Aspects of Canadian and US Business Cycles

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Introduction

The Canadian and US economies, by many measures and along many dimensions, are highly integrated and, possibly as a result of this integration, have highly correlated business cycles. This paper examines various aspects of the co-movement between the two economies. One objective is to document the relationship between the two economies at an aggregate level and to examine how the relationship might have changed over time. A further objective is to explore the relationship at a more disaggregate level by examining the interaction of the two economies on a sectoral basis.

A number of motives underlie these objectives. First, as a means for understanding the relationship between the two economies, it is useful to have a body of empirical regularities summarizing the co-movements of economic activity at different levels of aggregation. The second and more important motivation is to explore what linkages are important for explaining the behaviour of the two economies and for changes in this behaviour. In particular, the two economies have become increasingly integrated through international trade in goods and assets, including foreign direct investment, during the postwar period; it seems natural to ask whether this has led to increased synchronization of the two economies, as has been

* I would like to thank Maxym Chaban, René Lalonde, Glenn Otto, and Jean-François Perrault for helpful comments and discussions. I am solely responsible for any errors or omissions.

predicted by a number of recent cross-country studies of business cycle correlations.[1]

The behaviour of the two economies and whether the extent of synchronization has changed are of interest to those who wish to interpret or predict the behaviour of the Canadian economy. For instance, it might be of interest to know why the Canadian economy fared relatively well in recent years in contrast to the United States. The relationship between the two economies, however, is of broader interest than for this reason alone. The Canadian and US economies serve as a good example of how highly integrated but distinct national economies are likely to behave. In this sense, they serve as an alternative example to assessments of integration that compare regions within national economies, as explored by Clark and van Wincoop (2001) and Clark and Shin (2000). The analysis will visit these themes: a better understanding of the US-Canada relationship, and lessons more generally about the effects of integration on the synchronization of business cycles.

The analysis that follows has two features that merit comment. First, it is entirely non-structural in nature. In broad terms, the paper looks at a variety of measures of correlation between the two economies with an objective of providing a body of empirical regularities suggestive of the underlying linkages between the two economies. While the methods cannot provide definitive conclusions about the underlying shocks faced by the two economies and the methods by which they are transmitted, they do provide indirect evidence of important linkages and provide useful suggestions for future research. Furthermore, the methods lend themselves well to looking at a variety of issues, which might not be possible were more structured methods employed. Finally, the methods used here are very similar in spirit to the cross-country studies of business cycle correlations (such as Imbs (2004); Otto, Voss, and Willard (2003); Kose, Otrok, and Whiteman (2003); and Frankel and Rose (1998), among others) and the results from this literature inform the directions explored here. One way to interpret the analysis here is that it explores in detail the linkages between one of the cross-section data points, the US-Canada correlation, used in these studies. An advantage of doing so is that we can look systematically at instability in the relationship in considerable detail.

The second feature of the analysis is that it is somewhat disjointed, involving different data sets and empirical methods. As such, it is useful to

1. See, for example, Kose, Otrok, and Whiteman (2003) and Kose, Prasad, and Terrones (2003), which look specifically at the issue of stability of patterns of business cycle co-movements across countries.

provide a summary of what is done and why. The first task is to summarize the relationship between the two economies at an aggregate level. To do so, we examine dynamic correlations of four-quarter-ended growth rates of real output for the two economies over the past four decades. We consider the full sample, as well as two subsamples of equal size. The dynamic correlations give a slightly richer description of the business cycle interactions than is typically used in cross-section studies. The split sample is a simple means of examining any changes in the behaviour of the two economies.

We next examine the stability of the co-movement between the two economies more seriously, using Andrews (1993) parameter stability tests for unknown break points. This has the important advantage of providing estimates of the dates of structural break, as opposed to imposing them on the estimation and inference, and the results are useful for documenting changing business cycle correlations and how they might relate to increasing integration between the two economies. To foreshadow a key result, there is only weak evidence of a statistically significant change in the correlation between the growth rates of the two economies; this despite the increased integration of the two economies over the past four decades.

The results from this section also relate to recent studies that examine changes in mean and variation of growth rates in Canada (Curtis 2001; Debs 2001) and the United States (McConnell and Perez-Quiros 2000). Both McConnell and Perez-Quiros and Debs use similar methods to those here to identify structural breaks, and it will be useful to compare the results here to these studies.

The next step is to examine what might underlie the shifts in mean, standard deviation, and (possibly) correlation, by performing similar stability tests on the expenditure components of total output. This is similar to McConnell and Perez-Quiros (2000) and Debs (2001) and provides useful information about the role of domestic and external influences on the Canadian economy and its synchronization with the US economy.

The final part of the analysis again considers a disaggregation of output to better identify the linkages between the two economies. Now, however, the focus is on industry sectors. Data limitations prevent serious stability analysis, so the focus changes to an investigation of which sectoral linkages are important and what might explain this importance. Much of the analysis is similar to studies of the effects of borders on business cycle synchronization, e.g., Clark and van Wincoop (2001). These studies typically identify a significant border effect—countries are likely to be less synchronized than regions within national borders. This is interpreted as evidence of the effects of increased integration, viewed roughly as equivalent to removing national borders. Interestingly, our sector analysis identifies no border effect—Canada and the United States appear to operate, in terms of business cycle synchronization, at a sectoral level, as one large economic region. While this is interesting in its own right, we also consider how this contributes to the literature on integration and business cycle synchronization.

1 Canada-US Synchronization

1.1 Data

Throughout this section, we use quarterly, seasonally adjusted real GDP measures as a summary measure of economic activity. The sample used is 1961Q1–2004Q1. Details of the data and sources are provided in Appendix 1. To measure the cyclical behaviour of the two economies, we use four-quarter-ended growth rates. While this is not strictly a measure of the business cycle, it does have advantages over alternatives, such as the Hodrick and Prescott (1997) filter or Baxter and King's (1999) band-pass filter. Business cycle filters such as these involve the loss of data at both ends of the sample (see the discussion in Baxter and King). In the current context, this means that the information available from the past few years, where Canada and the United States have had somewhat different experiences, would not be available. In addition, growth rates are perhaps more readily interpretable than the filtered data. Finally, the use of growth rates is also consistent with recent related studies, notably Clark and van Wincoop (2001), Curtis (2001), Debs (2001), and McConnell and Perez-Quiros (2000), which makes comparison easier.[2]

1.2 Simple empirical summaries

Figure 1 presents four-quarter-ended growth of the two output series; evidently, the two series are highly correlated. Table 1 reports the means and standard deviations of Canadian and US GDP, as well as correlations between Canadian GDP, $x(t)$, and leads and lags of US GDP, $y(t \pm j)$, $j = 1 \ldots 4$. Statistics in all cases are reported for samples ranging over 1963Q1–2003Q1, which takes account of the growth-rate calculations and the leads and lags used in the construction of the dynamic correlations reported. In addition to the full-sample estimates, the tables also report estimates for two subsamples, 1963Q1–1979Q4 and 1980Q1–2003Q1. The

2. Many of the results discussed in what follows are robust to using alternative filters. A further alternative is to consider quarterly growth rates; the possible disadvantage is the additional associated noise in quarter-on-quarter growth series.

Figure 1
Canadian and US GDP

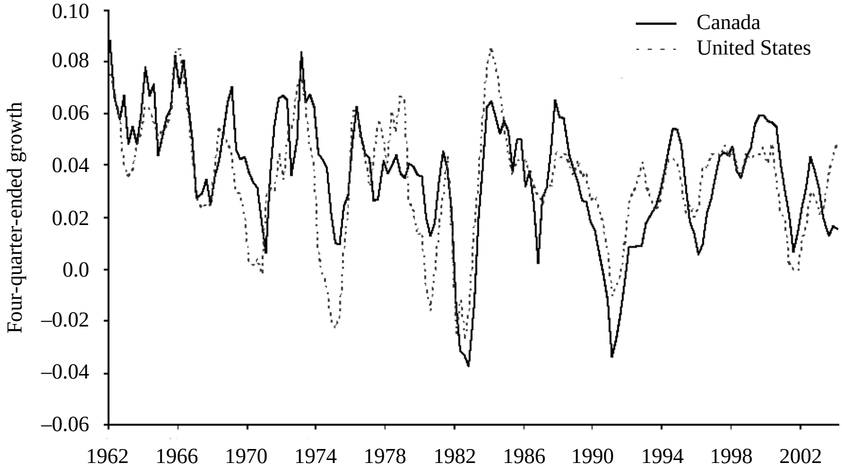

Table 1
Canadian and US GDP moments
Four-quarter-ended growth rates

	1962Q1–1979Q4		1980Q1–2004Q1		1962Q1–2004Q1	
Canadian GDP, $x(t)$						
μ_x	0.0466	(0.0034)	0.0285	(0.0048)	0.0361	(0.0035)
σ_x	0.0175	(0.0016)	0.0241	(0.0032)	0.0233	(0.0027)
US GDP, $y(t)$						
μ_y	0.0389	(0.0055)	0.0296	(0.0040)	0.0335	(0.0034)
σ_y	0.0246	(0.0034)	0.0208	(0.0029)	0.0230	(0.0021)
Correlations						
$\rho(x_t, y_{t-4})$	0.1666	(0.1411)	0.2554	(0.1256)	0.2831	(0.0789)
$\rho(x_t, y_{t-3})$	0.4100	(0.1281)	0.4197	(0.1264)	0.4576	(0.0771)
$\rho(x_t, y_{t-2})$	0.6227	(0.1108)	0.6109	(0.1099)	0.6278	(0.0700)
$\rho(x_t, y_{t-1})$	0.7286	(0.0997)	0.7693	(0.0786)	0.7445	(0.0580)
$\rho(x_t, y_1)$	0.6933	(0.0917)	0.7948	(0.0540)	0.7421	(0.0530)
$\rho(x_t, y_{1+1})$	0.5045	(0.0978)	0.6567	(0.0699)	0.5999	(0.0689)
$\rho(x_t, y_{1+2})$	0.3108	(0.1103)	0.4263	(0.0993)	0.4004	(0.0911)
$\rho(x_t, y_{1+3})$	0.1130	(0.1323)	0.1621	(0.1285)	0.1776	(0.1121)
$\rho(x_t, y_{1+4})$	–0.0653	(0.1558)	–0.0673	(0.1543)	–0.0177	(0.1308)

