International Transmission of Business Cycles: An Application of Spectral Analysis Presentation to **Project LINK International Meeting** Universidad Nacional Autonoma de Mexico **Mexico City** May 19, 2005

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Objective

- To examine co-movements of business cycles by comparing the leads based on the reference chronology from economic indicator analysis with results based on spectral analysis.
 - Country Groups: North America, Euro Zone, Asia Pacific
 - ✓ North America: US, Canada, Mexico
 - ✓ Euro Zone: UK, Germany, France, Italy, Spain, Sweden, Switzerland, Austria
 - Asia Pacific: Japan, India, Korea, Taiwan, Australia, New Zealand
 - Countries: US, UK, Germany, India, Japan

Economic Indicator Analysis (EIA)

- "Business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic..." --- Burns and Mitchell (1946)
- The business cycle is a consensus of cycles in many activities, which have a tendency to peak and trough around the same time.
- Thus, a single variable like the GDP or industrial production is insufficient to characterize the business cycle

Measurement of Current Economic Activity - EIA

- Current economic activity is measured by coincident index.
- Coincident Index is a composite of output, income, employment and sales, which collectively help to date peaks and troughs of business cycles.
- Source of data for coincident index for country groups and individual countries and the corresponding reference chronology is the Economic Cycle Research Institute (ECRI), New York.
- **Caveat:** Interpretation of reference chronology for country groups may not be meaningful since zones comprise heterogeneous group of countries.

Economic Indicator Analysis and Cycles

Three types of cycles:

- 1. Classical Business Cycles measure the ups and downs of the economy with absolute values of the variables entering the coincident index.
- 2. **Growth Cycles** trace the ups and downs through deviations of the actual growth rate of the economy from its long run trend rate of growth.
- 3. Growth Rate Cycles cyclical upswings and downswings in the growth rate of economic activity to characterize slowdowns and pickups.
- We use growth rate cycles in this paper.

Spectral Analysis: Background

- Concerned with the exploration of cyclical patterns of data.
- The purpose is to decompose a complex time series with cyclical components into the underlying sinusoidal (sine and cosine) functions of particular wavelengths.
- This spectral representation of a time series is used to infer spectral parameters like coherence and phase shifts.



Spectral Analysis

- The spectral representation translates the process from the time to the frequency domain.
- At each defined frequency, it facilitates the inference of the total variance of the process.
 - The area under the spectrum is the variance of the series, thus the variance of a series is the sum of the spectra over all frequencies (ω).
 - Purpose of frequency domain analysis is to detect the frequencies that contain a lot of information about the variance of a series.
 - Thus examination of spectrum enables us to check whether a sizable portion of the variance of the series is explained by variation at the business cycle frequencies.

Spectral Analysis

- For two cycles, with same frequency of occurrence, the degree of 'correlatedness' is the coherence at that frequency.
 - Coherency varies between zero and one. If the squared coherency is near one at a given frequency ω, it means that at that frequency, components of the two series are highly related.
- **Phase** indicates timing of peaks in one series relative to peaks in the other.
 - At frequency ω, phase lead of θ radians is equivalent to θ/ω periods. This implies that phase at frequency ω can be interpreted as number of periods by which a cycle of one series of above frequency occurs ahead of a similar cycle of another series.

Methodology

- Economic Indicator Analysis
- Spectral Techniques

Economic Indicator Analysis vs Spectral Technique

- EIA: Given the coincident index growth rates, dating of peaks and troughs is done for individual countries/zones.
- The peak and trough dates are compared for a pair of countries or zones to infer leads/ lags between the two series.
- Spectral: Spectral technique provides us with a phase shift parameter which defines lead or lag of one cycle over the other at a given frequency.
- EIA vs Spectral: To compare EIA with spectral analysis, we calculate peak-wise and trough-wise leads or lags between two cycles and average over them to get average lead or lag over the entire cycle.

Spectral Technique and International Co-movement

- Spectral analysis requires stationary series. Hodrick-Prescott filter is usually applied to the raw series to extract the cyclical component, and render it stationary.
- Coherence (analogous to the squared correlation coefficient) and phase shifts (indicating leads/lags) are calculated.
- Time duration of cycles can converted into corresponding frequency bands. Within these bands, spectral estimates give the correlation and phase sequencing of the two cycles over the entire cycle and not distinctly for peaks and troughs.
- We use ECRI's results that growth rate cycles have periods of 4 to 40 quarters. On a monthly scale, this implies a frequency band of [π/60, π/6]. Averages over the range are reported.

Coincident Index Growth Rates: North America, Euro zone



Coincident Index Growth Rates: Euro zone, Asia Pacific



Coincident Index Growth Rates: North America, Asia Pacific



Table A. Contemporaneous Correlation of coincident growth rates across regional country groups Sample: 1980.01 to 2004.09

	Asia Pacific	North America	Euro zone	
Asia Pacific	1.000000	0.133264	0.354455	
North America	0.133264	1.000000	0.294568	
Euro zone	0.354455	0.294568	1.000000	

Table B. Contemporaneous Correlation of CoincidentGrowth rates Across Countries

	US	UK	Germany	India	Japan
US	1.000000	0.535191	0.282882	0.073835	0.044957
UK	0.535191	1.000000	0.299779	0.132132	0.073283
Germany	0.282882	0.299779	1.000000	0.047602	0.396723
India	0.073835	0.132132	0.047602	1.000000	0.088473
Japan	0.044957	0.073283	0.396723	0.088473	1.000000

Summary of EIA Reference Chronology Results

Country Group Results

- North America leads Euro Zone by 2.41 months.
- North America leads Asia Pacific by 1.90 months.
- Asia Pacific leads Euro Zone by 1.54 months.

