Euro area	Japan	Rest of world	Mexico	Variance of domestic shocks
			Covariance				
United States			0.10	0.20	0.22	0.21	0.76
Europe	Correlation	0.20		0.11	0.12	0.20	0.30
Japan	Correlation	0.23	0.20		0.12	0.21	1.01
Rest of world	Correlation	0.45	0.38	0.21		0.09	0.31
Mexico	Correlation	0.17	0.26	0.15	0.12		2.14

Second half of sample: 1996Q1 to 2007Q2

		United States	Euro area	Japan	Rest of world	Mexico	Variance of domestic shocks
			Covariance				
United States			0.04	-0.02	0.05	0.14	0.16
Euro area	Correlation	0.32		0.03	0.05	0.02	0.08
Japan	Correlation	-0.06	0.12		0.12	0.05	0.58
Rest of world	Correlation	0.33	0.47	0.46		0.03	0.12
Mexico	Correlation	0.51	0.12	0.10	0.14		0.50

Source: IMF staff calculations.

Table 3. Canada: Variance Decompositions of Real GDP

Forecast period	Share explained by	Share explained after eight quarters		
		Lower bound 1/	Mean	Upper bound 1/
	Average across eight orderings			
1970–2007	United States	14.2	29.1	44.0
	Euro area	0.0	6.2	13.4
	Japan	0.0	1.0	7.0
	Rest of world	0.0	8.9	19.4
	Canada	41.5	54.7	67.9
1970–1988	United States	8.5	25.4	42.4
	Euro area	0.0	11.1	23.2
	Japan	0.0	5.4	17.9
	Rest of world	0.0	6.5	17.4
	Canada	34.4	51.6	68.9
1989–2007	United States	0.0	14.4	32.0
	Euro area	0.0	6.7	21.6
	Japan	3.0	22.6	42.3
	Rest of world	6.5	24.6	42.7
	Canada	15.6	31.7	47.8

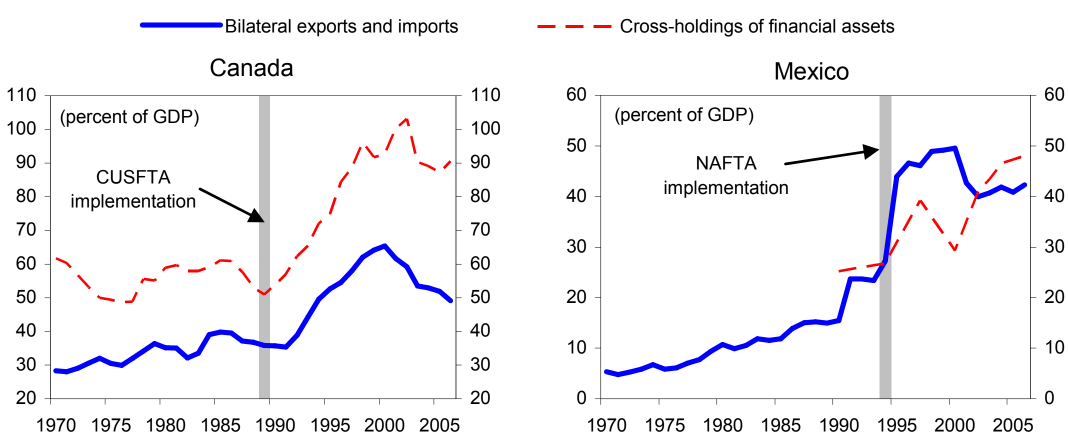
Source: IMF staff calculations.
1/ Bounds are the mean +/- two standard errors including specification uncertainty. The bounds are constrained to lie between 0 and 100.

Table 4. Mexico: Variance Decompositions of Real GDP

Forecast period	Share explained by	Share explained after eight quarters		
		Lower bound 1/	Mean	Upper bound 1/
		Average across eight orderings		
1970–2007	United States	0.0	4.9	13.4
	Euro area	0.0	4.5	12.2
	Japan	0.0	5.5	15.1
	Rest of world	0.0	2.0	7.9
	Mexico	68.6	83.0	97.5
1970–1995	United States	0.0	4.0	13.6
	Euro area	0.0	6.5	17.7
	Japan	0.0	7.3	20.3
	Rest of world	0.0	3.3	12.3
	Mexico	60.9	78.9	96.8
1996–2007	United States	9.9	30.7	51.5
	Euro area	0.0	14.5	35.3
	Japan	0.0	3.0	18.8
	Rest of world	0.0	15.9	38.2
	Mexico	17.4	35.9	54.5

