Business Cycle Spillovers

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Abstract:
We apply Diebold-Yilmaz spillover index methodology to monthly industrial production indices to study business cycle interdependence among G-6 countries. We show evidence that business cycle spillovers fluctuate substantially over time, increasing especially after the 1973-75 and 1981-82 recessions as well as during the expansion after the 2001 U.S. recession. Our most important result, however, is related to the current state of the world economy: In a matter of four months since September 2008, the business cycle spillover index recorded the sharpest increase ever and reached a record level as of December 2008, an unambiguous indicator that the global economy has already been in recession. Focusing on the direction of spillovers, we show that the recessionary shocks are originating mostly from the United States and spreading to other G-6 countries.

JEL classification: E32, F41, C32.
Key words: Business Cycles, Spillovers, Industrial Production, Vector Autoregression, Variance Decomposition, Unit Roots, Cointegration.
I. Introduction

What started in the US as the sub-prime mortgage crisis in 2007 has since been transformed into a severe global financial crisis that inflicted all major advanced and emerging economies. While it is too early to decide whether the global financial crisis had already reached its climax, it is by now certain that it will have a devastating effect on the global economy over the next two years. As a result of the global financial crisis at the moment the world economy is faced with the threat of the worst recession in decades, perhaps the first truly global recession.

The threat of a worldwide recession led to an increase in the interest on business cycles research. While the practitioners of the dismal science failed to predict the financial crisis, they are now doing everything to foresee how the recessionary dynamics will be unfolded in 2009 and beyond. For one thing the current global recession threat creates pressure for researchers to explain how the global capitalist system produced such a recession outburst after a two and half decade long “great moderation” of business fluctuations.

Recently there have been several studies focusing on past recessions in advanced economies, along with the episodes of financial crises in these countries since the Second World War. (Claesens, Kose and Terrones, 2008, Reinhart and Rogoff, 2008) By providing a closer look at the past crisis and recession episodes more carefully and systematically this literature helps us develop a better understanding of how the current recession episode will unfold.

In this paper, we propose a new framework to analyze the linkages among business fluctuations in G-6 countries. Our empirical analysis uses the spillover index methodology recently proposed by Diebold and Yilmaz (2009a) to analyze stock return and volatility spillovers across 19 stock markets around the world and developed further by Diebold and Yilmaz (2009b). Diebold-Yilmaz spillover index follows directly from the familiar notion of a variance decomposition associated with an \( N \)-variable vector autoregression, where all variables in the system are assumed to be endogenous. We propose to apply the Diebold-Yilmaz spillover index methodology to the seasonally
adjusted industrial production indices for G-6 countries to study the business cycle spillovers among G-6 countries.

Diebold-Yilmaz spillover index framework is quite simple to implement. It is also more powerful compared to earlier studies of world business cycles. Our paper is different from the Bayesian dynamic latent factor approach to the study of international business cycles (Kose, Otrok, and Whitman, 2008, 2003). While the common factor approach aims at obtaining a world business cycle measure, the spillover index framework distinguishes between idiosyncratic shocks to industrial production and spillover of industrial production shocks from other countries. Furthermore, we think that the spillover index that is based on a multivariate VAR can better be placed to capture the increased comovement of business fluctuations compared to bivariate correlation coefficients.

The intensity of business cycle spillovers may of course vary over time, and the nature of any time-variation is potentially of great interest. Using a rolling windows approach and calculating the spillover index for each window, we allow the business cycle spillovers across G-6 countries to vary over time from the late 1950s to the present. We show that spillovers are important, spillover intensity is indeed time-varying, and the United States and Japan are the major transmitters of business cycle shocks to other countries.

One important conclusion relates to the great moderation of business cycles since mid-1980s. It has been shown that all major industrial countries, perhaps with the exception of Japan, experienced substantial decline in the volatility of their GDP growth rates. While the great moderation result is a commonly shared conclusion of many different analyses, there is little agreement about the effect of globalization on the comovement of business cycle fluctuations.