Notes: Series are four-quarter-ended growth rates of seasonally adjusted GDP; see Appendix 1 for details and data sources. Moments are estimated using generalized method of moments (GMM) with numbers in parentheses Newey and West (1987) standard errors with a lag truncation parameter of four.

focus on a break at the midpoint of the series is arbitrary; tests for parameter stability with unknown break points are discussed below. The estimates of the means, standard deviations, and dynamic correlations and associated standard errors are calculated using GMM with Newey and West (1987) robust standard errors (the lag truncation parameter is set to four).[3]

For the full sample, Canadian and US GDP have, on average, grown at similar rates, 3 to 3.5 per cent, and with similar volatility in these growth rates (standard deviations are just over 2 per cent). The contemporaneous correlation between the two economies is, as is well known, quite strong, 0.74. Relative to most other relationships between industrialized countries, this is high. For example, Otto, Voss, and Willard (2003) consider the bilateral relationships between 22 Organisation for Economic Co-operation and Development (OECD) economies and report a mean correlation of 0.32 for the 1972–2000 period. The dynamic correlations suggest a slightly stronger correlation between lags of US GDP and current Canadian GDP than the reverse, providing weak evidence that the US economy leads the Canadian economy. This is consistent with the idea that the US economy is an important source of external shocks for the Canadian economy, at least in part because of the strong trading relationships between the two economies. Note, however, that the differences in correlations are not particularly large and, given the associated standard errors, it is not possible to make a strong argument in this regard.

Interestingly, this suggestion that the US economy leads the Canadian economy is not consistent with the evidence from more formal business cycle dating schemes, such as provided by the Economic Cycle Research Institute (ECRI), which uses the same dating methodology for a variety of countries as that used by the National Bureau of Economic Research (NBER) for the United States.[4] Since a number of other interesting points of comparison between the US and Canadian economies arise when considered from the perspective of these business cycle dating methods, we present a summary of the Canadian and US ECRI dates in Figure 2. An attractive feature of the dating schemes is that they allow for a comparison over a longer sample period, 1948–2004.

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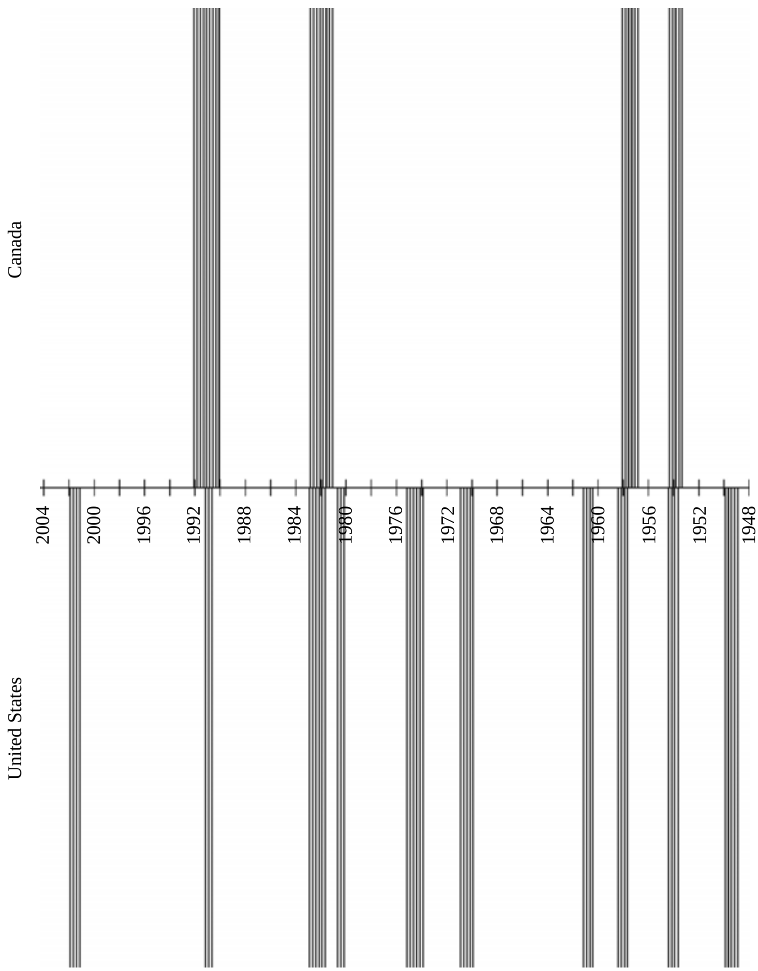
3. Newey and West standard errors are appropriate here, since the moment conditions are certainly serially correlated. The inverse of the Newey and West (1987) variance-covariance matrix is used as the weighting matrix for estimation. Five iterations are used in the estimation process.

4. The dates for the United States are taken directly from the NBER. The dates for Canada, the United States, and other countries are available at: <http://www.businesscycle.com/data.php#intldates>.

Figure 2
Canadian and US business cycle
ECRI business cycle peak and trough dates



The first striking feature is the significantly greater number of recessions (quarters between peak and trough) experienced by the United States relative to that of Canada—ten versus four. From this perspective, a recession in the United States is not sufficient cause for a recession in Canada, a conclusion not likely shared by many commentators on the Canadian economy. Nor is this conclusion an artifact of a particular time period: idiosyncratic recessions in the United States appear throughout the sample, including the most recent downturn in the United States in 2001.[5] The second striking feature concerns the timing of the contractions. For all four contractionary periods experienced by Canada, there is a roughly coincident contraction in the United States. And in each case, the Canadian economy led the way. This appears to be somewhat at odds with the notion that Canada is highly dependent upon the US economy and that downturns in the United States lead, through trade and possibly other channels, to downturns in Canada. Otherwise stated, there is no compelling evidence in Figure 2 that the United States is an important source of shocks to the Canadian economy.

Of course, what is missing in a simple comparison of business cycle dates is information concerning the linkages between the economies at all points in the sample, not just the start of periods of contraction. For example, during periods of expansion in the United States, variation in US output is almost certainly going to have some influence on Canadian output. This is why the focus here is the time-series properties of cyclical macroeconomic series. Nonetheless, Figure 2 is instructive in that at a coarse level, the US and Canadian economies often behave quite distinctly.

The strong relationship between the two economies over the past forty-odd years, as identified in Table 1, is generally well known. What is less well documented is how this relationship has evolved. Table 1 provides a comparison of estimates from arbitrary subsamples, 1963Q1–1979Q4 and 1980Q1–2003Q1 (roughly the midpoint of the sample). For these subsamples, there is a fall in growth rates between the early and later period, with the greatest dip for Canadian GDP (from nearly 4.5 per cent to less than 3 per cent). In addition, there are changes in volatility: the United States experiences a decline in the standard deviation of growth rates, while Canada experiences a rise. These results are consistent with earlier studies and will be discussed in further detail.

5. With respect to the number of peak to trough or contractionary periods, the United States appears to be unusually blessed relative to other countries, which typically have contractionary periods similar in number to Canada.

For the correlation statistics, while there are some changes suggested over the two subsamples, they are not, in most instances, particularly large relative to the reported standard errors. One result merits comment, however. In the early subsample, the strongest correlations occur between Canadian GDP growth and US GDP growth in the previous quarter, again suggesting that the US economy leads the Canadian economy. In the second subsample, this is no longer the case; the strongest correlation occurs between the two contemporaneous growth rates. We might argue that this reflects the growing integration of the two economies, but because the relative magnitudes are not particularly large, it is again difficult to argue this point strongly.

1.3 Tests for parameter stability—aggregate GDP

We next examine the instability of the moments of the output-growth series more formally, using parameter stability tests for GMM estimators proposed by Andrews (1993). These tests have the advantage of allowing for unknown break points and for providing an estimate of the timing of any structural break in the parameter estimate. Results for these tests (specifically the $\sup W$ statistics, which are the supremum of a series of standard Wald tests for equivalence of parameter vectors across a sequence of subsamples) are reported in Table 2, as are the associated break dates where relevant. Also reported are subsample estimates based on the estimated break date.

The main objective is to examine the stability of the correlation coefficient for the two growth rates. This is, however, not a straightforward task. We know from other studies, such as Debs (2001) and McConnell and Perez-Quiros (2000), as well as from the results in Table 1, that the means and standard deviations of the two series are not likely to be stable. Any test of parameter instability for the moments of these series is going to have to allow for this source of instability in addition to possible instability in the correlation coefficient. One simple means of doing so is to set up the estimation of the five-moment parameters (means, standard deviations, and correlation coefficient) simultaneously and test for stability across the entire vector of estimated parameters. This is the first approach taken, but it has two drawbacks. First, it considers only a single common date for structural change across the entire parameter vector. Second, it does not provide direct information about the correlation coefficient itself, only about the stability of the entire parameter vector. An alternative is to proceed in stages—first, identify any structural change in the means and standard deviations, then use this information to standardize the data so that the means and standard deviations are constant across the full sample. It is then possible to test for parameter stability of the correlation coefficient alone.