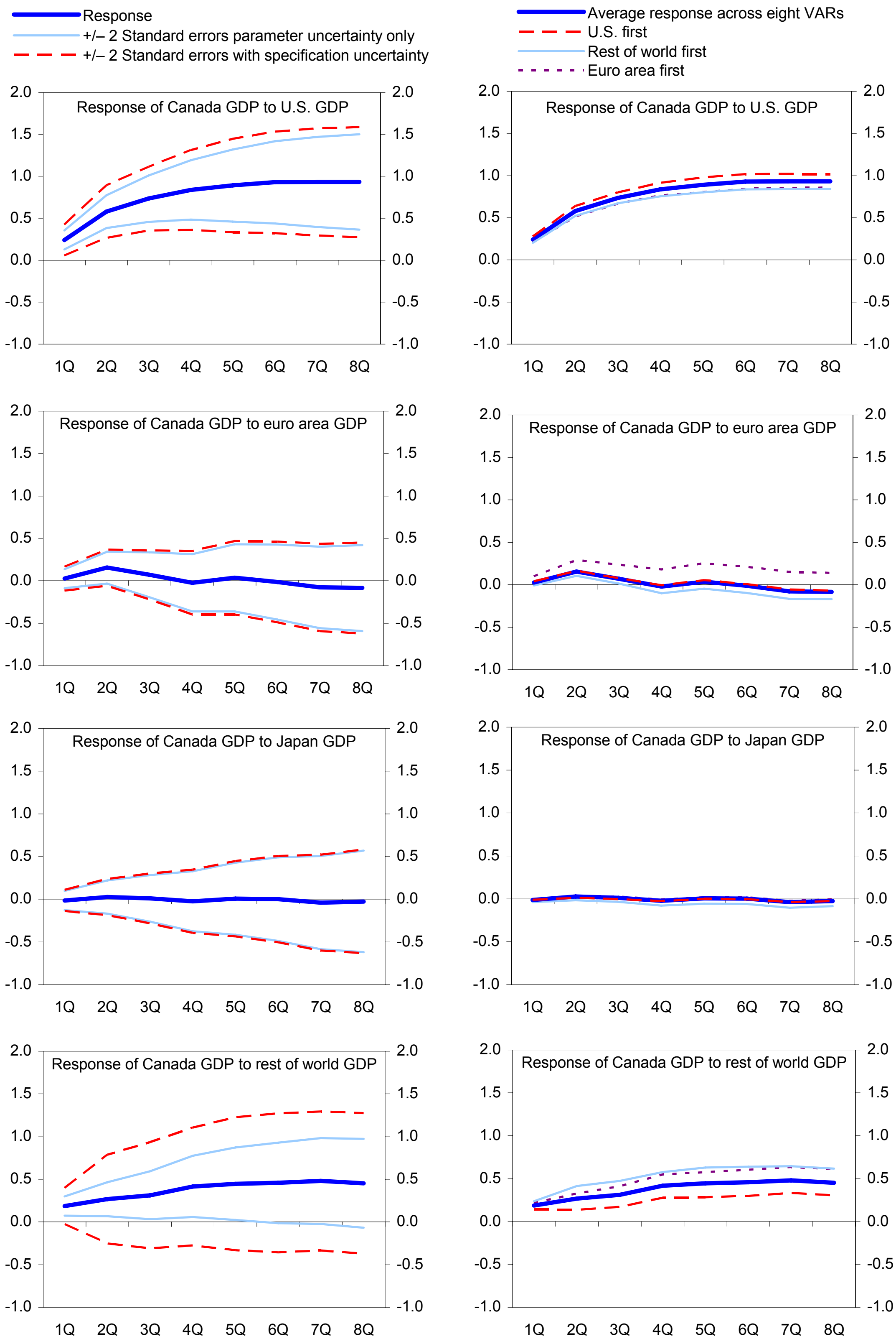
Source: IMF staff calculations.
1/ Bounds are the mean +/- two standard errors including specification uncertainty. The bounds are constrained to lie between 0 and 100.

