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[Article title] Measuring Macroeconmic and Financial Market Interdependence: A Critical Survey

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Structured Abstract:

Purpose - Study of the interdependence among economies is of considerable importance. This area includes issues such as the increasing importance of regional economic interactions, the effects of economic growth and recession in the advanced economies on emerging market countries, and financial contagion. A wide range of related terms and methodologies are used in the literature of interdependence. This paper reviews the major concepts and various measurements of interdependence in financial markets and the real economy, serving as a reference and benchmark for future research on interdependence among specific regional or global economies.

Design/methodology/approach - Major measurements of interdependence are reviewed from simple approach to more complicated ones, and strengths and weaknesses of the various measurements of interdependence are discussed.

Findings - This paper surveys the various major measurements of interdependence and illustrates how they have been used to address a substantial range of issues.

Originality/value - We show that studies of macroeconmic and financial interdependence use the same types of econometric measurements. Our review and critiques of these various types of measures should be of value to those wishing to do research in these areas and also to those wishing to have a better understanding of papers that they read.

Keywords: Interdependence; Contagion; Financial Crisis; Econometric Measurements

Article Classification: Research paper

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Running Heads:

1. Introduction

The rapid increase in international trade and capital flows associated with globalization has generated substantial interest in issues of financial and economic interdependence. These are often discussed under the labels of the international transmission mechanisms, business cycles and stock market synchronization, decoupling and recoupling, and international contagion.

The global financial crisis drew even more attention to the subject as the impacts of US subprime crisis on the world economies have provided evidences of global interdependence. Following the US subprime crisis, the financial markets and real economies in many advanced and emerging market countries were hard hit. Many financial institutions suffered huge losses due to their massive exposure to the subprime loans in 2008 and the US stock market collapsed. The Dow Jones Industrial Average dropped 18.1% and the S&P 500 fell more than 20% within one week in October after Lehman Brothers filed for bankruptcy. The turmoil in the US financial market triggered the global crisis. Many international stock markets experienced their worst short term declines in their history with drops of around 10% in many indices within one day in October, 2008.

Initially it was believed that the adverse effects on economic growth would be largely limited to the US and Europe whose banks were most affected, but as these economies fell into recessions, their large drops in imports began to hit heavily much of the rest of the world (for

discussion of the slow spread of the crisis see Willett, Liang, and Zhang (2010)). While US output growth fell to zero in 2008 and to -2.6 percent in 2009, world output growth in 2009 also turned negative in 2009 (IMF, 2010). Many had argued that with their rapid growth and the increase in intra regional interdependence, many of the emerging market economies (EMEs) had largely decoupled from the advanced economies. The crisis showed that this was overstated and highlighted the importance of careful empirical studies of global economic interdependence.

The study of financial and economic interdependence among countries and regions includes research not only under this specific title, but also under related terms such as business cycle synchronization, recoupling/decoupling, the extent of financial and economic integration, contagion, and so on. Most studies concentrate on a limited number of aspects of interdependence. Many of these aspects are closely related, however, and make use of the same types of measurement techniques such as correlation analysis, VAR analysis (impulse response functions), and factor analysis.

This paper focuses on the interrelationships among these different sets of studies, outlines the various major types of measurement techniques used and discusses their strengths and weaknesses. These are illustrated with reviews of a number of recent studies of major types of issues such as business cycle synchronization, and linkages such as contagion.

2. Channels and Concepts of Interdependence

Economic interdependence is a broad term covering the whole range of ways in which the behavior of variables such as stock market movement, interest rate, economic growth, etc. is influenced by developments in other economics. We can think of greater economic integration or globalization through international trade and capital flows as leading to greater international transmission of developments in one country to other countries and thus generating greater economic interdependence.

If one country goes into recession, it will decrease its imports from other countries. Its trading partners thus face reduction in their exports which in turn reduces their economic growth. The large reduction in the exports of developing countries caused by the recession in the advanced economies that resulted from their recent financial crises is an important example. Obviously, the greater are trade flows among countries, the greater those effects will be.

Likewise, international capital flow link financial and economic developments in one country to those in other countries. For example, both lower interest rates in the advanced economies and increased economic growth in emerging market economies increase the incentives for larger capital flows to the latter. This in turn may make these countries vulnerable to a sudden stop of these financial flows as we have seen in a number of crises.

Recent research has found that not only the levels but also the composition of trade and capital flows can have a large effect on the international transmission of such developments. For example, short term bank loans and portfolio investment are much more susceptible to contagion effects than are flows of direct investment[1]. Likewise, empirical studies have found that intra-industry trade plays a major role in increasing business cycle transmission, while inter-industry trade tends to reduce macroeconomic interdependence due to sector specific shocks (for analysis and references see (Li, 2011)).

Below we briefly discuss the topics of business synchronization among economies, the debate over decoupling and recoupling, and the spread of financial contagion.