Using a dynamic latent factor model, Kose et. al. (2008) shows that with the intensification of the globalization process the impact of the global factor on the correlation of GDP across countries increased in the 1990s and after. Doyle and Faust (2005), on the other hand, found no evidence of increased correlation of growth rates of output, consumption and investment across G-7 countries.
In section 2 we discuss the Diebold-Yilmaz spillover index methodology, emphasizing in particular the use of generalized variance decompositions and directional spillovers. In section 3 we first discuss the time series properties of industrial production indices for G-6 countries and then present the results of the business cycle spillovers analysis. In particular we discuss the total spillover plot along with the gross and net directional spillover plots for each of the G-6 countries. We conclude in section 4.

II. Spillover Index Methodology

Any study of the business cycle spillovers also needs to include the analysis of the direction of spillovers across countries. It is a well known fact that Cholesky factorization, upon which the Diebold-Yilmaz spillover index was built, allows one to consider orthogonalized shocks to variables in the model. However, the resulting impulse responses and variance decompositions are not robust to a change in the ordering of variables. As a result, it is difficult to use the variance decompositions from the Cholesky factor orthogonalization to study the direction of spillovers. With this understanding Diebold and Yilmaz (2009b) progress by measuring directional spillovers in a generalized VAR framework that eliminates the possible dependence of results on ordering.

Consider a covariance stationary $N$-variable VAR($p$), $x_t = \sum_{i=1}^{p} \Phi_i x_{t-i} + \varepsilon_t$, where $\varepsilon \sim (0, \Sigma)$. The moving average representation is $x_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}$, where the $N \times N$ coefficient matrices $A_i$ obey the recursion $A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \ldots + \Phi_p A_{i-p}$, with $A_0$ an $N \times N$ identity matrix and $A_i = 0$ for $i<0$. The moving average coefficients (or transformations such as impulse response functions or variance decompositions) are the key to understanding dynamics. We rely on variance decompositions, which allow us to split the forecast error variances of each variable into parts attributable to the various system shocks. Variance decompositions allow us to assess the fraction of the $H$-step-ahead error variance in forecasting $x_i$ that is due to shocks to $x_j$, $j \neq i$, for each $i$. 

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Calculation of variance decompositions requires orthogonal innovations, whereas our VAR innovations are generally correlated. Identification schemes such as that based on Cholesky factorization achieve orthogonality, but the variance decompositions then depend on ordering of the variables. We circumvent this problem by exploiting the generalized VAR framework of Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998), which produces variance decompositions invariant to ordering.

Let us define *own variance shares* to be the fractions of the $H$-step-ahead error variances in forecasting $x_i$ due to shocks to $x_i$, for $i=1, 2, N$ and *cross variance shares*, or *spillovers*, to be the fractions of the $H$-step-ahead error variances in forecasting $x_i$ due to shocks to $x_j$, for $i, j=1, 2, N$, such that $i \neq j$.

The generalized impulse response and variance decomposition analyses also rely on equation (2). Pesaran and Shinn (1998) showed that when the error term ($\epsilon_t$) has a multivariate normal distribution, the generalized impulse response function scaled by the variance of the variable is defined as:

$$
\gamma_j^g(h) = \frac{1}{\sqrt{\sigma_{jj}}} A_j \sum e_j, \quad h = 0, 1, 2, \ldots
$$

Denoting the generalized $H$-step-ahead forecast error variance decompositions by $\theta_{ij}^g(H)$, for $H = 1, 2, \ldots$, we have

$$
\theta_{ij}^g(H) = \frac{\sigma_{ij}^2 \sum_{h=0}^{H-1} (e_i A_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e_i A_h \sum A_h e_j)^2}.
$$

Note that they do not have to sum to one, and in general they do not: $\sum_{j=1}^{N} \theta_{ij}^g(H) \neq 1$.

To normalize the variance decompositions obtained from the generalized approach, we sum all (own and spillover of shocks) contributions to a country’s industrial production (business cycle) forecast error. When we divide each source of industrial production shock by the total of industrial production contributions, we obtain the relative contributions to each country by itself and other countries:
\[
\tilde{\theta}_{ij}^g(H) = \frac{\theta_{ij}^g(H)}{\sum_{j=1}^{N} \theta_{ij}^g(H)}.
\]

Now, by construction \(\sum_{j=1}^{N} \tilde{\theta}_{ij}^g(H) = 1\) and \(\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^g(H) = N\).