Figure 1. Measures of U.S. Integration with Canada and Mexico



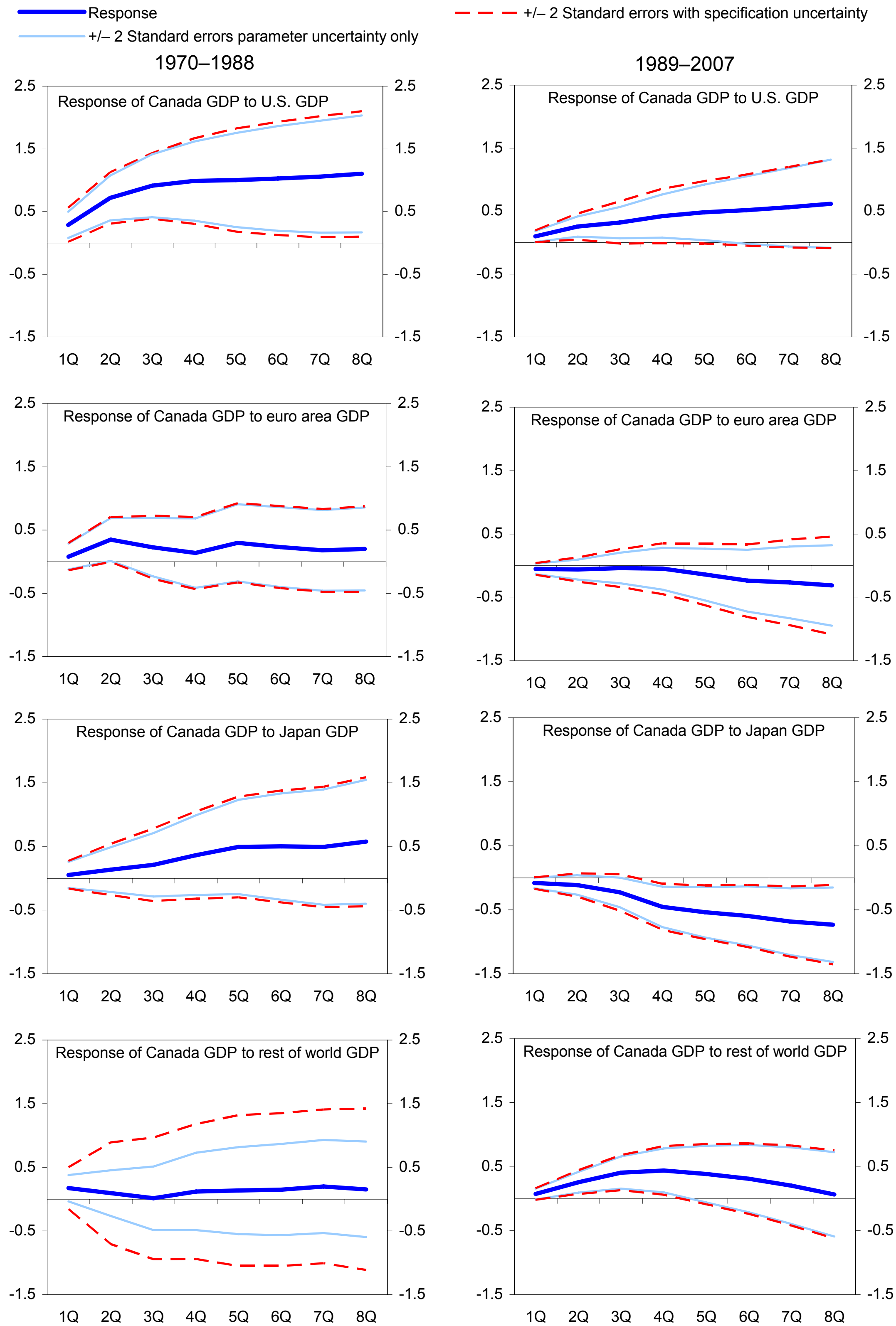
Sources: Haver Analytics; *Direction of Trade Statistics*; Bank for International Settlements; Coordinated Portfolio Investment Survey; U.S. Treasury International Capital System; and IMF staff calculations.

