ISSN 1440-771X
ISBN 0 7326 1063 X

MONASH UNIVERSITY

AUSTRALIA

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Working Paper 8/99
June 1999

DEPARTMENT OF ECONOMETRICS AND BUSINESS STATISTICS

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March 1999

[1] Acknowledgements: We thank James Ramsey for introducing us to the literature on coupled oscillators, and Dokoan Kim for research assistance.

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Abstract

This paper studies the relationship between international trade and output fluctuations. We find evidence that the business cycles of countries that are more open to international trade are more likely to be synchronized with the business cycles of their major trading partners. A detailed study of the South Korean case shows that while business cycles are related to openness, the diversification of export destinations seems to weaken these links. We find no relationship between openness and output volatility.

Key Words: Coherence, Common Cycles, Openness, Synchronization, Volatility.

JEL classification: C32, E32, F49.

1 Introduction

It is well known that linked biological and mechanical systems will often synchronize. Examples of this phenomenon include the co-ordination of the menstrual cycles of female room-mates, and the fact that the pendula of two pendulum clocks placed next to each other will start to swing in phase. Synchronization is so prevalent in nature that it has inspired extensive literatures in mathematics, physics and biology.[1] In this paper, we ask whether the business cycles of trading economies become sychronized, or whether they provide an exception to the above patterns of behavior. We also ask whether international trade affects the variance of output fluctuations.

We use the term synchronization when we observe that the business cycles in two countries move in phase. Thus, in the context of international output fluctuations, synchronization not only implies the stylized fact that detrended measures of output from different countries are positively correlated; it also implies that their shock propagation mechanisms are collinear. Our concept of synchronization is useful for thinking about questions such as whether the cycles of export-oriented countries become more similar to those of their major trading partners, or whether the cycles of inward-looking economies retain characteristics which differ from the rest of the world. Our analysis of business cycles in thirty seven countries finds many examples of synchronization, and we also find evidence that synchronization is related to trade. In particular, the business cycles of those countries which are relatively more open, tend to be synchronized with the business cycles of their major trading partners.

There is a particularly large literature on the relationship between openness and economic performance, but the vast majority of empirical studies in the international trade and development fields have focussed on the connections between an economy's openness and *growth*. This is hardly surprising, given that growth is a major policy objective for developing countries. Generally researchers have found a positive correlation between these two variables, although the extent of the growth-openness correlation and its economic

[1] See Strogatz and Stewart (1993) for an interesting and fun-to-read treatise on the "theory of coupled oscillators".

interpretation are often debated.[2] See Balassa (1989), Edwards (1993) and the references therein.

Given the emphasis on the relationship between openness and growth, the development and international trade literatures have paid relatively little attention to the empirical relationships between openness and the characteristics of business cycles. In particular, little is known about the empirical relationships between openness and comovement in cycles, or whether openness affects output volatility. However, there are intuitive reasons to think that trade should co-ordinate the business cycles of the countries involved. Whether one takes the pessimistic view of the now unpopular "dependency school" of thought, or the more popular "integrated-economy" view of modern trade theory, it is reasonable to believe that the business cycles of major trade partners should move in synchrony[3]. However, these two extreme positions can lead to different predictions about volatility of an export-oriented developing country. If trade leads to specialization in raw material production then it can increase volatility, but if it involves the development of a modern export sector alongside the traditional sector of the economy, then it can lead to more diversification and hence lower volatility in business cycles.

The modern dynamic macroeconomic literature has paid considerable attention to the connections between international trade and business cycles, although it has focussed on questions which differ from ours. One branch of this literature attempts to match stylized facts about cross-country data by altering the characteristics of "shocks" applied to two-country (or small open economy) versions of real business cycle models. Interest has centered on features of international business cycles such as cross-country contemporaneous correlations for output and consumption, the saving-investment correlation, and the cyclical behavior of the trade balance and terms of trade. See Backus et al. (1992), Baxter and Crucini (1993), Cantor and Mark (1988), Canova and Marrinan (1998), Mendoza (1991) and Stockman and Tesar (1995) for some examples, and Baxter (1995) for a review. A closely related branch of the macroeconomic literature uses econometric models includ-

[2] The measurement of openness is a controversial issue. See Harrison (1996) for a good recent discussion of this and other issues relating to the interpretation of the growth-openness correlation.

[3] Reviews of the relevent theories in the trade and development literatures can be found in Bliss (1989) and Krugman (1995).

ing vector autoregressive (VAR) models to investigate the relative importance of different sorts of shocks (e.g. global versus country-specific shocks). See, for instance, Ahmed et al. (1993), Canova and Dellas (1993), Kwark (1999) and Stockman (1988).

Only a handful of papers have gone beyond the question of whether output fluctuations are positively correlated, and directly addressed issues of synchronization. Indeed, out of all of the work cited above, only Canova and Marrinan (1998) describe the dynamic properties of the business cycles in their model. There are a few papers on the *dynamics* of international business cycles, which ask whether output fluctuations from different countries have high coherence over a range of different frequencies, or whether they exhibit similar serial correlation properties. Examples include Gerlach (1988), who uses spectral techniques to study the coherence between different country cycles at various frequencies, Engle and Kozicki (1993) who test for common serial correlation features in output growth in the G7 countries, and Gregory et al. (1997), who undertake a dynamic factor analysis of business cycle indicators in the G7 countries. Recently, Anderson and Ramsey (1999) have studied the *process of synchronization*, and provided empirical evidence that international linkages can lead to the synchronization of business cycles.