**Total Spillovers**

Using the industrial production contributions from our Generalized variance decomposition approach, we can construct a total business cycle spillover index:

\[
S^g(H) = \frac{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^g(H)} \cdot 100 = \frac{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^g(H)}{N} \cdot 100.
\]

**Directional Spillovers**

We now consider directional spillovers in addition to total spillovers. We measure directional business cycle spillovers received by market \(i\) from all other markets \(j\) as:

\[
S_{ri}^g(H) = \frac{\sum_{j=1,j \neq i}^{N} \tilde{\theta}_{ij}^g(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ij}^g(H)} \cdot 100.
\]

In similar fashion we measure directional business cycle spillovers transmitted by market \(i\) to all other markets \(j\) as:

\[
S_{ri}^g(H) = \frac{\sum_{j=1,j \neq i}^{N} \tilde{\theta}_{ij}^g(H)}{\sum_{j=1}^{N} \tilde{\theta}_{ij}^g(H)} \cdot 100.
\]

One can think of the set of directional spillovers as providing a decomposition of total spillovers into those coming from (or to) a particular source.

**Net Spillovers**
Finally, we obtain the net business cycle spillovers transmitted from market $i$ to all other markets $j$ as

$$S^e_i(H) = S^e_i(H) - S^e_j(H).$$

Net spillovers are simply the difference between gross business cycle shocks transmitted to and gross business cycle shocks received from all other markets.

III. Business Cycle Spillovers

In our empirical analysis we use monthly observations of the seasonally adjusted industrial production indices from January 1958 to the latest available observation, December 2008. Even though it is one of the G-7 countries we do not include Canada in our analysis, because the Canadian IPSA is highly correlated with the IPSA of the United States, with a correlation coefficient of 0.99. We present the descriptive statistics for all 6 industrial production indices in Table 1.

We plot the IPSA series for G-6 countries in Figure 1. As can be seen in Figure 1, IPSA series are trending upwards with occasional downward bumps. Furthermore, the most recent severe downturn in industrial production is clearly visible for all countries in Figure 1. The current downturn is one of the worst recessions (the other one being the 1973-75) since 1957 in the G-6 countries.

Log Industrial Production Series: Unit Roots and Cointegration

Before going ahead with the analysis of business cycle spillovers we first test whether the seasonally adjusted industrial production series for G6 countries are stationary or not. We use the most-preferred augmented Dickey-Fuller (ADF) test for this purpose. Test results for the whole period (1958:01-2008:12) are presented in Table 2. For all G-6 countries, the augmented Dickey-Fuller test fails to reject the null hypothesis that the log of industrial production series (allowed to have a constant and a linear trend term) possess a unit root. This result obviously implies that none of the six IPSA series are stationary in levels. Applying the tests to the first-differenced log industrial production series, however, we reject the non-stationarity of this series for all six
countries. Together these results indicate that all industrial production series are integrated of order one, I(1).

Once we show that all industrial production index series possess a unit root, we can now test for the presence of a cointegration relationship among these six series. Johansen cointegration test results (both trace and maximum eigenvalue tests), presented in Table 3, show that there is a single cointegration relationship among the seasonally adjusted IP series for the G-6 countries over the 1958:01-2008:12 period. Altogether test results imply that, instead of estimating a VAR model for the industrial production series for the G-6 countries, we need to estimate a Vector Error Correction (VEC) model which is effectively the VAR in first differences with the lagged error correction term from the cointegration equation incorporated.

As VEC is the correct model for the full sample, our spillover analysis relies on variance decomposition from the VEC model estimated over rolling 5-year (60-month) windows. We repeat the unit root and cointegration tests for each of the 5-year rolling windows in order to have the correct specification of the underlying model. The unit root test results in levels and first differences are presented in Figures 2 and 3. Over the overwhelming majority of the rolling windows considered the tests reject the presence of a unit root in first differences but not in levels. We estimate the VEC system with a three month lag over 5-year rolling windows. Once the VEC is estimated we obtain the variance decompositions based on Cholesky orthogonalization and Generalized VAR approaches for a 10-month forecast horizon.

We estimate the VEC model for the first 5-year sub-sample window (April 1958-March 1963) and obtain the Cholesky and Generalized variance decomposition based spillover indices. Moving the sub-sample window one month ahead we obtain the spillover indices for the next window and so on. Then we plot the spillover indices for all sub-sample windows and plot them, obtaining the spillover plot.