2.1 Business Cycle Synchronization

In the classic definition by Burns and Mitchell (1946), business cycle synchronization occurs when "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". According to their definition, "this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own". Business cycles are usually measured by GDP growth rate, domestic

consumption growth rate, domestic investment growth rate, employment rate, and inflation. Studies focus on both the strength of the relationships and the factors that influence them. One major topic is the effect of trade ties on synchronization measures. These relationships are important for issues of macroeconomic policy coordination and are one of the major criteria developed in the literature on optimum currency areas for determining the costs and benefits of joining a common currency area[2].

2.2 Recoupling/Decoupling

In recent years there has been considerable debate about the extent to which emerging market countries are decoupling or recoupling with the advanced economies. While increasing globalization would be expected to generate stronger coupling among economies, some have argued that the more rapid growth in emerging market economies and increases in regionalization would lead to a decoupling of their economic growth and stock market performance from developments in the advanced economies[3]. In this view, while economic interdependence has been increasing among some sets of countries, it has been decreasing among others. As decoupling implies a break in a relationship that was previously closely linked, this definition lends itself naturally to discussions of changes in patterns of comovements or correlations.

2.3 Contagion (or Spillover)

Contagion is usually referring to a spread of a crisis from one economy to another. The term of contagion is analogous to the spread of contagious diseases and became particularly popular since the Mexico peso crisis in the end of 1994.

Contagion implies the existence of interdependency but there can be a number of different types of interdependency and these can have very different implications for policy[4]. As a result, the term contagion requires one to specify what type in order to communicate effectively. In public discussions, there is often a connotation that contagion is due to irrational panic and thus reflects a failure of markets to operate efficiently. This is far from the only possible type of contagion, however. In its broadest sense, contagion can refer to any spread of economic developments in one country to other countries. In this sense, it is the same as interdependence. More commonly, contagion is used to refer to stronger than normal interrelationships associated with crises. One popular definition of contagion is that a crisis in one country increases the risk of crises in other economies. This type is measured by estimating the extent to which a crisis in one country increases the probability of crises in others from equations that control for a number of factors such as current account deficits, low international reserves and rapid credit growth that are often associated with crises[5].

For looking at effects on variables such as interest rates and stock prices, continuous measures are used. A typical definition of this more restricted view of contagion is the transmission of shocks to other countries or the cross-country correlation beyond any fundamental link among the countries and beyond common shocks (which is also called the "pure contagion"). This definition is usually referred to as excess comovements, commonly explained by herding behavior. This is often measured by looking at the increase in cross-country correlations increase during "crisis times" relative to correlations during "tranquil times".

Interpretations of the causes of the particular crises vary widely. In large part this is because there are often multiple causes and these can vary from one case to another. Thus careful empirical and case studies are essential to shed light on such episodes.

3. Measurements of Interdependence

The literature provides many methods to measure various aspects of interdependence. Here we discuss a number of the most widely used measures: correlation, cointegration, panel, vector auto-regression (VAR), and dynamic factor analyses[6]. Some research uses the combination of more than one of the above methods.

Table 1 summarizes the main measurements of interdependence discussed in this paper. These are discussed beginning with the simplest approach, correlation analysis, and moving on to more complicated ones and from single variable to multiple variable analyses.

Table 1 Summary of Measurements of Interdependence

Methodology	*Sub-Category*	*Description*	*Advantage and Disadvantage*
Correlation Analyses		Correlation analyses measure the overall comovements of two variables.	
Static Correlations	Simple Correlation	The simple correlation is obtained by dividing the covariance of the two variables by the product of their standard deviations. Example: Willett, *et al.* (2010)	The advantage of the simple correlation: straightforward and intuitive. The advantage of trend-filtered correlations: they can remove the effects from different trends of business cycles. The disadvantage of HP filtered correlation: the end-point problem. The calculation puts more weight on the observations at the end of the series. The disadvantage of static correlations: they are less powerful to capture high frequent time varying or dynamic characteristics of the comovements which are often shown in the fast-changing financial markets.
	Trend-filtered Correlation (Linear Trend)	OLS regression is often used to get the linear trend. The linear trend-filtered correlation is the correlation of deviations from the linear trends of two variables. Example: Permpoon and Willett (2007)	
	Trend-filtered Correlation (Non-linear Trend)	The Hodrick-Prescott filter is often selected to generate non-linear trend line. The HP-filter smoothes data with a procedure of squared error minimization and then removes short-term fluctuations. The HP-filtered correlation is the correlation of deviations from HP trends of two variables. Example: Willett *et al.* (2011).	

Table 1 Summary of Measurements of Interdependence (Cont.)