Our paper explicitly examines the dynamic aspects of the relationship between trade and comovement in international output fluctuations. Using the concepts of common cycles and coherence as measures of comovement, and data on the industrial production indices and trade for thirty seven countries, we find that comovement and openness are linked. The more open an economy is, the more likely that its production will have a common cycle with the production of its major trading partner. We also investigate the relationship between openness and the variability of a country's output around its trend. Regardless of whether we look at unconditional correlations, or whether we condition on relevant variables such as size and level of per-capita income, we find no significant relationship between openness and volatility.

Changes in openness may lead to changes in the relationships between different countries' business cycles, and we investigate this issue by using the experiences of South Korea as a case study. Korea's two major trade partners have been Japan and the US, and we ask whether or not the Korean business cycles have become "closer" to those of Japan and the

US. We find evidence that this has occurred when the share of these countries in Korean trade is "large" (more than 50% of the total), and evidence that these business cycles are not similar when this share becomes small.

The plan of our paper is as follows. Section 2 describes the sorts of dynamic co-movement that we use in our analysis, and provides formal definitions of common cycles and our measure of coherence at business cycle frequencies. This section also describes our data, and provides details relating to how we measure the openness of an economy. We then undertake our cross-sectional empirical analysis in Section 3, and our time series analysis of the Korean case in Section 4. Section 5 provides a summary and concludes.

2 Data and Measurement

2.1 Definition of a business cycle indicator

We base our measures of business cycles on the cyclical component of the logarithms of quarterly indices of industrial production. This follows the convention of using a quarterly measure of detrended output as a representative indicator for the multi-dimensional phenomenon of a business cycle, but it differs from standard practice in that we use industrial production, rather than GDP or GNP as our business cycle indicator. Our decision to use industrial production data was dictated by data availability, since GDP data for some countries is only available at an annual frequency. Our data set is drawn from the International Financial Statistics data base, and it includes industrial production indices for 37 countries as well as a composite index for industrial countries. We label this last index, the "world" index.[4] Appendix 1 provides a listing of the countries in our data set, together with the sample period for each country.

Although the use of GDP data would have made our analysis more comparable to other studies which have addressed the relationship between economic performance and openness, it is possible that industrial production data might be better suited for our purpose. Since GDP often contains a large "domestic services" component and the ways

[4] Most of the data reported by the IMF is seasonally adjusted. When unadjusted data was reported, we used the X-11 procedure to make the seasonal adjustments.

in which fluctuations in the industrial sector trickle down to other sectors in the economy might be country-specific, it is possible that total GDP in different countries will not move together, while industrial production might.

It would perhaps be more accurate if we replace the phrase "business cycle" with "the cyclical component of the logarithm of the seasonally adjusted quarterly industrial production index" throughout the paper. After all, a "business cycle" is a multi-dimensional phenomenon. However, it is usual in the empirical macroeconomic literature to talk about the procyclical or countercyclical behavior of different variables, based on the correlations with a detrended measure of output. Here, we follow the same convention, assuming that its inaccuracy is well understood.

2.2 Detrending methods and measures of common cycles

There are many different methods that can be used to decompose time series into their trend and cyclical components, and this has led to considerable controversy as to which detrending method is best for any given purpose. Canova (1998) provides a good discussion of the many aspects of the detrending debate. We acknowledge the detrending debate by working with two detrending procedures that are commonly used in the macroeconomics literature. Our first detrending method is Stock and Watson's (1988) multivariate generalization of the Beveridge and Nelson's (1981) trend-cycle decomposition, which leads to cycles that we call "BNSW" cycles. As discussed below, our common cycle tests are explicitly designed to analyze BNSW cycles. Our second trend/cycle decomposition is based on the Hodrick-Prescott filter (Hodrick and Prescott 1980). This alternative is provided for the purposes of comparison. A brief description of each of these procedures is provided in Appendix 2.

The techniques that we use to look for evidence of common cycles depend on the trend/cycle decomposition. The common cycle test developed by Vahid and Engle (1993) is appropriate for determining whether or not the cyclical components in the BNSW decomposition move together, but it is not suitable for analyzing the HP-filtered data.

Details of the common cycle test are provided in Appendix 2. In a bivariate example, the null hypothesis is that the cyclical components in the BNSW decomposition of the

(2×1) vector y_t are completely coherent.[5] This will happen if and only if there is a linear combination of the *first differences* of y_t, (i.e., Δy_t),which cannot be predicted from the past (i.e., p lags of Δy_t). For a sample of size T, the test statistic for this hypothesis is $-(T-p)\ln(1-\rho_1^2)$,where ρ_1^2 is the smallest sample squared canonical correlation between Δy_t and $\{\Delta y_{t-1}, \Delta y_{t-2}, \cdots, \Delta y_{t-p}\}$. This test statistic has an asymptotic chi-squared distribution, with $(2p-1)$ degrees of freedom.

It is theoretically possible to test for common BNSW cycles in all of the series at the same time, and if we had sufficiently long time series, it would have been appropriate to do this. However, it is well known that when the sample size is small, and the dimension of the problem increases, then the accuracy of the test diminishes. Hence we perform our analysis on pairs of countries, or one country and the "world". The disadvantage of pairwise testing is that since the tests are not based on common informational grounds (i.e., they test whether there is a linear combination which is unpredictable from the past information set of only two countries, and not all countries), we may encounter some logical inconsistencies. In particular, we may see that the hypothesis of common cycles between country A and B, and between country B and C might be rejected, while common cycles between A and C is not. One can relax the requirement that there is complete coherence between the BNSW cycles, and allow the cyclical components to differ slightly for at most one or two periods. Statistical tests for these weaker types of common cycles are developed in Vahid and Engle (1997), but are not used here because of data limitations.