However, before presenting the spillover plots, we estimate the VEC model for the full sample and report the generalized variance decomposition as well as the spillover index and the directional spillovers in Table 4. The spillover index for the full sample period is 27%, indicating that approximately 27% of the total variance of the forecast
errors for six countries is explained by spillovers from others, whereas the remaining 73% is explained by shocks to each individual country itself.

In terms of the directional spillovers transmitted to others (measured by $S_i^SH$), Japan is the country which contributed the most to other countries’ forecast error variance (52.4), followed by the US (29.5). Italy has contributed the least to other countries’ forecast error variance (11.7), followed by the UK (19). In terms of the directional spillovers received from others (measured by $S_i^SH$) USA appears to be the country that received the least of spillovers from other countries (8.7) followed by the UK (22.1) and Japan (24.1). Germany received the most (40.4) in terms of spillovers from other countries.

Finally, when we calculate difference between the “Contribution from” column sum and the “Contribution to” row sum we obtain the net directional spillovers given by $S_i^H$. Japan (28.3) and the USA (20.8) are the net transmitters of industrial production shocks to other countries, while all European countries in the sample (Italy (-18.3), Germany (-16.3), France (-11.5) and UK (-3.1)) are net recipients of business cycle spillovers for the full sample analysis.

**Dynamics I: The Rolling-Sample Business Cycle Spillover Plot**

The Spillover Table for the full sample provides important clues as to how the spillover index is calculated. Next in Figure 4 we plot the generalized spillover index for moving windows over time (obtained from generalized variance decompositions). In Figure 5 we present the generalized spillover index along with the Cholesky spillover index. We plot the two indices as an area band rather than two different lines to show that the differences between two indices for all sub-sample windows are in general not very large, seldom exceeding 10% of the index. Even though the small gap between the two indices varies over time, the two indices tend to move very much in harmony. Therefore, it would not be wrong to focus on the generalized VD based spillover index for the time being.
Our first observation about the spillover plot is the absence of a long-run upward or downward trend in the spillover index. The spillover plot clearly shows that while there are periods during which shocks to industrial production are transmitted substantially to others, there are other periods during which the spillovers of output shocks were much less important. This finding is important because it is in contrast to the recent work finding support that during the globalization process business cycles have become more synchronized (See by Kose et al).

While the spillover index does not follow an upward trend, the band within which it fluctuate moves slightly upwards since the current wave of globalization had started in earnest in the early 1990s. In the first phase of the great moderation period (1985-1994) the index fluctuated within a band of 35-50 percent. As the sample windows are rolled to include 1995 the index reaches close to 60% but decline down to 40% as the data for the late 1990s and 2000 are included. Towards the end of the mild recession of 2000-2001 the index started to increase reaching to 60% again by the end of 2002. However as the other G-6 countries followed the quickly recovering US economy to a major expansion the spillover index reached 70% in the second quarter of 2004. The index then declines to 60% again as the window is rolled to include second half of 2004 and then gradually moves down reaching its bottom around 40% from the last quarter of 2006 until the first quarter of 2008.

When we focus on the behavior of the index since 1989 we observe three complete cycles. It is interesting to note that each time the cycle lasted longer than the previous one and with an increased bandwidth. During the first cycle which lasted from 1989 to the end of 1992 the index fluctuated between 33 and 52, while in the second cycle that lasted from 1993 to 1999 the index fluctuated between 37 and 61. Finally, during the third cycle that lasted from 2000 to 2007 the index fluctuated between 41 and 72 percent.

Going further back in time we observe that until the oil price shock of 1973 the spillover index fluctuated around 40% range\(^1\). However, following the oil price hikes the

\(^1\) There is a spike in the index in 1968 as the French industrial production makes its largest historical drop. However, this event did not have any lasting impact on industrial output in France and in other G-6 countries.
The spillover index fluctuates substantially over time without a clear upward or downward trend. As a rule of thumb, from the 1960s onward, the spillovers contribute between 30% and 60% of the forecast error variance of the industrial production in the G-6 countries. The lowest level of spillovers is observed for the windows ending in 1971 and 1972.

The highest level of spillover index, on the other hand, is observed recently towards the end of 2004 and early 2005, during which the US economy was growing at a very high rate, 4 percent per annum. The most significant upward movement in the spillover index started in 2000, even before the 2001 US recession and continued for a long time, to reach close to 65%.