Table 2
Canadian and US GDP moments—stability tests
Four-quarter-ended growth rates

Canadian GDP, $x(t)$
US GDP, $y(t)$
Stability tests

	p	sup$W$	CVs [10%, 5%]	Date	Subsample Estimates First	Second
All moments						
$\mu_x, \mu_y, \sigma_x, \sigma_x, \rho_{x,y}$	5	47.2797	[15.17, 17.25]	1985Q1	*see below*	
First subsample	{0.0413, 0.0357, 0.0237, 0.0281, 0.7665}					
Second subsample	{0.0297, 0.0308, 0.0212, 0.0140, 0.7714}					
Individual moments						
μ_x	1	18.4790	[5.59, 7.05]	1974Q2	0.0532	0.0294
μ_y	1	5.1732		—	*0.0335*	
$\sigma_x \mid \hat{\mu}_{x1}, \hat{\mu}_{x2}$	1	5.5230		1981Q4	0.0163	0.0235
$\sigma_y \mid \hat{\mu}_y$	1	35.9995		1985Q1	0.0288	0.0131
$\rho_{x,y} \mid \hat{\mu}_{xj}, \hat{\mu}_y, \hat{\sigma}_{ij}, i = x, y; j = 1, 2$	1	4.6593		1980Q1	0.6410	0.7858

Notes: The sample is 1962Q1–2004Q1. The series are four-quarter-ended growth rates of seasonally adjusted GDP; see Appendix 1 for details and data sources. Moments are estimated using GMM with numbers in parentheses Newey and West (1987) standard errors with a lag truncation parameter of four.
Stability tests are the sup$W$ tests from rolling samples, as described in Andrews (1993). The sample break points used run from $0.25 \times T$ to $0.75 \times T$, T the full sample size. p identifies the number of parameters, and critical values (CVs) are from Table 1 in Andrews (1993). Where a break is evident at standard significance levels, the date is reported.
$m \mid \hat{n}$ indicates that the stability tests statistic for parameter m is constructed conditional on estimated sample or subsample estimates of $\hat{n}$. Sample or subsample estimates are indicated with subscripts 1 and 2, with break date as indicated in the table for the relevant parameter. For further details, see text. When estimation is conditioned on these initial estimates, the reported critical values serve only as a guide.

Table 2 reports the results of the parameter stability tests for Canadian and US GDP growth rates. The moments are estimated using GMM, as is done in Table 1. In contrast to Table 1, however, we consider only the contemporaneous correlations. A full assessment of the dynamic correlations is an extensive undertaking and, for brevity and clarity, we choose to focus on a smaller set of moments.

The first test considers parameter instability across all five moments: the means, standard deviations, and the correlation coefficient of Canadian and US GDP growth rates. For these five parameters, the null hypothesis of parameter stability is strongly rejected with an estimated break date of 1985Q1. (The critical values are reported in the table and are taken from Andrews (1993).) The reported subsample estimates indicate what underlies this result. Most noticeable are a substantial fall in mean growth rates for

Canada and a substantial fall in the standard deviation of US growth rates. At this break point, there is virtually no change in the correlation between the two growth rates.

As discussed, this gives only a partial picture of the underlying parameter instability. The remaining tests in the table attempt to isolate different sources of instability and allow for different possible break dates. To do so, each moment parameter is considered in turn.

We begin with the mean growth rates for Canada and the United States. For Canada, there is strong evidence of a structural break occurring in 1974Q2. For the United States, we cannot reject, at the 10 per cent level, the hypothesis that the mean growth rate is stable over the sample. This latter result is consistent with McConnell and Perez-Quiros (2000). The result for Canada is also consistent with previous work of Debs (2001).[6,7] The subsample estimates reported in Table 2 indicate the nature of the structural break—Canada experienced a fall in mean growth from roughly 5 per cent prior to the early 1970s to an average of roughly 3 per cent afterwards.

We next consider the behaviour of the standard deviations of the two series. Because of the estimated shift in mean for the Canadian series, the Canadian growth series is demeaned using the subsample estimates reported in Table 2. For the US growth-rate series, we assume that the mean is constant and demean using the full sample estimate.

The two series may now be reasonably assumed to have constant means (equal to zero). The next stage is to estimate the mean and standard deviation for each series and to test for structural change of the standard deviation parameter (treating the mean estimate as constant across the entire sample). For both the United States and Canada, we find evidence of parameter instability, though the evidence is much stronger for the United States than for Canada.[8] For the United States, the standard deviation in the

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6. The focus of Debs (2001) is on the residual variance of an AR process for quarterly growth rates of Canadian GDP. In doing so, Debs also considers the stability of the conditional mean parameters of the AR process, which relates loosely to the mean growth rates here, finding weak evidence of a structural break in the early 1970s consistent with results here.

7. The test statistic for the US mean growth rate is not far off the 10 per cent significance level, and one might wish to allow for a break in mean. We do not do so here, in part because a line has to be drawn somewhere and in part because of the evidence in McConnell and Perez-Quiros, which also suggests that the mean growth rate has been stable. For completeness, the early and late subsample estimates associated with the reported sup W statistic are 0.0452 and 0.0299; the associated break date is 1973Q4.

8. In fact, the test statistic is smaller than the 10 per cent critical value, but only just; we interpret this as a rejection of parameter instability.

latter sample is roughly half of what it is in the early sample, from 0.029 to 0.13. For Canada, the change is not so large and occurs in the opposite direction: the standard deviation of GDP growth has risen from 0.16 to 0.24. The timing of the changes is similar; for Canada, it occurs around 1981Q4, while for the United States it occurs a bit later, around 1985Q1. The US result is consistent with McConnell and Perez-Quiros (2000), which examines this shift in variation in some detail. The result for Canada differs somewhat from that reported in Debs (2001), which identifies a change in volatility of GDP growth in the early 1990s, though this is likely a reflection of the differing details in approach. Debs is concerned primarily with the residual variation of an AR model of GDP growth, in effect, examining the stability of variation in shocks to Canadian GDP growth. In contrast, the focus here is the standard deviation of GDP growth itself as this affects the correlation coefficients of interest.

Finally, we can consider the correlation between the two series in a similar fashion to that of the standard deviations. Starting with the demeaned US and Canada series, each is standardized using the estimated subsample standard deviations so that for the full sample we have series with means zero and standard deviations of one. The five-moment parameters (means, standard deviations, and correlation) are then estimated, and the stability of only the correlation coefficient is tested (the other parameters are assumed to be constant). The associated test statistic is reported in the final column of Table 2.

The test statistic is somewhat less than the 10 per cent critical value, so strictly speaking, we cannot reject, at the 10 per cent level, the hypothesis that the correlation coefficient is stable. For completeness, however, the associated date and subsample estimates are reported. As expected, the latter sample, post-1980Q1, has a higher correlation coefficient, 0.79 compared to 0.64. We interpret this as providing some limited, weak evidence that the correlation coefficient between the two economies has risen in the past two decades, although the change is not substantial.[9]

In summary, we have strong evidence that Canadian mean growth has fallen, associated with a structural break occurring in the early 1970s. There is no such change in mean growth for the United States. There is further evidence that Canada has experienced an increase in the volatility of output growth dating from the early 1980s; in contrast, the United States has experienced a decline in output fluctuations dating from the early to mid-1980s. Finally,

9. One reason we do not interpret the significance levels literally is that the test statistics are conditioned on estimates of structural breaks in the means and standard deviations that the inference does not properly consider. The critical values serve only as a guide.

there is weak evidence of a small rise in the correlation between growth rates of the two economies dating from the early 1980s. In the following section, the sources underlying the changes in the Canadian parameter estimates, including the correlation coefficient with US growth rates, are considered further. To do so, we follow McConnell and Perez-Quiros (2000) by examining how different expenditure sectors have contributed to the changing nature of Canadian growth rates.

1.4 Tests for parameter stability—expenditure components

Table 3 reports a similar analysis to that of Table 2 for the expenditure components of GDP: consumption (C), investment (I), government spending (G), exports (X), and final domestic demand $(C + I + G - M)$, where M is imports. (The exact definitions and sources are provided in Appendix 1.) The results for GDP (Y) are also reported (these are the same as in Table 2). As before, each series is first tested for a break in mean, then for a break in standard deviation, and finally for a break in correlation with US GDP. Where a break is identified in either mean or standard deviation, that information is used in standardizing the series for the subsequent parameter stability tests. For the expenditure components, the series are the growth contributions to GDP; that is, they are constructed as the four-quarter-ended growth rate for the sector weighted by the sector's share in GDP.

For the mean growth contributions, there is strong evidence of structural breaks occurring in the mid-1970s for consumption, government spending, and final domestic demand. The government spending contribution falls to about one third of its mean contribution in the 1960s and early 1970s; the mean consumption contribution falls by slightly less than half, as does that of final domestic demand. Although the estimated break dates vary somewhat across these expenditure components and total output, it is probably safest and most reasonable to interpret the dates as being roughly coincident. In contrast to consumption and government spending, the results show a stable contribution from investment and exports. Looking more closely at exports, there is a statistically significant break in the mean growth rate of exports around about 1973; growth falls from an average of 9 per cent to about 5 per cent. This appears to be offset, however, by an increasing share of exports in total GDP.[10]

It is not possible to determine from these results the cause of the slowdown in economic growth, but the results do provide useful information. First, as

10. The $\sup W$ statistic for mean export growth is 9.6408 with break date 1973Q3. The first sample mean growth rate is 0.0925, the second sample 0.0488.