There is no convenient common cycle test for HP cycles. Thus, in order to investigate if the HP cycles of two series move together, we compute the coherency between the two HP cycles at all "business cycle frequencies". We follow Baxter and King (1995) and choose all frequencies between $\frac{\pi}{16}$ and $\frac{\pi}{4}$ (cycles with periods 8 to 32 quarters, or 2 to 8 years). Following the example of Canova and Dellas (1993), we then take the average of squared coherencies for these frequencies as a measure of comovement between the HP cycles. The problem with this measure is that it can be sensitive to the window used for smoothing the

[5] By completely coherent, we mean that there is a squared coherence of 1 at all frequencies. The squared coherence at frequency ω between two time series, is roughly the R^2 between the cyclical components of the two time series at frequency ω.

spectral densities, and its precision cannot be easily determined. In our reported results, we have used the Parzen window for smoothing our periodograms, but we have done similar analyses which use quadratic spectral windows, and these results are qualitatively the same.

2.3 Explanatory variables

We use several potentially relevant explanators to investigate why common cycles might arise. Our primary openness variable (OPEN) is an average of the annual openness measure provided in the Summers-Heston (1991) Penn World Table (the sum of exports and imports divided by GDP). We average over the same time span as that covered by the industrial production series for each country. This measure is only one of many openness measures which have been used in the literature; see Leamer (1988) or Edwards (1992) for alternative measures that account for trade restrictions and institutional factors etc. We make brief use of another openness variable (EXPGDP), which measures the ratio of exports to GDP. This variable is also derived from the Summers-Heston (1991) Penn World Table, and, as above, it is the average of the annual ratios of exports to GDP, averaged over the same time span as that covered by the industrial production index series for each country.

Our other possible explanators for common cycles include some country size variables, (SIZE and SIZEPC) which are also from the Summers-Heston (1991) data set. The first of these variables measures the ratio of each country's total GDP to that of the United States, while the second measures the ratio of each country's per capita GDP to the United States. We also use a dummy variable, OECD, to indicate whether or not a country is a member of OECD. We identified each country's major trade partner from international trade data on exports to a major trading partner, available in various issues of the *Direction of Trade Statistics.*

3 Common Cycles in a Cross-Section of Countries

3.1 Common Cycles and Openness

We start our common cycle analysis by constructing four comovement statistics for each country in our data set. These statistics assess the similarity between the business cycles in the country of interest and its major trade partner. Three of these four statistics are based on the common cycle test explained in Section 2.2: CCMPVAL is the p-value for the common cycle test, while CCM5PCT and CCM1PCT are binary indicators which show whether CCMPVAL is larger than 5% or 1% respectively. A "large" p-value suggests a common cycle, and a p-value larger than 5% means that we cannot reject the null hypothesis that the country has a common cycle with its major trading partner, at the 5% level of significance. The fourth statistic, COHMP, is the measure of comovement between the HP-filtered industrial production series for the country of interest and its major trading partner, and it is constructed as described in Section 2.2.

Our common cycle tests indicate that many countries have a common cycle with their major trade partner. Out of the 37 countries we consider, we find eleven instances of common cycles when testing at the 10% level, fourteen when testing at the 5% level, and twenty-six when testing at the 1% level. To give some specific examples; at the 5% level, it appears that each of Belgium, Luxemburg, Poland and Sweden have a common cycle with their major trading partner (Germany), New Zealand has a common cycle with its major trading partner (Australia) and Ireland has a common cycle with the United Kingdom.

Table 1 provides Spearman rank cross correlations (see Kendall et al. (1991), p. 988) between the above measures of common cycles and the variables described in Section 2.3. We report rank correlations rather than simple correlations so as to limit the influence of outlying countries such as Singapore and Hong Kong. The results for simple correlations (not reported) are qualitatively the same. The correlation coefficients recorded in the first row of Table 1 (i.e., 0.389, 0.423 and 0.299) indicate a significant positive relationship between openness and the various indicators of common (BNSW) cycles[6]. This suggests that countries which have been relatively more open over the past twenty or thirty years are more likely to have common cycles with their major trade partners. In contrast, the correlation between openness and coherency of HP cycles is smaller and not statistically significant. This disagreement between the conclusions based on BNSW cycles and HP

[6]Results are the same regardless of whether we use OPEN or EXPGDP. This is not surprising, given that countries will not generally run a trade deficit or surplus over a long period of time. Later, in our regressions, we only use the variable OPEN.

cycles is evident throughout most of our analysis, and we discuss it further, below.

TABLE 1

Spearman Rank Correlation Coefficients

Variable	Common Cycle Measures with Major Trading Partner			
	CCMPVAL	CCM5PCT	CCM1PCT	COHMP
OPEN	0.389**	0.423***	0.299*	0.168
EXPGDP	0.404**	0.444***	0.277*	0.233
SIZE	-0.350**	-0.391**	-0.266	0.249**
SIZEPC	-0.053	-0.177	0.067	0.483***
OECD	-0.209	-0.219	-0.090	0.281*
CORRMLD	0.066	0.005	-0.017	0.738***
CORRMHP	-0.060	-0.104	-0.022	0.697***

Note: * means significant at 10%, ** means significant at 5% and *** means significant at 1% level.