However, as the US economy started to lose pace since 2005, Japan and European economies picked up momentum and grew faster. As a result, net spillovers from the United States to others declined sharply in 2005. As a result, the spillover index also declined as low as 38% in mid-2007 and stayed around 40% until the end of the first quarter of 2008. As the March 2008 observation is added to the sample the index increased to reach 47.2%, but declined back to 42-43 in April and May. With the inclusion of observations for June through August in the sample window the index jumped back to 47-49 level.

Now we can turn our focus to the most important part of our results, namely the recent behavior of the index in 2008 and 2009. Not only because it gives us more clue about the business cycle spillovers since the beginning of the sub-prime crisis in the US, but also because the index accorded the biggest jump in its history if we were to leave
aside the blip in 1968 due to a 32% decline reduction in French industrial production in May 1968 which was immediately reversed.

The index jumped the most, from 49 to 63, as the observations for September are included in the sample. While it declined slightly in October to 57, as the November numbers are fed into the VEC the spillover index jumped up to 73. While the generalized VD based spillover index jumped by 25 points in a matter of three months, Cholesky-based spillover index jumped by almost 30 points from 42.8% to 72.4%.

After analyzing the more recent developments in the spillover index, we now go back in time to 1970s. Following the rather uneventful spike in the index in 1968, the first major upward move in the spillover index was realized after the first oil price shock and during the ensuing recession in the US and other G-6 countries. The oil price shock was common to all countries, but different policy responses led to different forms of business fluctuations in different countries. The spillover index gradually increased from around 30% in 1972 to close to 60% by 1976 and stayed in the 50-60% range until the end of 1970s. A similar rise, albeit at a smaller scale and short-lived, was observed in the aftermath of the second oil price shock and during the short 1980 recession in the US.

Another jump in the spillover index is observed in the aftermath of the 1981-82 recession; spillover index reaching close to 60% in a matter of months in 1983. This sharp increase in spillovers is followed by a rapid decline in 1984 that took several years to fall down to 30-40% band. Despite a slow rise in the late 1980s the BC spillovers stayed around 40-50% band until 1994, when it gradually rose to around 60%, followed by a fall towards the end of the 1990s, especially after the East Asian crisis.

So far we have discussed the spillover plot based on 5-year rolling windows. Obviously here the window size is a critical factor that can have an impact on the shape of the spillover plot. For that reason, we present the spillover plots for 4, 6, and 7-year rolling windows in Figure 6. Irrespective of the window size we choose, the spillover index follows similar patterns. It dropped quite rapidly over the last two-three years from a peak in late 2004. As of the start of the current global recession downturn, the business cycle spillover index across G-6 countries was at its lowest level in more than a decade. With such an initial starting point, the spillovers are less likely to jump up in a matter of
less than a year. In all three plots the spillover index jumps up at least 30+ percentage points since September 2008. As the window size increased the spillover plot becomes smoother giving more clues about the business cycle spillovers.

Dynamics II: Rolling-Sample Directional Business Cycle Spillover Plots

Following the detailed analysis of the total business cycle spillovers, we can now move the analysis of the directional spillovers as described in detail in Section 2. During the 1970s Japan has been the most important transmitter of both gross (Figure 7) and net (Figure 9) directional spillovers. During the 1973-75 recession and during the second half of the 1970s the spillovers transmitted from Japan to others reached as high as 25% of the total gross spillovers (Figure 7), whereas the spillovers received by Japan from others was only around 8% of the total spillovers (Figure 8), leading the net spillovers from Japan to reach as high as 20% of the total spillovers (Figure 9). Germany was the second most important transmitter of business cycle spillovers during the 1970s. United States, on the other hand, was a net recipient of business cycle spillovers over the most of the 1970s, with the exception of 1973-75 recession.

The roles were reversed in the 1980s: US has become the major net transmitter of the spillovers whereas Japan became the net recipient of spillovers. The gross spillovers transmitted by the U.S. to others jumped above 15%, and as high as 30%, and net spillovers fluctuated between 10-15% after the 1982 U.S. recession. Japan’s net spillovers, on the other hand, declined to as low as -11% of total spillovers after the 1982 recession and lasted at low levels until the end of 1987. While Germany and U.K. were also net positive transmitters of spillovers after the 1982 recession, their roles were rather secondary compared to the U.S. and Japan (Figure 9).