Table 3
Expenditure decompositions
Four-quarter-ended growth-rate contributions

			Subsample		Estimates
	sup*W* (*p* = 1)	**CVs [10%, 5%]**	**Date**	**First**	**Second**
Break in μ					
C	23.9768	[5.59, 7.05]	1977Q1	0.0287	0.0150
I	2.6639		—	*0.0068*	
G	44.8486		1976Q2	0.0126	0.0043
X	3.6016		—	*0.0152*	
C + *I* + *G* – *M*	23.0744		1976Q2	0.0519	0.0258
Y	18.4790		1974Q2	0.0532	0.0294
Break in σ					
C	16.7502		1992Q4	0.0101	0.0049
I	4.5012		—	*0.0110*	
G	10.6443		1972Q4	0.0059	0.0040
X	38.7843		1972Q3	0.0082	0.0185
C + *I* + *G* – *M*	5.8353		1993Q1	0.0212	0.0136
Y	5.5230		1981Q4	0.0163	0.0235
Break in ρ(*z*,*y*)					
C	19.2644		1992Q2	0.7473	0.4742
I	9.7577		1984Q4	0.2944	0.7013
G	5.7071		1981Q1	–0.3770	–0.0714
X	23.3641		1972Q3	–0.0174	0.6145
C + *I* + *G* – *M*	14.1945		1972Q2	0.7874	0.4133
Y	4.6593		1980Q1	0.6410	0.7858

Notes: The sample is 1962Q1–2004Q1. The series are four-quarter-ended growth rates of seasonally adjusted GDP; see Appendix 1 for details and data sources. Moments are estimated using GMM with numbers in parentheses Newey and West (1987) standard errors with a lag truncation parameter of four.
Stability tests are the sup*W* tests from rolling samples, as described in Andrews (1993). The sample break points used run from $0.25 \times T$ to $0.75 \times T$, T the full sample size. p identifies the number of parameters, and critical values (CVs) are from Table 1 in Andrews (1993). Where a break is evident at standard significance levels, the date is reported. Where no break is evident, the full sample moment is reported. For the correlation coefficient, the date of the associated statistic is always reported.
For the mean and standard deviation, if a break is assumed evident (date reported), then the subsequent stability tests use the estimated break dates to adjust the moments; see Table 2 and text for further explanation.

noted, despite the fall in export growth, its contribution has remained stable (at approximately 0.015) and does not appear to be the source of the decline. The decline in consumption growth (and as its major component, final domestic demand) is difficult to explain, since there are many possible causes, not the least of which is the decline in income growth, which we wish to explain. The declining contribution from government spending can be more easily interpreted as a possible cause of the declining output growth rate. This is similar to the interpretation provided by Curtis (2001). He argues that the decline in the GDP growth rate, which he informally dates around 1980, is coincident with a change in emphasis of fiscal policy. The results in Table 3 tend to support this argument, although the effects occur earlier than suggested. This, however, provides no information about whether the decline in government spending growth was appropriate or not, merely that there may have been a link between the two.[11]

For the standard deviation of the growth contributions, recall first that the standard deviation of GDP growth increases with a (weakly) statistically significant break occurring in 1981Q4. When we look at the expenditure component contributions individually, no clear story emerges to explain the source of this break. There is evidence of a break in variation for consumption, government spending, exports, and final demand; however, these do not occur at a similar time. Consumption and final demand both have a break in standard deviation in the early 1990s and, in both instances, the standard deviation falls. The growth contribution of government spending also falls but does so much earlier in the early 1970s. These sectors—in particular, consumption and government spending—are clearly not the source of the rising variation in GDP growth. The culprit appears to be the export growth contribution, which saw a dramatic increase in variation in the early 1970s.[12] A natural explanation for this result, though it is conjecture, is that the increased variation of the export contribution roughly coincides with the move to a floating exchange rate in the early 1970s. Greater variation in exchange rates may have given rise to greater variation in export contribution. In addition, the increased variation may also be related to increased variation in energy commodity prices occurring at this time. A better understanding of the behaviour of Canada's export sector and its contributions to GDP would seem to be important for an understanding of the increased volatility of Canadian GDP growth in the past thirty years.

Curtis (2001) also considers possible explanations for the rising standard deviation of output and argues that the refocusing of macroeconomic policy away from aggregate demand stabilization to medium-term objectives

11. The discussion implicitly treats government spending as largely exogenous, but this is clearly a simplification. It is perfectly possible that the fall in government spending arose in part through lower aggregate output/income growth. Sorting out cause and effect requires a structural model. The contribution of our approach is to identify the timing of the event and the role government spending may have in understanding the decline in mean growth rates.

12. It is not possible to be definitive, because the variation of output depends not only upon the variance of its components' growth contribution but on the covariation among the different expenditure components as well.

(budget balance in the case of fiscal policy and money or inflation targeting in the case of monetary policy) is partly responsible. This argument, however, is not supported by the results here; were this argument correct, we would almost certainly observe a similar rise in standard deviation in consumption and final demand, with expenditure components likely to be sensitive to monetary and fiscal stabilization policy. In fact, the evidence points to these falling after the early 1990s.[13]

Conditional on these estimates, we now consider the changing nature of correlations between expenditure components (growth contributions) and US GDP growth. In Table 2, we find an increase in correlation for Canada and US GDP that is, at best, weakly significant; of interest here is to see what sectors, if any, might underlie this small increase. It is also interesting to consider the behaviour of these sectors in their own right, since they shed light on the linkages between the two economies.

All expenditure components have evidence of a statistically significant (10 per cent level) change in correlation with the United States. The direction and timing of the changes, however, are not consistent across sectors. Three sectors see an increase in correlation with US GDP: investment, government spending, and exports. The largest absolute change is with the export contribution: for the period 1962–1972Q3, the correlation with US GDP is roughly zero; for the period 1972Q4–2004Q1, the correlation is 0.61. As we might suspect, the growing trade linkages and increasing trade volume with the United States are important factors in the business cycle synchronization of the US and Canadian economies. Interestingly, this happens well before events such as NAFTA and other increases in integration. The correlation between investment and US GDP also rises significantly, though the estimated break date occurs later, 1984Q4. While there may be many possible causes, three potential explanations (all possibly related) are the following. First, the increasing financial integration of the Canadian and US economies may link investment growth in this country much more closely to what is happening in the United States. Second, strong growth in the United States may encourage investment in Canada in the tradables sector. Finally, the responsibility may lie with foreign direct investment in Canada, which has become easier in the past two decades.[14]

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13. One possibility is that we are missing the breaks in standard deviation in these series, coincident with that of aggregate output as they are dominated by the break in the early 1990s. In other words, there may be more than the single break for which we test. As this is not the principal focus of this paper, we leave this for later work.

14. The other sector that has seen an increase in correlation with US GDP is the contribution from government spending. What underlies this increase, however, is not clear.

Turning to consumption and, the closely related measure, domestic final demand, we have the opposite result: a significant fall in correlation with US GDP with an estimated break date in the early 1990s. The cause of this change is not clear, though the timing suggests that the longer and lengthy recession experienced in Canada may be a contributing factor.

Rather than further speculate on the underlying sources, it is more useful to consider the broader picture. The results in Table 3 suggest that expenditure components, such as investment and exports that have possibly strong external linkages, have increased their degree of correlation with US growth. This is very much consistent with arguments elsewhere that the degree of synchronization between economies has increased as barriers to international trade and finance have fallen in recent decades. Offsetting this, however, is a domestic sector captured by consumption and domestic final demand that has weakened its relationship with external influences. The net effect of this is a relatively stable correlation (or one that shows a small increase) between US and Canadian GDP growth. Given that consumption is such a large component of GDP, to better understand the relationship between Canada and the United States requires a better understanding of consumption behaviour in Canada.

The results here can be usefully related to studies that ask whether greater integration is likely to lead to greater synchronization of business cycles. This theme arises in studies such as Frankel and Rose (1998), which is concerned with optimum currency area criteria: whether countries that become more closely integrated through trade and/or financial linkages are more likely to have synchronized business cycles.[15] More generally, studies such as Kose, Prasad, and Terrones (2003) ask whether globalization, broadly defined, will affect business cycle synchronization. Theoretically, the conclusions for greater integration or globalization are ambiguous (see Kose, Otrok, and Whiteman (2003) or Imbs (2004) for a summary); empirically, however, there appears to be a consensus that stronger trade and financial linkages contribute to greater synchronization, at least in a cross-section of countries for a particular sample.

Studies that specifically look at whether synchronization has increased over time with the greater integration of trade and financial linkages, that is, globalization, are less clear. For example, Kose, Otrok, and Whiteman (2003) specifically consider changing patterns of synchronization for a broad set of countries and do not find evidence of increasing

15. Many studies of business cycle synchronization use the optimum currency area as a motivation. This is also explored using regional data; see, among others, Clark and Shin (2000).

synchronization over recent periods of greater integration. The results here cast light on possible reasons. What we observe is that trade integration does contribute to growing synchronization; however, against this is a weakening of the synchronization of Canadian consumption with the US economy. One might argue that this latter condition is in line with growing financial integration if we view the US economy as the major source of disturbance for the Canadian economy. This is only suggestive but does point to the possibility that the lack of evidence of globalization reported in Kose, Otrok, and Whiteman may reflect the competing effects integration has on economies and business cycle synchronization.

2 Canada-US Correlations—Industry Sector Data

This section examines the set of simple contemporaneous correlations between nine industry sectors located in Canada and the United States. It summarizes the relationships between industry components of the Canadian and US economies, including evidence on the role of common sector and national shocks, as well as on the relationships between tradables and non-tradables sectors. An examination of sector relationships within and across borders is also a natural extension of recent studies that emphasize the interaction among sectors as part of the propagation of business cycles within an economy. For Canada, see Barillas and Schleicher (2003).