Apart from our openness measures, the only other variable that seems to be related to common BNSW cycles is SIZE. This relationship is negative, meaning that the larger the country, the less likely it is to have common cycles with its major trading partner. The corresponding correlations for the income per capita (SIZEPC) variable and the dummy for the OECD countries (OECD) are negative, but not statistically significant at the 5% level. The results based on the coherency measure of the HP-filtered data are quite different. Here, we see a significant positive relationship between coherence and our measure of size (SIZE), which seems counter-intuitive, given the relatively small role of trade in large economies. The other measures of size and economic development (SIZEPC, OECD) also have a significant and positive correlation with coherency.

We believe that the results based on the coherency of the HP cycles are largely influenced by contemporaneous correlations between the industrial production variables. This is because the HP filter and the spectral measures of coherence both involve two-sided filtering and smoothing of the time-series. To examine the relationship between our different measures of common cycles and the contemporaneous correlations, we first calculated CORRMLD, the contemporaneous correlation between first-differenced production in each country and its major trading partner. We also calculated CORRMHP, the contemporaneous correlations between the HP-filtered production in each country and its major trading partner. Then, we calculated the correlation between these correlations and our measures of common cycles. These are reported in the last two rows of Table 1. The large and significant correlation between the coherency of HP cycles and either CORRMLD or CORRMHP supports our view that the coherency measure is largely influenced by contemporaneous correlations. On the other hand, the measures of common BNSW cycles show no significant correlation with CORRMLD and CORRMHP. This is consistent with the fact that the measures of common BNSW cycles assess the similarity between the propagation mechanisms of shocks over time (i.e., cycles), and not just the similarity between the shocks themselves.

Table 2 is the same as Table 1 except that the comovement statistics assess the similarity between business cycles in each country and the industrial world. In this case, there are no significant correlations between any of the common cycle and the openness measures. We do not put too much emphasis on Table 2 because the "world" industrial production measure is an aggregate of industrial production in industrial countries, and is not an appropriate measure of the "rest of the world" for any country. Moreover, it is difficult to interpret the cyclical component of this aggregate measure, unless industrial production of the countries that are represented in this aggregate all have a single common cycle, which is certainly not the case.

TABLE 2

Spearman Rank Correlation Coefficients

Variable	Common Cycle Measures with World Business Cycle			
	CCWPVAL	CCW5PCT	CCW1PCT	COHWP
OPEN	0.031	0.091	0.086	0.129
EXPGDP	0.097	0.167	0.102	0.181
SIZE	-0.055	-0.025	-0.117	0.331**
SIZEPC	-0.137	0.035	-0.020	0.609***
OECD	-0.299*	-0.242	0.158	0.583***
CORRWLD	0.086	0.137	0.046	0.776***
CORRWHP	-0.056	0.010	-0.036	0.811***

Note: * means significant at 10%, ** means significant at 5% and *** means significant at 1% level.

The above correlation coefficient analysis summarizes simple bivariate relationships. For example, Table 1 shows that countries which are more open are more likely to have common cycles with their major trading partners, and it also shows that larger countries are less likely to have common cycles with their major trading partners. However, given that larger countries are usually less open (see Perkins and Syrquin (1989)), it is natural to ask whether the positive correlation between openness and common cycles will survive once one controls for size. This can be answered by regression analysis.

We firstly concentrate on explaining the common cycle indicator variables (CCM5PCT and CCM1PCT), and run logistic regressions to account for the binary nature of the dependent variable. These regressions are reported in Table 3. Columns 1 and 3 use all of our explanatory variables. Column 2 reports the same regression as column 1 after those variables which have a negligible effect on the pseudo R^2 measure have been dropped. The first regression (column 1) suggests that openness has the most significant effect on common cycles, and that size is insignificant. Dropping the variables which have little effect on fit raises the t-value for the openness coefficient to 1.8. When we use CCM1PCT as the dependent variable, the only coefficient with a t-value larger than 1 is that of the openness variable. If we drop the least significant variables, we will get back to the unconditional correlation between CCM1PCT and OPEN, which was reported in Table 1.

The fact that openness is still the most significant variable in these regressions assures us that the unconditional correlations between cycles and openness in Table 1 are not a simple artifact of the use of GDP in the denominator of our openness measure. Admittedly, our regression evidence on how openness affects cycles is weak, but given that we have only 37 observations, and that we construct our dependent variable using the results of statistical tests, the lack of a strong signal is understandable.

TABLE 3

Openness and Common Cycle from Logit Models

Variable	CCM5PCT	CCM5PCT	CCM1PCT
CONSTANT	-0.528	-0.636	-0.668
	(-0.63)	(-0.81)	(-0.60)
OPEN	0.016	0.018	0.031
	(1.42)	(1.81)	(1.40)
SIZE	-2.088		2.156
	(-0.37)		(0.65)
SIZEPC	-1.802	-2.196	1.102
	(-0.69)	(-1.46)	(0.42)
OECD	-0.070		-1.328
	(-0.06)		(-0.94)
Pseudo R^2	0.135	0.132	0.114

Note: The numbers in parentheses are t-values.