Summary of EIA Reference Chronology Results

•	Germany leads Japan	1.67
•	Germany leads UK	2.75
•	US leads Germany	3.25
•	UK leads US	1.05
•	Japan leads UK	2.20
•	UK leads India	3.13
•	Germany leads India	3.47
•	India leads Japan	2.33
•	US leads India	4.00
•	Japan leads US	1.08

Interpretation of Spectral Results

- Within the cycle frequency band, [π/60,π/6] calculated averages of parameters may be inferred as
- Coherence Squared Correlation Coefficient
- Phase shift (θ^d) : Average lead/lag of one cycle over the other, such that
- (θ^d) > 0 ⇒ First in the defined pair leads the second by the stated margin.
- $(\theta^d) < 0 \Rightarrow$ First in the defined pair lags.

Spectral Analysis Results Cross - Spectral Statistics: Average Coherences and Phase Shifts

	Cvcle Frequency		High Frequency		
Country	Čoherence	Phase	Coherence	Phase	
pair		(periods)		(periods)	
Sample period 1980.01	to 2004.09				
Regional Country Gr	oup Pairs				
NAM-Asia Pacific	0.59	1.62	0.58	1.62	
Euro zone-Asia Pacific	0.62	-0.60	0.59	-0.64	
NAM-Euro zone	0.70	2.00	0.66	1.94	
Country Pairs					
US-India	0.52	3.00	0.46	2.98	
Japan-India	0.44	-2.50	0.44	-2.50	
Japan-US	0.55	2.07	0.52	1.99	
India-Germany	0.33	-2.01	0.27	-2.00	
UK-India	0.37	1.86	0.35	1.86	
Japan-UK	0.39	2.29	0.39	2.03	
UK-US	0.53	0.79	0.51	0.70	
Germany-US	0.55	-3.37	0.53	-3.31	
UK-Germany	0.65	-2.13	0.65	-2.12	
Germany-Japan	0.47	1.47	0.44	1.43	

Note: Cycle frequency refers to a frequency band of between $\pi/60$ to $\pi/6$, while the high frequency band lies from $\pi/30$ to $\pi/6$. (-) phase for a pair means the first in the pair lags the second

Table above shows averages of coherence and phase shifts within these defined bands.

Inferences Based on Spectral Analysis

Spectral Analysis Results for Country Pairs

Country Data	Inference London Country in the Driv
1980-2000	Leader Country in the Pair
Japan-US	Japan
US-India	US
Japan-India	India
Germany-India	Germany
UK -India	UK
UK -Japan	Japan
UK-US	UK
Germany-US	US
UK -Germany	Germany
Germany-Japan	Germany

Summary Based on Spectral Analysis

•North America leads Euro Zone by 2.00 months.

•North America leads Asia Pacific by 1.62 months.

•Asia Pacific leads Euro Zone by 0.60 months.

Summary Based on Spectral Analysis

The Spectral results are graphically depicted in the next few slides.

- •Two graphs are shown on each slide, with the left hand Y-axis measuring coherence, and the right hand Y-axis measuring phase shifts.
- •The horizontal axis measures frequency, as fractions of π . The band delineated indicates growth rate cycle frequency of between $\pi/60$ and $\pi/6$ (corresponding to 4-40 Quarters)

North America-Euro zone



The horizontal axis measures frequency, as fractions of π . The band delineated indicates growth rate cycle frequency of between $\pi/60$ and $\pi/6$ (corresponding to 4-40 Quarters)

North America-Asia Pacific



Euro zone-Asia Pacific



United Kingdom-United States



Germany-US



US-India



Japan-US



India-UK



Highlights of Results

- Both the Reference chronology and the spectral techniques give directionally the same results, although magnitudes differ by a small margin.
- North America leads Asia Pacific by 1.62 months by spectral technique and by 1.90 months by reference chronology.
- North America leads Euro zone by 2.00 months by spectral methods and by 2.41 months be reference chronology.
- Euro zone lags Asia Pacific by 0.60 months using spectral techniques, and by 1.54 months by reference chronology dating.

Highlights of Results

	»»	EIA	Spectral method
•	Germany leads Japan	1.67	1.47
•	Germany leads UK	2.75	2.13
•	US leads Germany	3.25	3.37
•	UK leads US	1.05	0.79
•	Japan leads UK	2.20	2.29
•	UK leads India	3.13	1.86
•	Germany leads India	3.47	2.01
•	India leads Japan	2.33	2.50
•	US leads India	4.00	3.00
•	Japan leads US	1.08	2.07

Summary Based on Vector Autoregression

- •North America Granger causes Euro Zone.
- •North America Granger causes Asia Pacific.
- •Euro Zone does not Granger cause Asia Pacific.
- •Asia Pacific does not Granger cause Euro Zone.

Conclusions

- The frequency domain analysis of growth rate cycles provides similar results as the time domain analysis and the reference chronology technique, in terms of both direction and magnitude.
- However, in comparing the lead/lag of country groups, it may be more instructive to look into the relationship of each country in a given group with each in the other to recognize the heterogeneity within the group.