The importance of industry sectors for understanding international business cycles has also been emphasized in previous studies. One issue is the degree of integration between countries and the relative importance of sector and national/regional shocks. Clark and Shin (2000) argue, for example, that increased integration between regions or countries raises the relative importance of sector-specific shocks. Since Canada and the United States are highly integrated, we anticipate that sector- or industry-specific shocks are likely to be important; our analysis provides some means of gauging just how important they are. A further issue relates to production specialization as an explanation for business cycle synchronization. Imbs (2004) argues that countries with similar patterns of production are likely to be highly correlated, through common shocks or common response to shocks. The analysis here provides information in this regard for Canada and the United States.

2.1 Data and the empirical model

The data used are annual gross value-added measures by sector from the OECD STAN Database for the period 1978–2001. For reasons discussed previously, we use annual growth rates as a simple measure of cyclical behaviour in each sector.[16] There are nine sectors at a coarse level of aggregation; they are: agriculture, hunting, forestry, and fishing (AFF); mining and quarrying (MQ); total manufacturing (MAN); electricity, gas, and water supply (EGW); construction (CON); wholesale and retail trade, restaurants, and hotels (WRT); transport and storage and communication (TSC); finance, insurance, real estate, and business services (FIR); and community social and personal services (CS). The nine sectors across two countries give 18 time series and 153 correlation pairs.

Table 4 provides a simple summary of the set of correlation pairs: mean, range, and extreme correlation pairs. This is done for the full sample and for two subsamples that roughly split the sample in half. The means and ranges are fairly similar across the different samples, suggesting that the distribution of the correlation pairs is reasonably stable. Perhaps surprisingly, the maximum correlations in all samples are a cross-border correlation, while the minimum correlations are within Canada for two of the three samples. A further notable result is that two of Canada's export sectors, mining and agriculture, are so strongly negatively correlated. Investigating these sorts of issues is the purpose of the following more systematic examination of the patterns of correlations.

2.2 Border effect

Table 5 presents a simple breakdown of the correlation pairs into two groupings: within country and across country. The table reports the mean for each group and the difference that, following Clark and van Wincoop (2001), is termed the border effect. The border effect identifies the extent to which correlations within a country's borders exceed those across borders. Results for the full sample are reported, as are results for the two subsamples. The number of time-series observations available for the subsamples is quite small, which qualifies any conclusions.[17] For both the full sample and the subsamples, there is no evidence of a border effect: correlations across sectors within either the United States or Canada are, on average, the same as those correlations between sectors across the US-Canada border.

16. The output series are real volume index measures. The advantage of the OECD STAN Database is that it provides a consistent set of comparable sector data for the two economies.
17. The reported standard errors are based on White's (1980) heteroscedasticity robust covariance matrix estimator; we use the weighting matrix HC3 as defined in Davidson and MacKinnon (1993, 552). Estimation issues are discussed further below.

Table 4
Sector correlations—summary statistics

	1978–2001	1978–89	1990–2001
Mean	0.1957	0.1965	0.1706
Standard deviation	0.2774	0.3696	0.3714
Minimum	–0.5340	–0.7366	–0.7857
Sector pair	MQ(CA):AFF(CA)	MQ(CA):AFF(CA)	CS(US):MQ(CA)
Maximum	0.8753	0.8995	0.8743
Sector pair	MAN(US):MAN(CA)	MAN(US):MAN(CA)	CON(US):WRT(CA)

Notes: The data consist of bilateral correlations of annual growth rates of value-added volume measures of sector production available from the OECD STAN Database. The correlations are constructed for growth rates over the samples indicated. The sectors are: agriculture, hunting, forestry, and fishing (AFF); mining and quarrying (MQ); total manufacturing (MAN); electricity, gas, and water supply (EGW); construction (CON); wholesale and retail trade, restaurants, and hotels (WRT); transport and storage and communication (TSC); finance, insurance, real estate, and business services (FIR); and community social and personal services (CS). Two countries with nine sectors each provides 153 correlation pairs. CA refers to Canada; US refers to the United States.

Table 5
Sector correlations

Sample period	Within-country average	Cross-country average	Border dummy
Border effect			
1978–2001	0.1896	0.2011	–0.0115
	(0.0342)	(0.0301)	(0.0456)
1978–89	0.2043	0.1895	0.0148
	(0.0447)	(0.0408)	(0.0606)
1990–2001	0.1578	0.1820	–0.0242
	(0.0449)	(0.0411)	(0.0608)

Tradables sector	Constant	Within CA	Within US	Within common sector	Within tradables sector
Common sector and tradables sector effects, 1978–2001					
AFF, MQ, MAN, TSC	0.1734	–0.034*4	0.0443	0.1528	0.0156
	(0.0474)	(0.0632)	(0.0529)	(0.1079)	(0.0490)
MAN	0.1375	–0.0344	0.0443	0.1720	0.2121
	(0.0310)	(0.0609)	(0.0497)	(0.0913)	(0.0581)
MAN	0.1400	—	—	0.1695	0.2121
	(0.0243)			(0.0891)	(0.0576)

	Constant	Common sector	MAN(CA): CA	MAN(CA): US	MAN(US): CA	MAN(US): US
Common sector and manufacturing effects, 1978–2001						
	0.1402	0.1460	0.1697	0.2970	0.1249	0.2535
	(0.0239)	(0.0800)	(0.1260)	(0.1042)	(0.1125)	(0.0965)

Notes: The data are as described in Table 4. Numbers in parentheses are White (1980) heteroscedasticity robust standard errors using weighting matrix HC3 as defined in Davidson and MacKinnon (1993, 552).

The lack of a border effect in industry correlations is evidence of the considerable integration between the two economies. It also suggests that nation-specific factors are not particularly important for the business cycles of the two economies. This sets Canada and the United States apart from the expected behaviour of most national economies; most country-industry-based studies tend to conclude that nation-specific shocks are more important than common industry-based shocks at an international level (see the discussion in Clark and Shin (2000)). Put somewhat differently, the lack of border effect means that Canada and the United States behave, as far as their business cycles are concerned, as two integrated regions within an aggregate economy.

This lack of a border effect is potentially very useful information for assessing the impact of integration for national economies. Canada and the United States are highly integrated along many dimensions. Bilateral trade, financial markets, and direct investment are all high relative to most countries. Moreover, the Canada-US exchange rate is relatively stable over short horizons. On other non-economic dimensions, such as language and legal institutions, the two countries are also very similar. Thus, the two countries seem to represent a good example of what countries can expect of this extent of integration, short of full political and economic union, in terms of synchronization; and may be a better example than afforded by regional analysis. Viewed from another perspective, the results here support the regional analysis, such as Clark and Shin (2000), which argues that on the basis of regional comparisons, greater integration of national economies is likely to lead to greater synchronization and a dominant role for sector-specific shocks.

2.3 Common shocks and tradables sectors

In the second part of Table 5, we further decompose the set of correlations, using a simple dummy-variable regression model to identify possible effects. The first set of dummy variables identify within-country effects on correlation levels. We separate sector correlations within Canada and within the United States. If country-specific shocks are important, such as national monetary and fiscal policies, country-specific productivity, or other types of supply shocks, then the effect on predicted correlation should be positive.[18] Note that the two country effects are a decomposition of the within-country measure used in the first part of the table; the decomposition allows for different effects within the United States and Canada.

18. At the coarse level of aggregation used here, it is also possible that the country-specific effect may pick up consistent differences in sectors across countries; that is, the sectors are insufficiently similar to identify a common sector shock.

The second set of dummy variables, in this case, a single-dummy variable, identifies the set of correlations within a sector—by definition, across countries. There are nine such correlations. If sector-specific shocks are influential, we might expect these pairs to have higher correlations, all else being equal. In this limited sense, this effect captures the importance of common industry shocks, and by comparing the importance of this effect relative to the within-country effect, we obtain information about the relative importance of nation-specific shocks versus common industry shocks. The idea of a common industry shock is quite broad. It captures factors that might directly influence the behaviour of a particular industry sector across countries, for instance, a common supply shock. It also captures factors that influence a sector in one country that is then transmitted to the same sector in the other country through trade and/or investment linkages. Manufacturing in the United States and Canada is a natural example of such possible linkages within an industry sector. The next set of dummy variables attempts to control for these possible linkages.

The third set of dummy variables identifies sectors that are traditionally viewed as tradables sectors. If trade is an important transmission mechanism, we might suspect correlations between these sectors to be higher than average, all else being equal. Two possible sets of sectors are considered as representing tradables sectors. The first consists of what are essentially commodity-producing sectors, AFF, MQ, and MAN, and one service sector, TSC. This is roughly consistent with exchange rate studies, such as Engel (1999) and De Gregorio, Giovannini, and Wolf (1994), that rely on separating production sectors into tradables and non-tradables. The remaining sectors, primarily different types of services, are treated as non-tradables. The correlations we wish to identify as within a tradables sector are those pairs that involve at least one of the tradables sectors and possibly both. As examples of the linkages we are considering, correlations within a tradables sector include: (i) Canadian MAN with Canadian AFF; (ii) Canadian MAN with US FIR; and (iii) Canadian MAN with US MAN. Note that this grouping will overlap with the common sector grouping discussed previously. We also consider a variation on this definition, restricting attention to manufacturing. In part, this reflects the fact that manufacturing receives a lot of attention in industry sector studies, so it is of some interest to determine whether it has different effects. It also reflects that fact that the manufacturing sector is heavily integrated and traded between the two economies, and in each country, the manufacturing sector is a significant part of the aggregate economy.