Throughout the 1990s Japan was neither a net transmitter not a net recipient of the business cycle spillovers among the G-6 countries. We think that this result is consistent with the decade long recession Japan suffered with almost no effect on other G-6 countries. Neither was the United States not was Germany major net transmitters of spillovers in the 1990s. It was rather France, Italy and United Kingdom that were net positive transmitters of spillovers, even though the spillovers originating from these
countries were not as large and not as persistent as the ones originated from the U.S., Japan and Germany in the 1970s and 1980s.

Moving closer to our times, the United States and Japan returned to their locomotive roles in the 2000s with a 10% net spillover transmission to other countries. Germany and France, on the other hand, have been the net recipients of spillovers in 2000s. Italy’s role as a transmitter of gross spillovers also increased in 2000s, but as a net transmitter its role continued to be rather small along with that of the United Kingdom.

Lately, with an as low as -10% net spillover transmission since 2007, Japan has become a net recipient rather than a net transmitter of business cycle spillovers, while the net transmission from the U.S. gradually increased with the intensification of the sub-prime crisis since mid-2007. As we have emphasized above, since September 2008 the total spillover index jumped substantially up to reach close to 80% and the United States was the most important contributor to the increase in business cycle spillovers. The gross directional spillovers from the U.S. jumped close to 25 percent since the collapse of the Lehman Brothers in September 2008.

IV. Conclusions

To be written…
References


Table 1a. Descriptive Statistics – Industrial Production Indices  
(1958:01-2008:12)

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Table 1b. Descriptive Statistics – Log Industrial Production Indices  
(1958:01-2008:12)

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<td>4.175</td>
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<td>4.301</td>
<td>4.260</td>
<td>4.314</td>
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<td>Minimum</td>
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<td>3.409</td>
<td>3.008</td>
<td>2.097</td>
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Table 2a. Unit Root Test – Augmented Dickey-Fuller Test Statistics  
(1958:01-2008:12)

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<tr>
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<th>France</th>
<th>Germany</th>
<th>Italy</th>
<th>Japan</th>
<th>UK</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Levels (with constant term and intercept)</td>
<td>-1.401</td>
<td>-2.862</td>
<td>-2.010</td>
<td>-1.124</td>
<td>-1.824</td>
<td>-2.680</td>
</tr>
</tbody>
</table>

Table 2b. Critical Values for the Augmented Dickey-Fuller Test Statistics

<table>
<thead>
<tr>
<th></th>
<th>1%</th>
<th>5%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log levels (with constant term and trend)</td>
<td>-3.973</td>
<td>-3.417</td>
<td>-3.131</td>
</tr>
<tr>
<td>Log first differences (with constant term)</td>
<td>-3.441</td>
<td>-2.866</td>
<td>-2.569</td>
</tr>
</tbody>
</table>
Table 3: Johansen Cointegration Test - G-6 Industrial Production Indices (logs, 1958:01-2008:12)

<table>
<thead>
<tr>
<th>Hypothesized Cointegration Rank Test (Trace)</th>
<th>Trace Statistic</th>
<th>0.05 Critical Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None *</td>
<td>102.99</td>
<td>95.754</td>
<td>0.015</td>
</tr>
<tr>
<td>At most 1</td>
<td>58.397</td>
<td>69.819</td>
<td>0.288</td>
</tr>
<tr>
<td>At most 2</td>
<td>35.027</td>
<td>47.856</td>
<td>0.447</td>
</tr>
<tr>
<td>At most 3</td>
<td>15.596</td>
<td>29.797</td>
<td>0.740</td>
</tr>
<tr>
<td>At most 4</td>
<td>5.350</td>
<td>15.495</td>
<td>0.771</td>
</tr>
<tr>
<td>At most 5</td>
<td>0.455</td>
<td>3.841</td>
<td>0.500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hypothesized Cointegration Rank Test (Maximum Eigenvalue)</th>
<th>Maximum Eigenvalue Statistic</th>
<th>0.05 Critical Value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None *</td>
<td>40.078</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>At most 1</td>
<td>33.877</td>
<td>0.502</td>
<td></td>
</tr>
<tr>
<td>At most 2</td>
<td>27.584</td>
<td>0.382</td>
<td></td>
</tr>
<tr>
<td>At most 3</td>
<td>21.132</td>
<td>0.721</td>
<td></td>
</tr>
<tr>
<td>At most 4</td>
<td>14.265</td>
<td>0.755</td>
<td></td>
</tr>
<tr>
<td>At most 5</td>
<td>3.841</td>
<td>0.500</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Linear deterministic trend in the data and an intercept in the cointegrating equation; * denotes rejection of the hypothesis at the 0.05 level