Figure 2. Canada: Spillovers Across Eight VARs



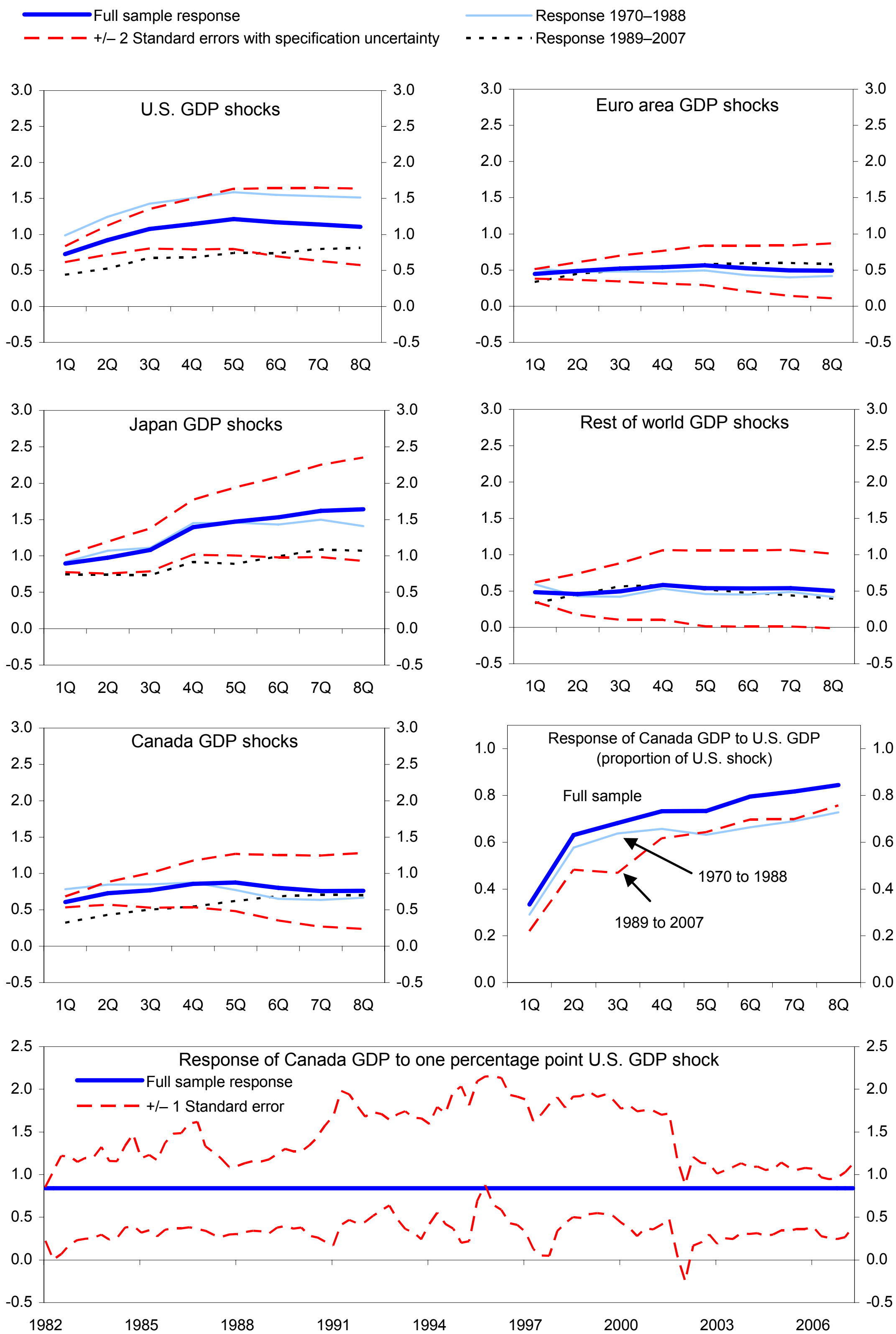
Source: IMF staff calculations.

Figure 3. Canada: Spillovers Across Eight VARs by Subsample



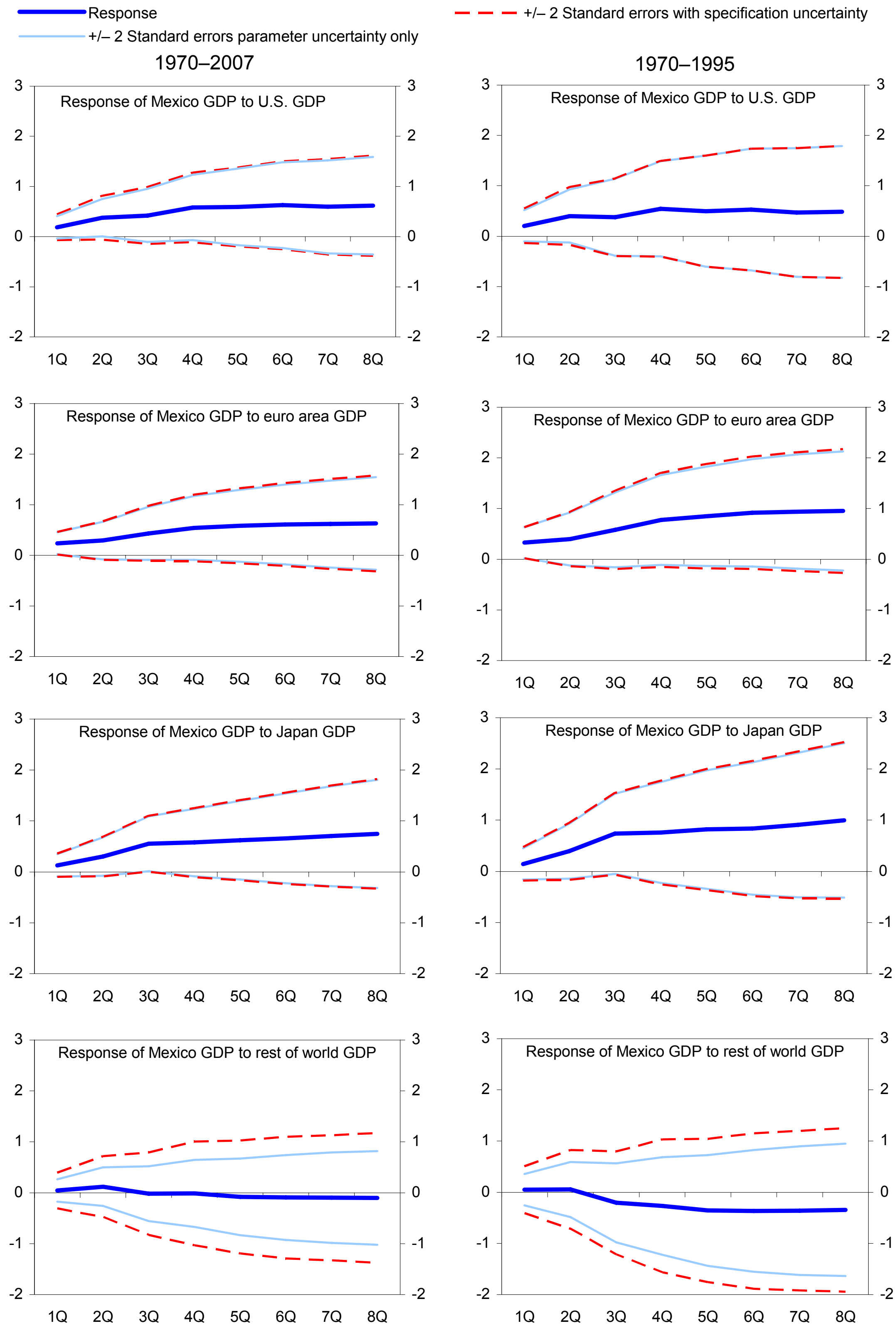
Source: IMF staff calculations.