We also ran regressions to examine how our explanatory variables are related to our measure of coherence between the HP-filtered data of a country and its major trade partner (COHMP). As above, we first used all of our explanatory variables in the regression, and then removed variables which had a negligible effect on fit. The resulting regression is

$$\underset{}{COHMP_i =} \underset{(8.23)}{0.392} \underset{(1.45)}{+0.0006} \; OPEN_i \underset{(1.33)}{+0.204} \; SIZE_i \underset{(2.18)}{+0.191} \; SIZEPC_i + \hat{\varepsilon}_i \; ,$$

$$R^2 = 0.298.$$

This regression suggests that openness is positively (although weakly) related to common cycles measured by coherence, which is consistent with the logit models in Table 3. $SIZEPC$ has a positive effect on coherence, even after controlling for other relevant variables. Since the major trading partners of most countries are developed countries, the contemporaneous correlation between industrial production of developed countries and their major trading partners is higher than that of underdeveloped countries and their major trading partners. Therefore, it is more likely that $COHMP$ for developed countries is higher than that for developing countries. We suspect that this is responsible for the significance of the positive coefficient.

3.2 Volatility and Openness

This section examines the effects of openness on the volatility of output fluctuations. As discussed in the introduction, there are different views about how openness might affect volatility. Table 4 provides some simple cross correlations between two measures of volatility and several relevant variables. Our volatility measures are the standard deviation of the log-differenced industrial production, and the standard deviation of the HP-filtered logarithms of industrial production.

TABLE 4

Cross Correlation Coefficients

Variable	Volatility Measures	
	VOLLD	VOLHP
OPEN	0.117	0.007
EXPGDP	0.012	-0.035
SIZE	-0.595***	-0.370**
SIZEPC	-0.585***	-0.427***
OECD	-0.458***	-0.404***

Note: * means significant at 10%, ** means significant at 5% and *** means significant at 1% level.

The first notable result is that neither measure of openness has any significant correlation with volatility. Next, we note that volatility is significantly and negatively correlated with the measures of size and the level of development. Thus, the larger countries, the more developed countries, or the OECD countries tend to have a lower volatility in output, regardless of how volatility is measured. This may be due to the fact that developed countries have more diversified economies, and therefore their output is less volatile.

Regression analysis leads to similar conclusions. The following equations report the estimated regressions of VOLLD on our list of explanatory variables, for all 37 countries, and for developed and developing countries separately. We use the OECD indicator to distinguish between developed and developing countries. Only regressions for the log-differenced data are presented, but the results for VOLHP are similar. Since the dependent variable is positive by definition, we also ran similar regressions with the logarithms of VOLLD as the dependent variable, but the results are qualitatively similar, and are not reported.

All countries (37 countries)

$$\underset{}{VOLLD_i =} \underset{(11.89)}{4.665} \underset{(0.02)}{+0.0001} OPEN_i \underset{(-0.59)}{-0.727} SIZE_i \underset{(-3.94)}{-2.897} SIZEPC_i + \hat{\varepsilon}_i \ ,$$

$$R^2 = 0.40.$$

OECD countries only (21 countries)

$$VOLLD_i = \underset{(4.75)}{4.394} \underset{(0.93)}{+0.007} OPEN_i \underset{(0.19)}{+0.254} SIZE_i \underset{(-2.32)}{-3.238} SIZEPC_i + \hat{\varepsilon}_i \ ,$$

$$R^2 = 0.30.$$

Non-OECD countries only (16 countries)

$$VOLLD_i = \underset{(9.56)}{5.577} \underset{(-0.36)}{-0.002} OPEN_i \underset{(-2.37)}{-15.97} SIZE_i \underset{(-1.82)}{-4.065} SIZEPC_i + \hat{\varepsilon}_i \ ,$$

$$R^2 = 0.47.$$

There appears to be no significant relationship between openness and output volatility, either unconditionally, or after we have controlled for other co-variates. This finding is consistent with Razin and Rose (1994) who find no relationship between volatility and openness (measured by restrictions on trade and capital mobility). The per capita income size is the only important variable in explaining industrial production volatility of OECD countries. For developing countries (non-OECD countries), economy size as well as the per capita income level are negatively related to volatility.

4 Common Cycles Over Time: Korea and her Major Trade Partners

In the previous section we concluded that countries which have been more open to international trade over the past twenty or thirty years are more likely to have common cycles with their major trade partners. Our analysis used the cross-sectional variation between different countries to identify the correlations between our common cycle indicator variables and our measures of openness. However, some countries that were relatively closed twenty to thirty years ago have become much more open to international trade in recent years, and these changes in openness may have led to changes in the relationships between different country's business cycles. In this section we study how changes in openness may have influenced the similarities between a country's cycles and those of its major trade partners. We focus on the case of South Korea, because this country is often viewed as a good example of a country that has successfully implemented a policy of export oriented growth. Here, our emphasis is on cycles rather than growth, and we ask whether or not Korean business cycles have become "closer" to the business cycles of her major trade partners, as her trading practices have changed.

Korea's two major trade partners, in terms of total trade (total value of exports and imports), have been the United States and Japan. This is illustrated in Figure 1, which plots US and Japanese trade with Korea, as a proportion of total Korean trade. Our sample consists of 125 quarterly observations, dating from the third quarter of 1962 to the third quarter of 1997.[7] Figure 1 shows that approximately 75 percent of Korea's total trade in the first decade of the sample was with the US and Japan. However, the share in Korea's total trade attributable to the US and Japan has declined quite steadily over the last three

[7] This data was extracted from various issues of the *Direction of Trade Statistics,* and the span of the sample was dictated by data availability.

decades of the sample. Also, the United States and Japan have changed roles as Korea's major trading partner on several occasions. Figure 2, which plots Korean exports, shows that the shares of exports to the US and Japan have declined. The main difference between the two figures is that the total export shares of US and Japan peak at about 1972, whereas the total trade shares of US and Japan peak much earlier, at the beginning of the sample.