With these sets of dummy variables defined as D_1, D_2, D_3, we have the following simple statistical model. Let $i, j = 1...9$ denote sectors and $m, n = 1, 2$ denote countries. The linear regression model is:

$$\rho_{im,\, jn} = \beta_0 + \beta_1 D_1 + \beta_2 D_2 + \beta_3 D_3 + \varepsilon_{im,\, jn},$$

where $\rho_{im,\, jn} = corr(x_{im}, x_{jn})$, $i, j = 1...9$, $m, n = 1, 2$, $i \neq j$, if $m = n$.

Though simple, care must be taken in estimating this model. First, as noted by a number of authors, the errors in the regression model are not going to be homoscedastic, since the correlation pairs are likely to be interrelated; in previous studies using such equations, such as Otto, Voss, and Willard (2003) and Frankel and Rose (1998), this is corrected for using White (1980) heteroscedasticity robust standard errors, and this is what we do here. In contrast, Clark and van Wincoop (2001) argue for a more sophisticated method for estimating the covariance matrix that takes explicit account of the sampling error in constructing the bilateral correlations. We leave this for future work.[19]

There is a further potential problem with the statistical model above that is usually overlooked. The dependent variable is constrained to be between –1 and 1, which means that the above cannot be treated as a simple linear regression model. It is straightforward to correct for this using a simple transformation of the model; details are in Appendix 1. We present results using both estimation methods (Appendix 1 describes the estimation of the transformed model with results in Table A1.1); the former because they are more easily interpreted, the latter as a check that the simple linear model is not providing grossly misleading results.

The first regression reported in Table 5 uses the broad definition of the tradables sector. The next two use the manufacturing sector definition. Consider first the within-country effects, either within Canada or within the United States. Consistent with the upper half of the table, there is no border effect for these two countries, even when looking on an individual country basis. This result is robust to the two tradables sector specifications. Consider next the common sector effect. In this case, the effect is positive and statistically significant; again, this result is consistent across both definitions of the tradables sector.

Finally, there does not appear to be a tradables sector effect when tradables are broadly defined. Given the strong results in the literature that identifies a significant positive role for bilateral trade for business cycle synchronization, this seems surprising. If instead we narrow the definition and focus on linkages involving the manufacturing sector, we find a very strong, positive, and statistically significant effect. If we appeal to the simple linear model, sectors involving the manufacturing sector are expected to have

19. Whether or not this is an important issue is not clear; Imbs (2004) suggests that using Clark and van Wincoop's methods does not substantially alter his results.

correlation coefficients 0.21 higher than average, all else being equal. The next specification in the table drops the insignificant within-country effects, leaving the following summary of the sector correlations (again, using the simple linear model): the common sector effect adds about 0.17, while the within-manufacturing (tradables) sector effect remains at 0.21.

The tradables sector effect treats correlations within countries (e.g., US manufacturing and construction) the same as correlations across countries (e.g., US manufacturing and Canadian manufacturing). To see if there is a border effect within this class of correlations, we decompose the within-manufacturing effect into four possible effects: (i) linkages between Canadian manufacturing and other Canadian industries; (ii) linkages between Canadian manufacturing and US industries; (iii) linkages between US manufacturing and Canadian industries; and (iv) linkages between US manufacturing and other US industries.

The common sector effect remains significant though slightly smaller in magnitude. The manufacturing effects vary somewhat, both in size and whether they are statistically significant or not. If we first consider the within-country effects, denoted MAN(CA):CA and MAN(US):US, we find a statistically insignificant effect for Canada (a coefficient of 0.17 with a two-sided *p*-value of 0.18) and a strongly significant effect for the United States (a coefficient of 0.25 with a two sided *p*-value of 0.01). The magnitude of the US effect is also substantially larger than that for Canada. This suggests that the linkages between US manufacturing and the remaining US industry sectors are much stronger than the similar relationships for Canada. A possible explanation is that Canada's manufacturing sector is more outward-looking than that of the United States and consequently less integrated with the other sectors of the national economy.

If we next consider the cross-border manufacturing effects, denoted MAN(CA):US and MAN(US):CA, we find further evidence of the dependence of Canadian manufactures on the US economy. The effect for MAN(CA):US is very strong and statistically significant (a coefficient of 0.30 with a two-sided *p*-value of 0.01). In contrast, the coefficient for MAN(US):CA is statistically insignificant and small in magnitude (0.12 with a two-sided *p*-value of 0.27). US activity appears to be important for Canadian manufacturing, while US manufacturing does not seem to have a significant effect on Canadian industries.

In summary, the tradables sector linkages, as measured by interactions of all sectors with manufactures, are important only for cross-border correlations if they involve Canadian manufactures. As this involves only nine correlation pairs, they are provided in Table 6 for the full sample and the two subsamples. Five of the nine sectors have very strong and remarkably stable

Table 6
Manufacturing and common sector correlations

	AFF	MQ	MAN	EGW	CON	WRT	TSC	FIR	CS
US industry sectors									
1978–2001	0.17	0.13	0.88	0.34	0.81	0.64	0.46	0.74	0.05
1978–89	0.17	0.26	0.90	0.49	0.88	0.61	0.46	0.74	0.35
1990–2001	0.20	–0.10	0.86	0.18	0.76	0.68	0.52	0.77	–0.25
Industry sectors									
1978–2001	0.06	0.33	0.88	0.17	–0.04	0.51	0.56	0.16	0.37
1978–89	0.17	0.33	0.90	–0.04	–0.41	0.36	0.63	–0.05	–0.19
1990–2001	–0.18	0.47	0.86	0.40	0.53	0.73	0.61	0.59	0.54

Note: The data are as described in Table 4.

correlations with Canadian manufacturing. These are US manufacturing (MAN); construction (CON); wholesale and retail trade (WRT); transportation, storage, and communication (TSC); and financial services (FIR). Clearly, the integration of the Canadian manufacturing sector across these US industries is likely to explain an important part of the overall synchronization between the two economies.[20]

In contrast, the common sector effect is much less uniformly strong and stable; for comparison, these are reported in Table 6, as well. It is useful to consider these correlations somewhat further with the idea of assessing to what extent the correlation across particular sectors can be explained by interdependence between the sectors themselves (for example, Canadian and US manufacturing are possibly quite closely linked through trade and foreign direct investment); by shocks common to particular sectors; and by a similar response of sectors to common aggregate shocks. Although we are unable to provide a definitive answer to the relative importance of these possible explanations, we can make some inferences along these lines.

There are four sectors that have high, relatively stable correlations: mining (MQ), manufacturing (MAN), trade (WRT), and transportation (TSC). Of these, manufacturing is much the strongest correlation, while mining is the weakest. For mining, it seems reasonable to think that an important component of this is global commodity demand and supply shocks and/or a similar response of these sectors to common aggregate shocks. For the remaining sectors, however, such a simple assessment is not as compelling, since it seems likely that these sectors are linked across the border. We

20. These results are robust to controlling for the restricted nature of the dependent variable; see Table A1.1. The coefficient magnitudes in this case are not directly interpretable; however, the relative magnitudes and inference are all unchanged from the simpler linear models reported in Table 5.

return to this point below; before doing so, however, there are two points to consider. First, one sector that would seem naturally to fall into the category of having important common shocks (or common response to aggregate shocks) would be the financial sector. Here, however, we see no common pattern of behaviour. The second interesting feature is the quite strong correlations in the final part of the sample across all sectors. The bulk of this sample involves a steady expansion of the two economies. One way to interpret the results is that the expansion had comparable effects on each industry sector; that is, a particular sector responded in a similar fashion over the expansion in both Canada and the United States.

A simple means of exploring the relative importance of whether common shocks are important in particular sectors or whether there are substantial linkages between the two is to estimate simple bivariate VAR models for each sector, consisting of growth rates of the US and Canadian sectors, and to examine the correlation of the residuals.[21] Small correlations relative to the correlation of the sector growth rates suggest that interdependence between the two sectors is important, while larger correlations suggest that common shocks may be important.[22] Table 7 reports the simple correlation for the bivariate VAR residuals for each sector. It does so using both growth rates and log levels. (The results are also similar if a trend is included in the log level regressions.) The focus is on the four sectors with high raw correlations identified above. For manufacturing, the residual correlations are very high, comparable to the sector-output correlations for manufacturing. A similar conclusion holds for trade and transportation. For mining, we obtain the interesting result that the shocks are more highly correlated than the outputs of the US-Canada sectors. Overall, there is little evidence of much dynamic interdependence between these sectors, suggesting that what underlies the high correlations of these sectors are common shocks or similar responses to common aggregate shocks. Given the broad conclusions from Table 6, which tend to support the role of trade linkages (at least through manufacturing), this result is puzzling. A more thorough study of the transmission mechanisms between Canada-US industries might resolve these issues.

21. This is similar to Canova and Dellas (1993), though they perform their analysis on GDP for a cross-section of countries. See also Canova and Marrinan (1998), which explicitly examines the role of trade interdependence versus common shocks.

22. This is an imperfect means of investigating the underlying relationships between sector growth rates, but has the advantage of not requiring identification restrictions. Imposing identification restrictions to perform a more standard VAR-type analysis, for example, a recursive causal ordering, would allow more concrete statements to be made. However, as there is no obvious compelling structural identification to impose on the estimation, it seems preferable to carefully interpret the reduced-form VAR models.