Figure 4. Domestic Shocks and Canadian Responses by Subsample



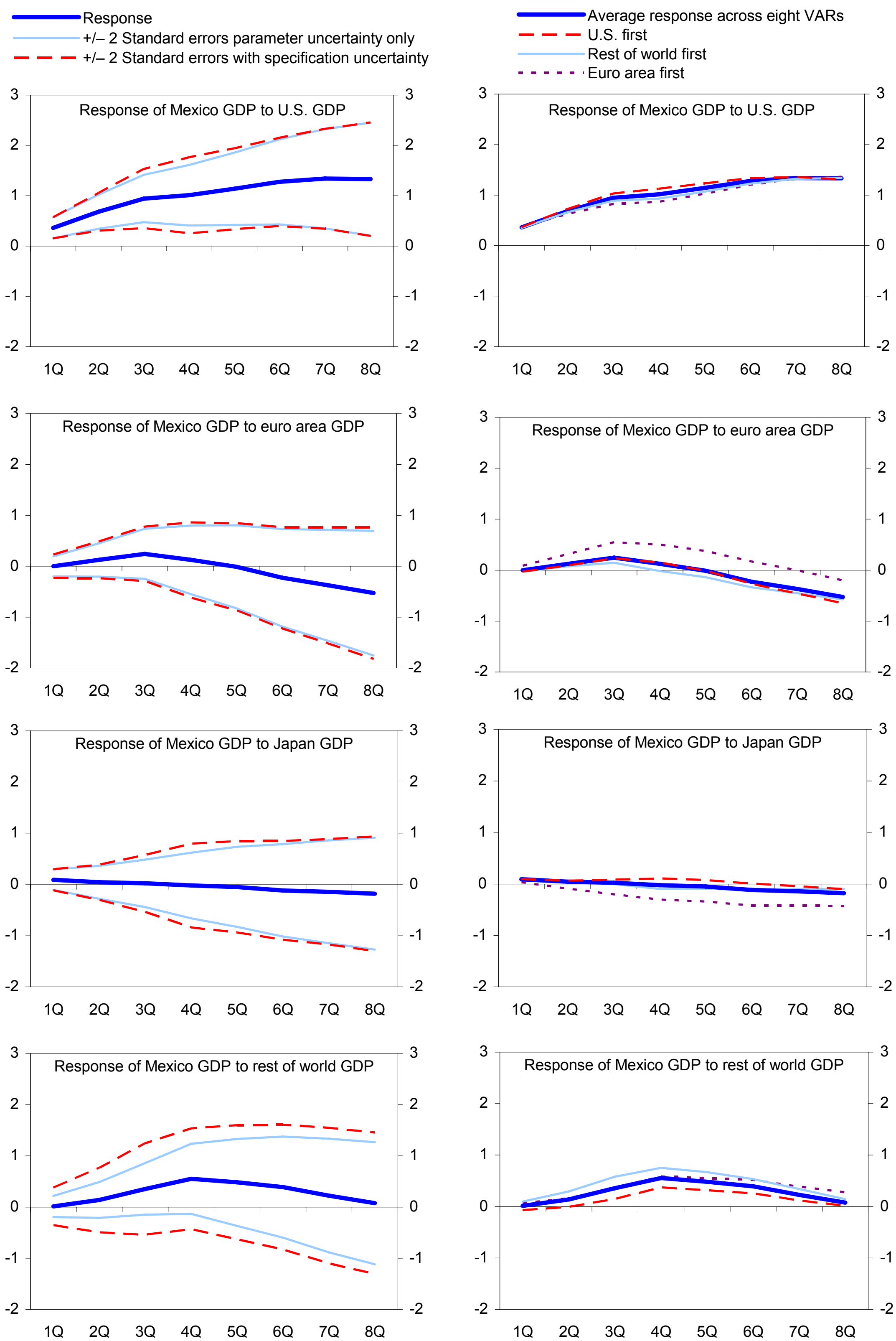
Source: IMF staff calculations.