We use common cycles tests (from Section 2.2) to determine whether or not Korean business cycles have become "closer" to the business cycles of the US and Japan. The tests are based on three variable systems containing the logarithms of industrial production of Korea, Japan and the United States from 1957.2 to 1998.1 (164 observations), and we employ two strategies for studying how common cycles change over time. In the first method, we start with 20 observations on the three variables and test for common cycles, and then we repeatedly add one observation and test for common cycles until we exhaust the entire data set. In the second method, we test for common cycles based on four non-overlapping samples, which each cover just over a decade of data (41 observations).

The p-values[8] for the recursive tests are plotted in Figure 3. Here, we can see that the general trend in the p-values is somewhat similar to the general trend of export shares illustrated in Figure 2. The largest p-value (0.62) is observed when the data set spans the period from 1957.2 to 1972.1, which corresponds to the period when the share of exports to Japan and United States was more than 50% of total Korean exports, and this export share was rising. The p-value of 0.62 means that we cannot reject the null hypothesis that business cycles in Korea were a linear combination of business cycles in the United States and Japan, unless we allow for at least a 62% probability of a wrongful rejection. Thus, there is little evidence against the common cycle hypothesis for this 15 year period. However, when we add the data from the rest of 1970's, which covers the period over which the importance of exports to Japan and the US declined to below 50% of total exports, the evidence of common cycles declines as well. The hypothesis of common cycles gets rejected for the first time at the 10% level when we base the test on data up to 1980.2, and at the 5% level when we base the test on data up to 1984.2. As the data for late 1980's are added

[8] It is important to note that we use degrees of freedom adjusted version of the test to account for the fact that the recursive tests are based on different sample sizes. See the Appendix for more details.

to the sample, the p-values for the test rise above the 10% level. This is consistent with the fact that US and Japanese export shares rose again, to above 50%, towards the end of 1980s. After 1990, when US and Japanese export shares started to decline again, the common cycle p-values also started to decline again, falling below 10% and 5% in 1994.2 and 1995.1 respectively.

The evidence from the recursive common cycle tests suggests that Korea has common cycles with the US and Japan, when the export shares going to these latter countries are high. Since US and Japanese shares in Korean exports have declined, Korea's business cycles have become less like business cycles in the US and Japan. However, the recursive tests are dependent on each other because they use overlapping data sets, and this can invalidate inference. To correct for this problem, we divide our sample of 164 observations into four non-overlapping samples of 41 observations, and test for common cycles in each of these subsamples. The subsamples include data from 1957.2 to 1967.2, from 1967.3 to 1977.3, from 1977.4 to 1987.4, and from 1988.1 to 1998.1 respectively. The p-values for the common cycles tests based on these subsamples are 0.22, 0.38, 0.32 and 0.07 respectively. These p-values are consistent with our earlier recursive tests, and they suggest that as the share of Japan and the United States in the total exports of Korea has declined, the coherence between Korean business cycles and business cycles of Japan and United States has weakened.

Whether the diversification of export markets is a natural outcome of the export-oriented growth process, or whether it has been brought about through the conscious efforts of Korean exporters and policies of Korean government, is an important question that has to be studied, but it is outside the scope of the present paper.

5 Concluding Remarks

In this paper we examine the relationship between openness and comovement in business cycles. Our cross-country analysis suggests that the cyclical variation in the output of an economy that is more open, is more likely to be completely synchronized with that of its major trading partner. In other words, the propagation mechanisms for shocks or the impulse response functions for output in open economies, are likely to become collinear with those of their major trade partner. The variance of these cyclical components does not seem to be correlated with the level of openness, and it seems to depend only on various measures of a country's size. Our analysis of the Korean case provides some evidence that synchronization can be broken through the diversification of trade partners.

Like any other applied paper that uses real data, the conclusions of this paper are conditional on the decisions that we had to make in the data selection and data processing stages. These decisions, which might be controversial, include our choice to use industrial production series, our seasonal adjustment of the non-adjusted data, our methods of detrending, and our measures of openness and comovement. These decisions were partly dictated by data limitations, partly guided by our assessment of usual practice in the profession, and partly influenced by our biases and limitations. However, we believe that we have established that the business cycles of trading countries are more likely to become synchronized, as they trade more.

Theoretical models of open economies often attempt to generate the stylized fact that the business cycle components of output in different countries are positively correlated. Here, we provide an additional fact that such models of open economies ought to be able to reproduce. Since the synchronization of the cycles of linked dynamic systems is a stylized fact in biological and mechanical systems, our findings in this paper indicate that economic systems are no different from other dynamically linked systems. This supports the suggestion made by Anderson and Ramsey (1999) that the mathematical models of coupled oscillators that have been used in other disciplines may be useful for developing theoretical models of dynamic open economies.

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Appendix 1: List of Countries