Table 7
Correlation of sector shocks

	Common sector VAR(p): residual correlation coefficients								
	AFF	**MQ**	**MAN**	**EGW**	**CON**	**WRT**	**TSC**	**FIR**	**CS**
Industry sectors									
Growth rates	–0.26	0.76	0.91	0.06	0.19	0.45	0.58	0.07	0.25
Log levels	0.09	0.75	0.91	0.06	0.12	0.53	0.31*	0.49	0.34

Notes: The data are as described in Table 4. Correlations are for the estimated residuals from a bivariate VAR of order p . The VAR order was chosen on the basis likelihood ratio tests and tests for serial correlation in the residuals. VAR orders used for the above range from 2 to 4. An * indicates evidence of serial correlation even with a maximum lag length of four.

2.4 Further discussion

Examining simple correlations as we have done here does not provide direct information on cause and effect. At best, we can establish simple empirical features of the relationship between the Canadian and US economies that suggest underlying linkages. In this section, we review and discuss the results and attempt to place them in context. At their simplest, the results provide a descriptive summary of the Canada-US sector relationships. These might be useful as a guide to further theoretical and empirical research, for example, as a means of assessing sector business cycle models, such as Ambler, Cardia, and Zimmermann (2002). Moreover, the results here complement other studies of Canadian business cycle features, such as Koustas (2003), Barillas and Schleicher (2003), and Beine and Coulombe (2002).

The main points from the results in this regard are as follows. First, there is no border effect; equivalently, there is no evidence of national shocks for Canada and the United States. This result appears to be stable (given the limited data), so that the growing integration of the US and Canadian economies has not altered this conclusion. This is in line with the aggregate economy results in the first part of the paper that find only weak evidence of increased correlation between the two economies in recent decades. Second, there is a common sector effect, although it is not large. This might be explained by industry-specific shocks or by industry-specific responses to common aggregate shocks. The effect, however, is not uniform and there is evidence of instability over time.

Third, correlations involving sectors broadly defined as tradables are not significantly higher than the average. This result is surprising, since Canada and the United States have strong trade linkages, and Canadian tradables are likely closely interdependent with US sectors. This may reflect problems with looking across a broad set of sectors that have differing degrees of dependence upon trade generally and trade specifically with the United States. A narrower definition of tradables that includes only the manufacturing sector does provide evidence of higher than average correlations. This is especially true for Canadian manufactures with the US economy and, in particular, Canadian manufactures are highly synchronized with US manufacturing, construction, wholesale and retail trade, and the financial industries. Moreover, this synchronization appears to be quite stable.

The next direction is to consider what information these results provide in regard to the synchronization or correlation of the two economies as a whole. The correlation of aggregate output growth rates will depend upon the underlying sector-growth correlations scaled by the share parameters for the sectors and the standard deviations of the sectors relative to standard deviations of the aggregate output measures. More simply, sectors that are highly correlated, that are relatively volatile, and relatively important in both economies, are going to lead to highly correlated aggregate output levels. The results above establish that common sector and tradables (manufacturing) sector groupings are more likely to contribute to higher aggregate correlation than other sectors holding these other scale factors constant.[23]

Finally, the results here can be interpreted within the context of the literature that examines the determinants of business cycle synchronization. These studies have emphasized trade and financial linkages, as well as production specialization. The results here support the broad conclusions of this literature. Whether due to common shocks or common sector response to shocks, the common sector effect identified in the sector correlations is indirect support for Imbs' (2004) arguments that the more similar are two economies in production structure the more likely are their business cycles to be synchronized. That said, however, only a subset of the industry sectors are strongly synchronized across the US-Canada border, most notably manufacturing. Interestingly, many of the cross-country studies use indexes of comparable specialization based only on manufacturing (that is,

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23. To be more precise, one should calculate the various scale factors; since there are 81 sectors that contribute to the aggregate output correlation (of the 153 cross-sector correlations, only 81 are across-border), a comparative assessment along these lines requires considerable effort. I leave this for future work. Furthermore, given the relatively large role for manufacturing in both economies (in recent years, about 18 per cent in Canada and 14 per cent in the United States), it seems reasonable to accept that the tradables sector involving manufacturing linkages is likely to contribute in an important way to the overall aggregate correlation between the two economies.

manufacturing subsectors), primarily for reasons of data quality.[24] The results here suggest that broad-based conclusions about the interaction between production specialization and business cycle synchronization may not be possible using manufacturing-based specialization indexes—the manufacturing sector seems to behave differently from other sectors in the economy in this regard.

The tradables sector effect, when narrowly defined to manufactures, provides indirect evidence on the importance of trade linkages for the transmission of shocks between the two economies, particularly in the case of the synchronization between Canadian manufactures and US sectors. The fact, however, that there is no tradables sector effect when we use a broad definition of tradables presents a small puzzle. This conclusion does not seem to fit well with the general result from the literature that bilateral trade is important for understanding international business cycle synchronization. One possibility is that we are ignoring the scale factors when assessing the contributions to aggregate correlations. If this does not overturn the result, one might conclude that what matters for aggregate correlations are only certain tradables sectors, in this case, manufacturing broadly defined. It is of some interest whether this result holds more broadly for cross-country synchronization and is not specific to the Canada-US situation.

Conclusion

This paper examines two facets to the relationship between the US and Canadian economies. The first is at an aggregate level and specifically examines whether the relationship between the two economies has been stable. This is done informally by looking at changes in the dynamic correlations of aggregate output growth rates and more formally for the simple correlation between output growth rates. The key result is that there is only weak evidence of an increase in synchronization despite the growing trade and financial integration. The increase in integration is evident, however, in the increased synchronization of Canadian investment and export sectors with the United States.

24. Imbs (2004), for example, uses both manufacturing sectors and broadly defined sectors similar to those here to construct indexes for specialization; however, his discussion focuses on the manufacturing-based specialization index. Similarly, Otto, Voss, and Willard (2003) consider broad- and manufacturing-based specialization indexes, but finds that the manufacturing-based index provides a better fit for the data.

The second facet is the relationships between industry sectors in the United States and Canada. Here, the main result is no evidence of a border effect—Canada and the United States, from this perspective, operate as a large economic region. This suggests that Canada and the United States provide a good benchmark for the effects of broad-based integration on business cycle synchronization that other countries might expect, for example, countries in the European Union, as economic, political, and cultural ties increase. We also provide evidence that, at a coarse level of industry definition, manufactures are a key sector in understanding business cycle synchronization.

Appendix 1
Data

Real GDP data for Canada are taken from CANSIM II Table 3800002, Gross Domestic Product (GDP), Expenditure-Based. All series are seasonally adjusted, chained 1997 dollars. The series labels are as follows:

Table A1.1

Variable	Description	Series label
Y	Gross domestic product (GDP) at market prices	V1992067
C	Personal expenditure on consumer goods and services	V1992044
I	Business gross fixed capital formation	V1992052
G	Government current expenditure on goods and services	V1992049
X	Exports of goods and services	V1992060
$C + I + G - M$	Final domestic demand	V1992068

Note that the definition of final domestic demand is not equal to $C + I + G - M$, as defined here as G excludes public investment.

The industry-sector data are taken from Source OECD STAN Industrial Structural Analysis Database Edition (ISSN 1608–1307) available at: <new.sourceoecd.org/database/stan>. The series descriptions are as follows:

Table A1.2

Variable	Description
AFF	Agriculture, hunting, forestry, and fishing
MQ	Mining and quarrying
MAN	Total manufacturing
EGW	Electricity, gas, and water supply
CON	Construction
WRT	Wholesale and retail trade; restaurants and hotels
TSC	Transport and storage and communication
FIR	Finance, insurance, real estate, and business services
CS	Community social and personal services

Dependent variable transformation for correlation regressions

The following transformation is proposed in Otto, Voss, and Willard (2003) to take account of a dependent variable that is restricted to be between –1 and 1. We assume the following non-linear structure for the regression model:

$$\rho_{ij,\tau} = f(W_{ij,\tau}\beta + \varepsilon_{ij,\tau}).$$

Here, $\rho_{ij,\tau}$ is the correlation measure between two countries or sectors i and j measured over sample period τ taking values between –1 and 1; $W_{ij,\tau}$ is the set of regressors, and $\varepsilon_{ij,\tau}$ is the error term. The function f must map from the real line to the interval –1 to 1; we use the following function:

$$\rho = f(w) = \frac{\exp(w) - 1}{\exp(w) + 1}.$$

As w becomes very large (small), $f(w)$ gets closer to 1 (–1); and $f(0) = 0$. To estimate the model, we transform the LHS variable of equation (1) by the inverse of $f(w)$:

$$f^{-1}(w) = \ln\frac{1+\rho}{1-\rho}.$$

That is, the linear regression we estimate is:

$$\ln\frac{1+\rho_{ij,\tau}}{1-\rho_{ij,\tau}} = \ln z_{ij,\tau} = W_{ij,\tau}\beta + \varepsilon_{ij,\tau}.$$

See Otto, Voss, and Willard (2003) for details concerning predicted values.

Estimation and Testing for Structural Break in Correlation Coefficient

The two series of interest are denoted x_i and y_i for the sample $1 \ldots T$. Both series may contain structural breaks in means and standard deviations, as well as in the correlation coefficient.

The first step is to estimate and test for parameter stability for the first-moment condition for each of x_i and y_i separately:

$$E(x_t - \mu_x) = 0, \quad t = 1 \ldots T$$

$$E(y_t - \mu_y) = 0, \quad t = 1 \ldots T.$$

The mean parameter is estimated using GMM, and the Andrews (1993) test for parameter stability over unknown break points is used to test for structural change and to identify any break point.