Figure 5. Mexico: Spillovers Across Eight VARs



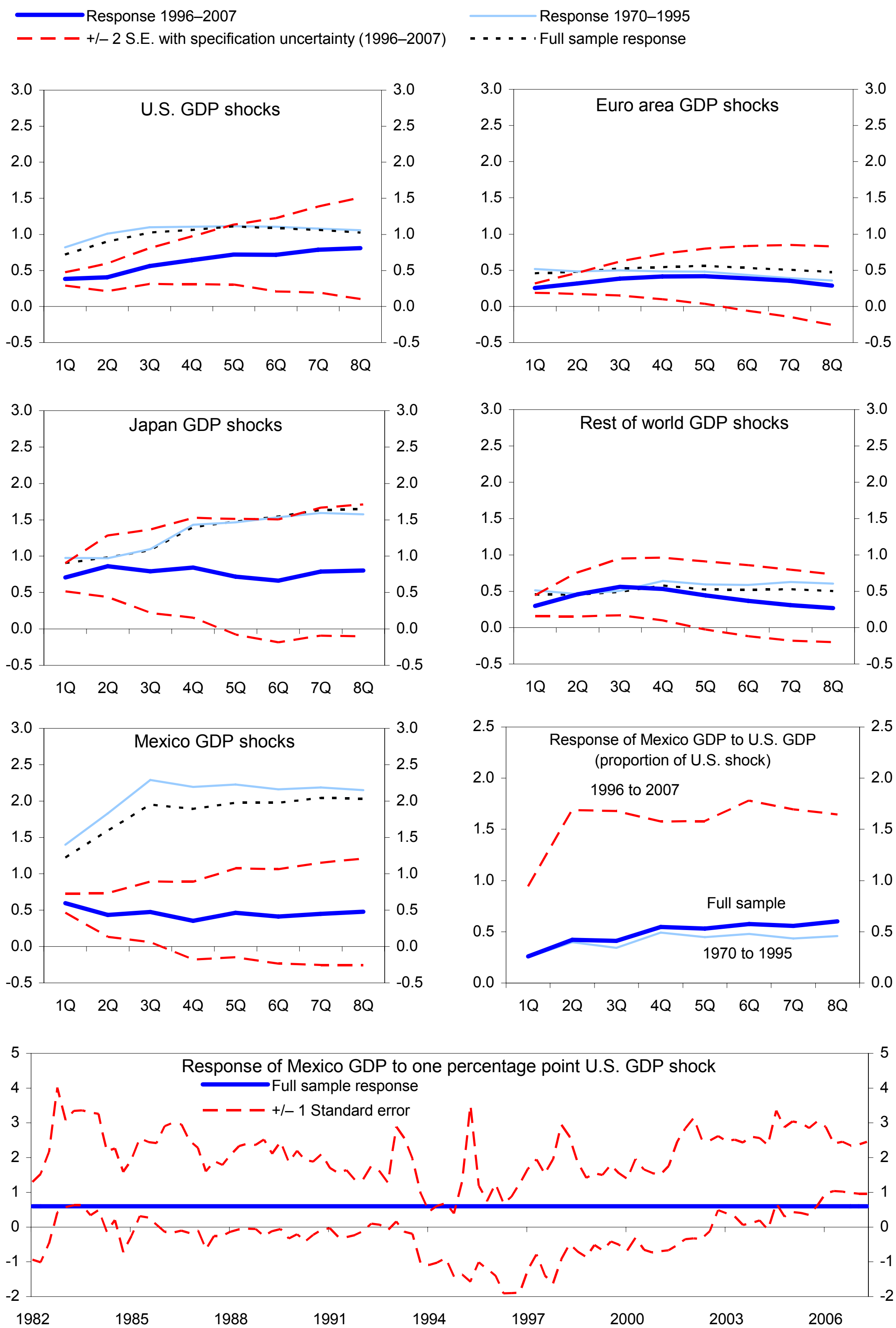
Source: IMF staff calculations.