Table 4: Generalized Business Cycle Spillover Table for G-6 Countries (1958:01-2008:12)

<table>
<thead>
<tr>
<th>Directional Spillovers (FROM – TO)</th>
<th>US</th>
<th>Germany</th>
<th>Japan</th>
<th>France</th>
<th>UK</th>
<th>Italy</th>
<th>Index=26.97%</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>91.3</td>
<td>0.5</td>
<td>2.5</td>
<td>2.6</td>
<td>2.2</td>
<td>0.8</td>
<td>8.7</td>
</tr>
<tr>
<td>Germany</td>
<td>4.3</td>
<td>59.6</td>
<td>23.0</td>
<td>6.2</td>
<td>6.8</td>
<td>0.2</td>
<td>40.4</td>
</tr>
<tr>
<td>Japan</td>
<td>10.3</td>
<td>6.8</td>
<td>75.9</td>
<td>3.6</td>
<td>2.0</td>
<td>1.3</td>
<td>24.1</td>
</tr>
<tr>
<td>France</td>
<td>3.6</td>
<td>11.3</td>
<td>10.2</td>
<td>63.4</td>
<td>3.6</td>
<td>7.9</td>
<td>36.6</td>
</tr>
<tr>
<td>UK</td>
<td>7.3</td>
<td>4.8</td>
<td>5.5</td>
<td>3.0</td>
<td>77.9</td>
<td>1.5</td>
<td>22.1</td>
</tr>
<tr>
<td>Italy</td>
<td>3.9</td>
<td>0.7</td>
<td>11.2</td>
<td>9.7</td>
<td>4.4</td>
<td>70.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Directional TO Others</td>
<td>29.5</td>
<td>24.1</td>
<td>52.4</td>
<td>25.1</td>
<td>19.0</td>
<td>11.7</td>
<td></td>
</tr>
<tr>
<td>Directional Including Own</td>
<td>120.8</td>
<td>83.7</td>
<td>128.3</td>
<td>88.5</td>
<td>96.9</td>
<td>81.7</td>
<td></td>
</tr>
<tr>
<td>Net Directional Spillovers</td>
<td>20.8</td>
<td>-16.3</td>
<td>28.3</td>
<td>-11.5</td>
<td>-3.1</td>
<td>-18.3</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. Seasonally Adjusted Industrial Production Indices for G-6 Countries (1957-2008)
Figure 2. Unit Root Tests for SA Log Industrial Production Index in Levels
(5% significance level)
Figure 3. Augmented Dickey-Fuller Test for Unit Roots in First Differences of SA Log Industrial Production Index (5% significance level)
Figure 4. Generalized Spillovers for G-6 countries (%, 5-year rolling window, VAR(3))

Figure 5. Cholesky and Generalized VD based Business Cycle Spillover Indices for G-6 countries (5-year rolling window, percent, VAR(3))
Figure 5. Cholesky and Generalized VD based Business Cycle Spillover Indices for G-6 countries (2000:01-2008:12, 5-year rolling window, percent, VAR(3))

(Cholesky, Generalized)
Figure 6. Business Cycle Spillover Indices for G-6 countries

a) 4-year rolling window

b) 6-year rolling window

c) 7-year rolling window
Figure 7. Gross Directional Business Cycle Spillovers Transmitted to Others
(5-year rolling window, VAR(3); with official US recession episodes)
Figure 8. Gross Directional Business Cycle Spillovers Received from Others (5-year rolling window, VAR(3); with official US recession episodes)

France

Germany

Italy

Japan

United Kingdom

United States
Figure 9. Net Directional Business Cycle Spillovers Transmitted to Others

(5-year rolling window, VAR(3); with official US recession episodes)