Country	Period	Name of Series	Major Trade Partner
1. Australia	57Q3-97Q4	Industrial Production Index	Japan
2. Austria	59Q1-95Q4	Industrial Production Index	Germany
3. Bangladesh	73Q3-97Q3	Industrial Production Index	USA
4. Belgium	57Q1-97Q4	Industrial Production Index	Germany
5. Canada	57Q1-97Q4	Industrial Production Index	USA
6. Chile	58Q1-98Q1	Manufacturing Production Index	USA
7. Denmark	68Q1-98Q1	Industrial Production Index	Germany
8. Finland	57Q1-97Q4	Industrial Production Index	Germany
9. France	57Q1-97Q4	Industrial Production Index	Germany
10. Germany	57Q1-98Q1	Industrial Production Index	France
11. Greece	60Q1-97Q4	Manufacturing Production Index	Germany
12. Hong Kong	82Q1-97Q4	Manufacturing Production Index	USA
13. India	60Q1-97Q4	Industrial Production Index	USA
14. Ireland	57Q1-97Q4	Industrial Production Index	UK
15. Israel	57Q1-97Q4	Industrial Production Index	USA
16. Italy	57Q1-93Q4	Industrial Production Index	Germany
17. Japan	57Q1-98Q1	Industrial Production Index	USA
18. Korea	57Q1-98Q1	Industrial Production Index	USA
19. Luxemburg	57Q1-97Q2	Industrial Production Index	Germany
20. Malaysia	70Q1-97Q3	Industrial Production Index	Singapore
21. Mexico	57Q1-97Q2	Industrial Production Index	USA
22. Morocco	59Q1-97Q3	Industrial Production Index	France
23. Netherlands	57Q1-97Q4	Industrial Production Index	Germany
24. New Zealand	77Q2-96Q4	Industrial Production Index	Australia
25. Nigeria	70Q1-97Q2	Manufacturing Production Index	UK
26. Norway	60Q1-98Q1	Industrial Production Index	UK
27. Pakistan	70Q3-97Q1	Industrial Production Index	USA
28. Peru	79Q1-98Q1	Manufacturing Production Index	USA
29. Poland	82Q1-95Q4	Manufacturing Production Index	Germany
30. Portugal	60Q1-95Q4	Industrial Production Index	Germany
31. Singapore	66Q1-97Q3	Industrial Production Index	USA
32. South Africa	61Q1-97Q4	Manufacturing Production Index	UK
33. Spain	61Q1-97Q4	Manufacturing Production Index	France
34. Sweden	57Q1-97Q4	Industrial Production Index	Germany
35. Switzerland	65Q1-97Q4	Industrial Production Index	Germany
36. UK	57Q1-97Q4	Industrial Production Index	USA
37. USA	57Q1-98Q1	Industrial Production Index	Canada
38. World	57Q1-98Q1	Industrial Production Index	

Appendix 2: Detrending Methods and Common Cycles Tests

(a) Multivariate Beveridge-Nelson Decomposition

This method allows for deterministic and stochastic trends in the series, and it relies on the reasonable assumption that the first difference of the series are stationary and hence have a possibly infinite moving average representation. This representation is given by

$$\Delta y_t = \mu + C(L)\varepsilon_t, \tag{1}$$

where Δy_t is the $n \times 1$ vector of first differences of the time series under investigation, μ is the $n \times 1$ vector of unconditional means of Δy_t, and ε_t is an $n \times 1$ vector of zero mean random variables which are independently and identically distributed for all t. $C(L)$ is an $n \times n$ matrix of possibly infinite order polynomials in the lag operator L, which satisfies $C(0) = I_n$ and the conditions that make $C(L)\varepsilon_t$ a strictly stationary and ergodic n-dimensional process. See Brockwell and Davis (1991), for example, for the relevant stationarity conditions.

Using the identity that $C(L) \equiv C(1) + (1-L)C^*(L)$, in which $C^*(L)$ is another $n \times n$ matrix of possibly infinite order polynomials in the lag operator which satisfies the same conditions as $C(L)$, equation (1) can be written as

$$\Delta y_t = \mu + C(1)\varepsilon_t + (1-L)C^*(L)\varepsilon_t.$$

Integrating both sides of the above, we obtain

$$\begin{aligned} y_t &= \underbrace{y_0 + \mu t + C(1)\sum_{i=1}^{t}\varepsilon_i}_{} + \underbrace{C^*(L)\varepsilon_t}_{}. \\ y_t &= \quad \text{trend}_t \quad + \quad \text{cycle}_t \end{aligned} \tag{2}$$

The trend is the sum of deterministic and stochastic components, and the latter of these is an $n \times 1$ vector of random walk processes. One way of justifying this as the trend component of the time series at time t, is that it is the part of series that contains all of the available information for long-term forecasting of the series, given the information set at time t. The trend components are retrieved by inverting an estimated vector autoregressive model for

Δy_t. When y_t has common trends[9], these components are derived from an estimated vector error correction model for Δy_t. The cyclical components are the residual components of y_t after subtracting the trends, and they are called the "detrended" y_t. It is important to note that the cyclical component of y_t is not given by Δy_t, and our method of testing whether the cyclical components move together does not require preliminary extraction of the cyclical components. We explain this latter point in the last part of this appendix.

(b) Hodrick-Prescott Filtering

The second detrending method that we use is based on the Hodrick-Prescott filter (Hodrick and Prescott 1980). According to this method, trends are retrieved by fitting a smooth line to the data points for each individual series. This smooth line is derived from minimizing the following loss function, which penalizes lack of fit and lack of smoothness:

$$\min_{\{\text{trend}_t\}_{t=1}^T} \left[\sum_{t=1}^T (y_t - \text{trend}_t)^2 + \lambda \sum_{t=2}^T \left(\Delta^2 \text{trend}_{t+1} \right)^2 \right].$$

The parameter λ determines relative importance of the lack of smoothness to the lack of fit. For quarterly data, the value of $\lambda = 1600$ is usually used, and this is what we use in this paper. Algorithms for applying this detrending method are now provided in most time series econometric packages. For a large sample size, and away from the beginning and the end points of the sample, the trend component of a series is given by:

$$\text{trend}_t^{\text{HP}} = \frac{1}{1 + \lambda(1-L)^2(1-L^{-1})^2} y_t.$$

Hence, the HP trend is the result of passing the series through a two-sided filter. The cyclical component is the residual component after subtracting the trend.