Figure 6. Mexico: Spillovers Across Eight VARs, 1996–2007



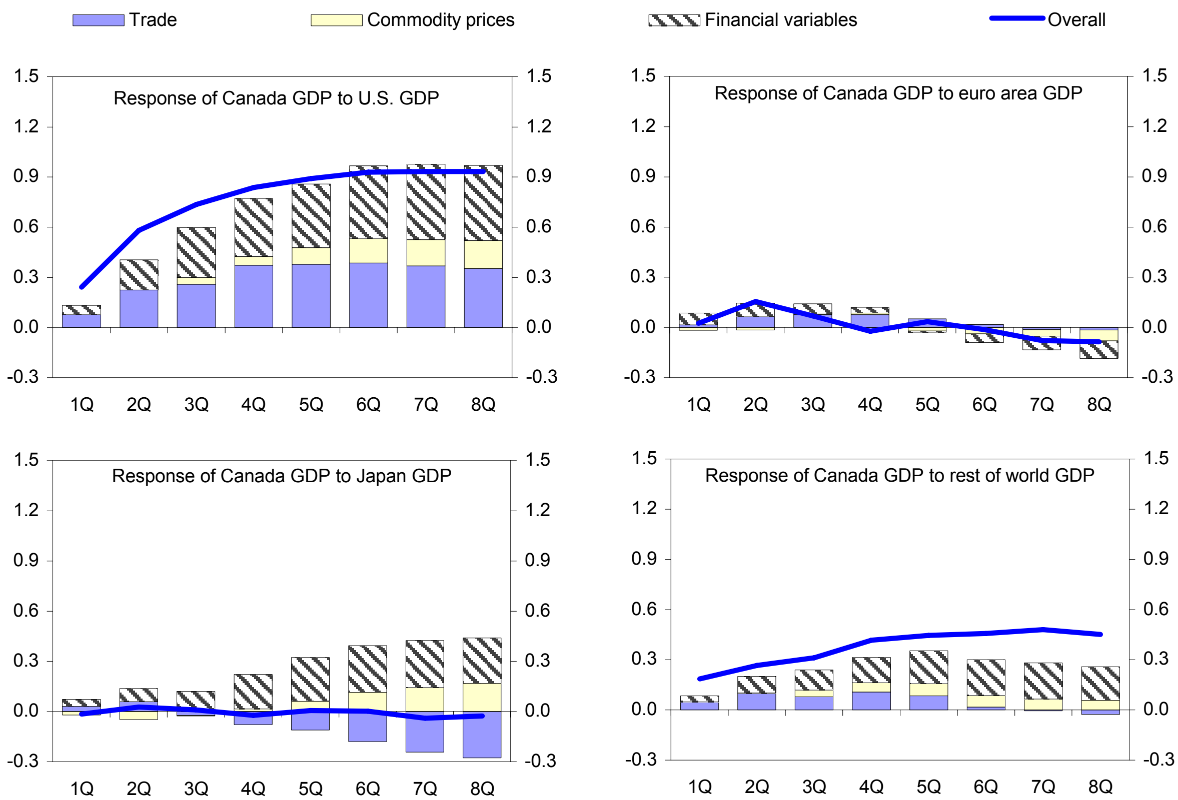
Source: IMF staff calculations.

Figure 7. Domestic Shocks and Mexican Responses by Subsample



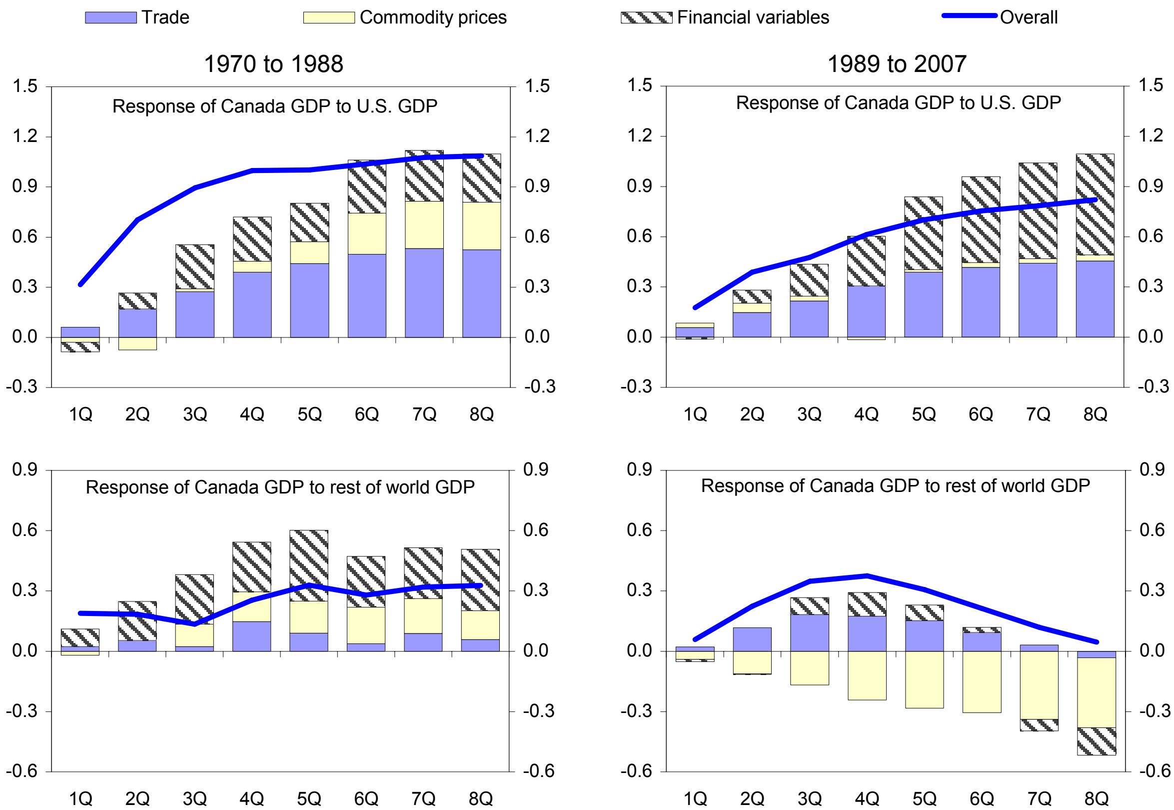
Source: IMF staff calculations.