Consistent with what is reported in the paper, assume that a break in mean is identified for series x, while no break is identified for series y. Assume that the break date is T_1. Construct the series $x'_{1t} = x_t - \hat{\mu}_{x1}$ for $t = 1 \ldots T_1$ and the series $x'_{2t} = x_t - \hat{\mu}_{x2}$ for $T_1 + 1 \ldots T$. Where

$$\hat{\mu}_{x1} = (1/T_1) \times \sum_{t=1}^{T_1} x_t, \qquad \hat{\mu}_{x2} = (1/(T - T_1)) \times \sum_{t=T_1+1}^{T} x_t .$$

Now stack the two series to obtain x'_t, which has a mean of zero over the whole of the sample.

Then estimate and test for parameter stability for the mean and standard deviation of each series; for example, for x':

$$E(x' - \mu_{x'}) = 0, \quad t = 1...T$$

$$E(x'_t - \mu_{x'})^2 - \sigma_{x'}^2 = 0, \quad t = 1...T .$$

As $\mu_{x'}$ may reasonably be assumed to be constant over the sample, test only for structural change in the standard-deviation parameter $\sigma_{x'}$. For the series, it is not necessary to demean on a subsample basis, so one can proceed as usual to estimate and test for parameter stability of the standard-deviation parameter σ_y. Again, since μ_y may reasonably be assumed to be constant, test only for structural change in the standard-deviation parameter.

Suppose, again consistent with the paper, that both x' and y are found to have a break in standard deviation. For the x' series, this occurs say at time T_x, while for the y series, it occurs at time T_y. For each associated subsample, construct an estimate of the standard-deviation parameters, denoted $\sigma_{1,x'}, \sigma_{2,x'}$ for the x' series and $\sigma_{1,y}, \sigma_{2,y}$ for the y series.

Now standardize each series on a subsample basis. For example, for the first subsample period for the x series, construct a subseries,

$$x''_{1t} = \frac{x'_{1t} - \mu_{1,x'}}{\sigma_{1,x'}}$$

$$\mu_{1,x'} = (1/T_x) \times \sum_{t=1}^{T_x} x'_t$$

$$\sigma_{1,x'}^2 = (1/T_x) \times \sum_{t=1}^{T_x} (x'_t - \mu_{1,x'})^2 .$$

Having done this for each of the subsamples for each of the series, we can stack the subsample series to create the x'' and y''_t for which we can reasonably assume stable means and standard deviations (of 0 and 1, respectively).

The final step is to estimate and test for parameter stability of the correlation coefficient. The moment conditions are:

$$E(x''_t - \mu_{x''}) = 0, \quad t = 1 \ldots T$$

$$E(x''_t - \mu_{x''})^2 - \sigma^2_{x''} = 0, \quad t = 1 \ldots T$$

$$E(y''_t - \mu_{y''}) = 0, \quad t = 1 \ldots T$$

$$E(y''_t - \mu_{y''})^2 - \sigma^2_{y''} = 0, \quad t = 1 \ldots T$$

$$E(x''_t - \mu_{x''})(y''_t - \mu_{y''}) - \rho_{x'', y''}\sigma_{x''}\sigma_{y''} = 0, \quad t = 1 \ldots T.$$

Since we can assume that $\{\mu_{x''}, \sigma_{x''}, \mu_{y''}, \sigma_{y''}\}$ are constant, we impose this condition and test only for parameter instability of $\rho_{x'', y''}$.

Table A1.3
Sector correlations using transformed dependent variable

Tradable sector	Constant	Within CA	Within US	Within common sector	Within tradables sector
Common sector and tradables sector effects, 1978–2001					
AFF, MQ, MAN, TSC	0.3952	–0.0809	0.0773	0.3932	0.0453
	(0.1203)	(0.1502)	(0.1250)	(0.3165)	(0.1224)
MAN	0.3073	–0.0809	0.0773	0.4409	0.5424
	(0.0766)	(0.1442)	(0.1174)	(0.2649)	(0.1527)
MAN	0.3064	—	—	0.4418	0.5424
	(0.0573)	—	—	(0.2598)	(0.1512)

	Constant	Common sector	MAN(CA): CA	MAN(CA): US	MAN(US): CA	MAN(US): US
Common sector and manufacturing effects, 1978–2001						
	0.3038	0.3743	0.4576	0.8107	0.3629	0.5864
	(0.0572)	(0.2143)	(0.3378)	(0.3044)	(0.2832)	(0.2316)

Notes: The data are as described in Table 4.
Numbers in parentheses are White (1980) heteroscedasticity robust standard errors using weighting matrix HC3 as defined in Davidson and Mackinnon (1993, 552).

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Discussion

Jean-François Perrault

Over the past several decades, global trade flows have expanded exponentially, as the gradual removal of barriers to trade has allowed countries to benefit from comparative advantages. The increasing reliance on trading partners for various types of imports has led to increased economic integration on a global scale: sovereign nations are more tightly linked to foreign trading partners than at any other time. As a result, many economists believe that the economic outcomes of individual states are now more heavily influenced by supranational developments. Thus, global business cycles are viewed as being a more important determinant of national business cycles than in earlier periods. Canada has been in the vanguard of this phenomenon. Most recently, the Free Trade Agreement (FTA) of 1991 and the North American Free Trade Agreement (NAFTA) of 1994 represent milestones in trade liberalization and have served as a clear marker for empirical analyses seeking to identify the impacts of integration on the Canadian economy. Indeed, two other papers presented at this conference look at Canadian business cycle dynamics pre- and post-NAFTA (see Gosselin et al. and Cardarelli and Kose in this volume).

Voss uses a rigorous statistical approach to assess whether increased integration has led to an increase in the synchronization of Canadian and US real GDP growth. In contrast to other studies, Voss does not postulate the existence of a break around the implementation of NATFA. Rather, he establishes the existence of a structural break in the variance and correlation between US and Canadian sectoral output using an endogenous test for such breaks.

Using dynamic correlation analysis, Voss finds no evidence of a border effect. Correlations across sectors in Canada are about the same as those between sectors across the border. Thus, Voss argues that “nation-specific factors are not particularly important for the business cycles of the two economies" (page 431). In addition, he finds only weak evidence of a break in the correlation between Canadian and US real GDP growth rates. This break is estimated to have occurred in 1980Q1, some distance from the implementation of NAFTA.

Voss's findings contradict much of the research on business cycle coherence done at the Bank of Canada and elsewhere. Indeed, he concludes that there is no border effect, that "Canada and the United States appear to operate, in terms of business cycle synchronization, . . . as one large economic region" (page 414). This contradicts a number of findings, such as McCallum (1995) and Helliwell (1998), which suggest the opposite: that the Canada-US border seems to have an important role in explaining differences in economic structure and business cycle dynamics.[1] Indeed, the findings of Gosselin et al. (this volume) suggest that there is generally a strong domestic component to Canadian regional and sectoral output fluctuations.[2] However, both Voss and Gosselin et al. find that in some sectors, the Canada-US linkages are strong. This is particularly so in the manufacturing sector, in which there seems to be an important degree of synchronization on both sides of the border.

Though Voss's work is a forceful and well thought-out application of correlation analysis, his approach may not be sophisticated enough to tease out findings that are more consistent with previous studies. Notably, his approach does not allow for the explicit identification of the sources of variation of his variables of interest. A structural approach would permit the decomposition of business cycle fluctuations into different components. Perhaps the most promising approach would be to include a regional element to his analysis. In fact, this is almost necessary. To conclude that a sector-specific output variable behaves no differently in Canada than in the United States, one has to be able to identify a Canada-specific industrial disturbance from a North American perspective. In the context of Voss's approach, this could be achieved by assuming three types of disturbances: one that is specific to an industry but common to Canada and the United States; a second that is common to all industries but specific to one country; and a third that is specific to one industry but common to all Canadian regions, or a subset thereof. The empirical analysis could then be augmented by including a regional dummy variable in the simple model used to identify the extent of business cycle synchronization. By doing so, Voss's analysis

1. Note that Helliwell (2002) found that the importance of the border effect diminished rapidly in the late 1980s and early 1990s.
2. A number of studies have also found this result, going back to Gregory, Head, and Raynauld (1997).

would be somewhat more structural than his original specification. This may alter his findings.

A second finding of interest is Voss's conclusion that there is only modest evidence of an increase in business cycle synchronization between Canada and the United States. What is more, the estimated break in the business cycle coherence is estimated to have occurred in 1980Q1. Again, this is an interesting though less controversial finding. Although one may have a natural inclination to assume that Canadian business cycle dynamics changed following the implementation of either the FTA or NAFTA, there is little evidence to suggest that this is the case. Gosselin et al. find only weak evidence that business cycle synchronization increased post-NAFTA. Goss's findings of an earlier break are more consistent with studies that have examined country-specific business cycle dynamics. In Canada, for example, Curtis (2001) finds that the variability of Canadian output permanently increased in the early 1980s, while McConnell and Perez-Quiros (2000) find such a shift in the mid-1980s for the United States.

As might be imagined, Voss's findings, if confirmed by other studies, would have dramatic impacts on the design of economic policy in Canada. From the perspective of a central bank, there is little reason to maintain an independent monetary policy characterized by a flexible exchange rate if most disturbances affect Canada and the United States in the same fashion.[3] In fact, Voss's findings suggest that Canada and the United States satisfy at least some of the criteria for an optimal currency area.

That said, Voss's work does represent an interesting addition to the growing literature on business cycle transmission, notably as it has been applied to the Canada-US economic relationship. Given the intriguing and important policy implications of his findings, more work is required to fully understand the factors driving Voss's results. Is it specific to his approach, as would be suggested by the contradictory findings of other researchers? Or perhaps his results highlight weaknesses in previously used empirical strategies. In either case, further research is warranted, given the importance of this research agenda for policy in Canada.

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3. This presupposes that an independent Canadian monetary policy is not a cause of these tight business cycle linkages.

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