(c) Common Cycles Test

We use the common cycles test developed by Vahid and Engle (1993) to determine whether the cyclical components in the BNSW decomposition move together. Since we consider pairs of countries each time we conduct this test, this discussion describes the logic behind the test when y_t is 2×1. The common cycles test, tests if the BNSW cycle

[9] That is when y_t are cointegrated. In the case of stochastic cointegration $C(1)$ will have rank less than n, and in the case of deterministic cointegration $(\mu \mid C(1))$ will have rank less than n. In both cases, the appropriate model for Δy_t will be a vector error correction model (VECM) rather than a VAR. See Engle and Granger (1987). In our application, none of the pairs of series which we analyze are cointegrated.

in one series is a multiple of the BNSW cycle in the other. If a common cycle is present, then the BNSW cycles in the two elements of y_t will be completely coherent. Under this assumption, there will be a linear combination of y_t which will not contain any cyclical component, and from equation (2), this will imply that

$$\alpha' y_t = \alpha' \text{trend}_t.$$

Given the definition of trend_t in equation (2), the first difference of the above relationship is

$$\alpha' \Delta y_t = \alpha' \mu + \alpha' \varepsilon_t,$$

which is white noise. This will imply that in the VAR (or if appropriate the VECM) model of Δy_t, all coefficient matrices must have rank 1, and all must have the same left null-space. That is, if the VAR model is denoted by

$$\Delta y_t = A_0 + A_1 \Delta y_{t-1} + \cdots + A_p \Delta y_{t-p} + \varepsilon_t,$$

then null hypothesis of common BNSW cycles can be presented as

$$H_0 : \alpha' A_1 = \alpha' A_2 = \cdots = \alpha' A_p = 0.$$

The test statistic for this hypothesis can be formulated in terms of the squared sample canonical correlation between Δy_t and $\{\Delta y_{t-1}, \Delta y_{t-2}, \cdots, \Delta y_{t-p}\}$ for $t = p+1, ..., T$. Specifically,

$$-(T-p)\ln(1-\rho_1^2) \ \xrightarrow{d}\ \chi^2_{2p-1},$$

where ρ_1^2 is the smallest sample squared canonical correlation between the above two sets of variables. Most statistical packages such as SAS have built in procedures for calculating the sample canonical correlations. Small sample corrections are often used to make this asymptotic test more accurate in small samples. Our small sample correction is based on Rao's (1974) F-approximation to the above criterion, which is automatically calculated by the `cancor` procedure in SAS.

Figure 1: Shares of trade with US and Japan in total trade of Korea

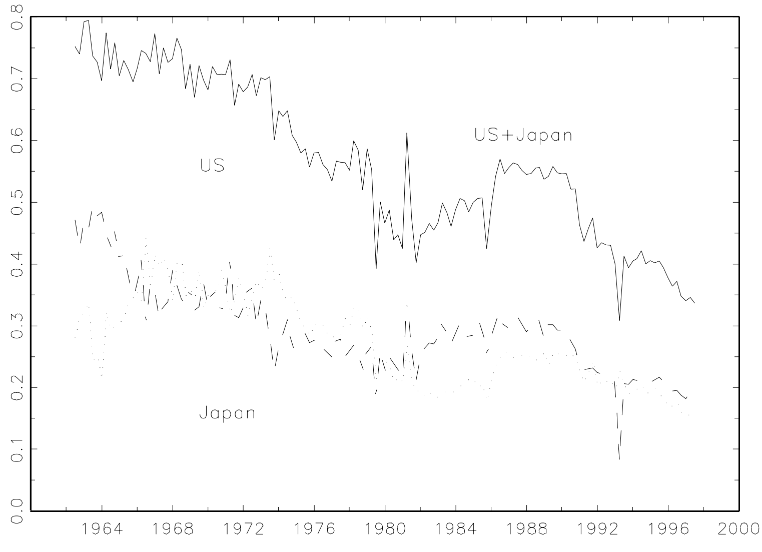

Figure 2: Shares of exports to US and Japan in total exports of Korea

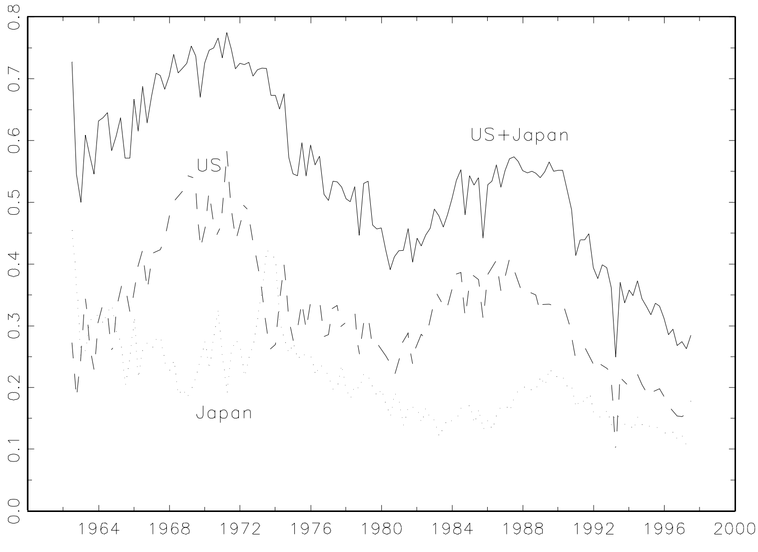

Figure 3: P—values of the test for common cycles