Figure 8. Canada: Decomposition of Spillovers



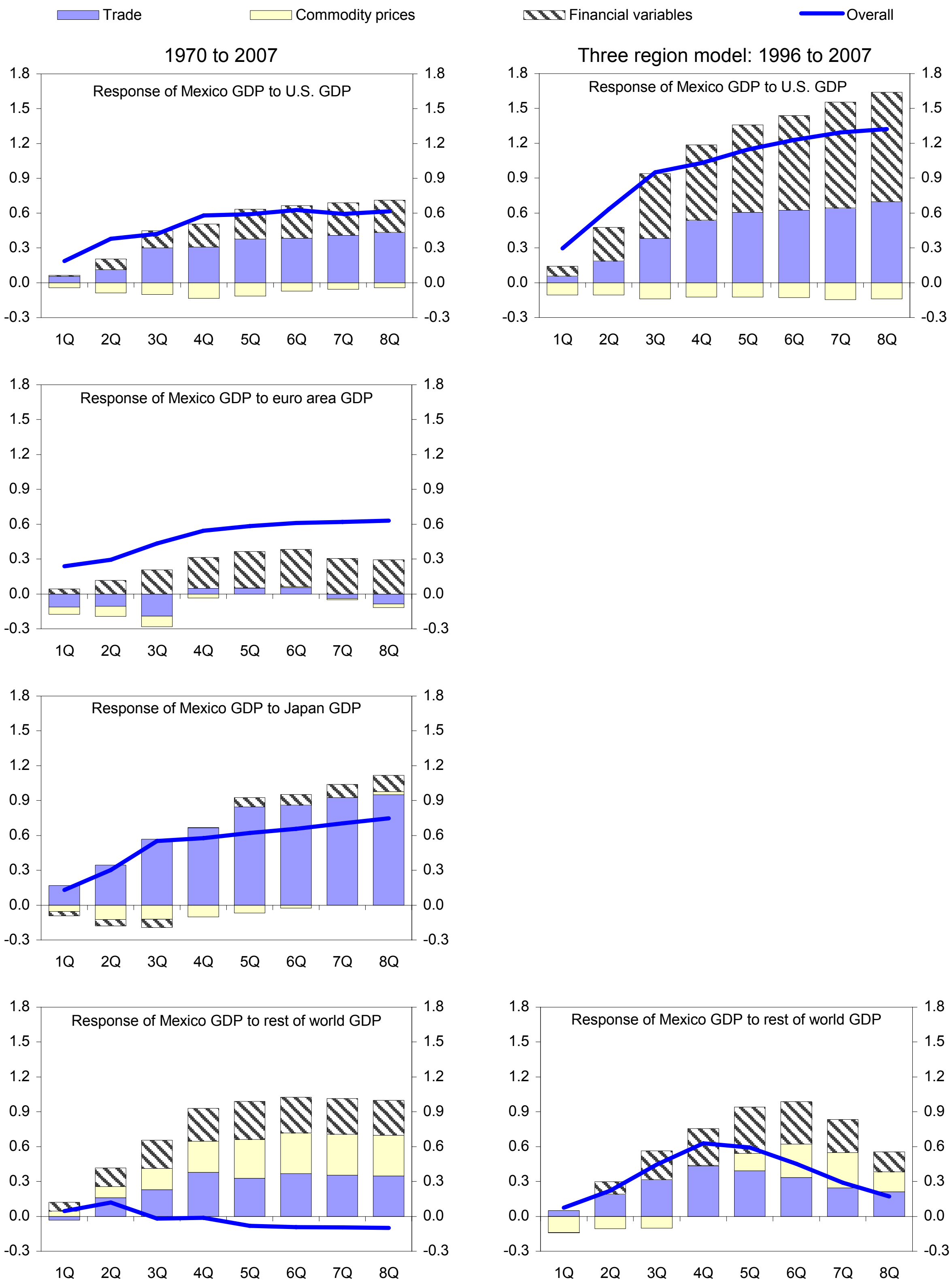
Source: IMF staff calculations.

Figure 9. Canada: Decomposition of Spillovers by Subsample



Source: IMF staff calculations.

Figure 10. Mexico: Decomposition of Spillovers



Source: IMF staff calculations.