Methodology	*Sub-Category*	*Description*	*Advantage and Disadvantage*
Dynamic Correlations	Dynamic Conditional Correlation (DCC)-GARCH	DCC-GARCH takes the volatility or heteroscedasticity, and autocorrelation of the variables into account to produce a time-varying correlation calculation. It is estimated in a two-stage procedure. First, univariate GARCH models are fitted for each of the variables in the specification. Second, using transformed residuals resulting from the first stage, the dynamic conditional correlation estimators are estimated. Example: Engle (2002); IMF (2008).	Advantage: DCC-GARCH can capture high frequent time varying correlations and has shown to be more robust than the static correlation models. Disadvantage: the parameters of the DCC-GARCH model assumes that errors are normally distributed thus the estimations may be greatly affected by outliers.
	Time-Varying-Coherence Functions (TVCF)	The Time Varying Coherence Functions (TVCF) not only captures degrees of comovements but also their behavior in each frequency. The coherence is interpreted as the squared linear correlation coefficient for each frequency of the spectra of two series. Example: Essaadi and Boutahar (2008).	Advantage: it not only detects comovement dynamics in different cycles but also identifies changes in synchronization processes at different frequencies; the frequency approach doesn't depend on any detrending technique and doesn't have the "end-point" problems.
Cointegration Analyses		Cointegration tests capture the integration relationship among economies. Mathematically, if some linear combination of two or more series has a lower order of integration, the series are considered cointegrated. Example: Burdekin and Siklos (2011).	Advantage (also disadvantage): it is especially and only suitable to analyze the long-run relationship between nonstationary economic variables.

Table 1 Summary of Measurements of Interdependence (Cont.)

Methodology	*Sub-Category*	*Description*	*Advantage and Disadvantage*
Panel Analyses	Panel regression with fixed effects	The panel fixed effect model is a statistical model that represents the observed quantities in terms of explanatory variables that are all treated as if those quantities were non-random. Example: Baur and Fry (2008); IMF (2008).	Advantage: the panel model enables great flexibility in modeling differences in behavior across individuals controlling for individual effects. Disadvantage: the panel model relies on availability of more sets of variables.
Vector Auto-regression (VAR) Analyses		The VAR model analyzes the dynamic impact of random disturbances and describes the evaluation of a set of endogenous variables in the system as a linear function of their past evolution. Example: Kim, Lee, and Park (2009)	Advantage: it can analyze the effect of the innovational shocks allowing interactions among variables and provides dynamic solutions which are often hidden to standard procedures such as OLS or other static regressions. Disadvantage: the robustness of the VAR estimations depends on a plausible setup on the endogenous assumptions among variables; all effects of omitted variables are in the residuals, which may lead to major distortions in the impulse responses, making them more difficult for structural interpretations.

Table 1 Summary of Measurements of Interdependence (Cont.)

Methodology	*Sub-Category*	*Description*	*Advantage and Disadvantage*
Dynamic Factor Analyses		Dynamic factor analysis is a technique used to detect common patterns in a set of time series and relationships between these series and explanatory variables. Example: Kose *et al*. (2008)	Advantage: it allows for the separation of idiosyncratic components and common comovements. Therefore, the dynamic factors can describe contemporaneous and temporal covariance among the variables. Disadvantage: it needs relatively long time series and it is easy to lose degrees of freedom. In addition, it cannot be used to analyze bilateral comovements between concerned countries.

3.1 Correlation or Comovement Analyses

Correlation or comovement analysis is one of the most widely used measurements in recent interdependence or contagion literature. It includes static and dynamic analysis. It is important to remember that correlation need not imply causation, nor does it measure only the degree of interdependent among variables. Correlations are often influenced by common shocks. Furthermore even with country specific shocks correlations across countries will often vary with

the nature of the shock. As a result the correlations among asset prices used for the allocation of investment portfolios and among economic growth rates used to look for patterns and trends in macroeconomic interdependence often vary considerably over time.

3.1.1 Static Correlations

a. Simple Correlation

The simple correlation measures the overall comovements and serves as the basic framework for a quick assessment of interdependence. It is obtained by dividing the covariance of the two variables by the product of their standard deviations[7].

Many researchers have used correlation analysis to test for interdependency or its related terms. For example, defining contagion as a significant rise in the correlation among asset returns, Baig and Goldfajn (1999) test for evidence of contagion between the financial markets of Asian countries during the crisis of 1997-98 and find that correlations for currency and sovereign spreads increase significantly while the equity market correlations offer mixed results.

The advantage of the simple correlation is its straightforwardness and intuitiveness. However, it has important limitations. One of the most important limitation is that as noted

above correlations are the product of both the sensitivity of developments in one country to those in another (interdependence) and those developments themselves. Thus a high correlation could occur because of a common shock. This explains a substantial portion of the increases in the correlation of growth rates among Asian economies during their financial crisis of 1997-98 and among many of the advanced economies during the financial crisis of 2007-2009[8].

Different patterns of shocks within the economies in question can also lead to substantial differences in correlations. Thus we often see correlations vary substantially over time. Zhang (2011a) finds this for stock returns of the US and Asian economies. Correlations almost always rise during crises. The frequent instability of correlations suggests that we should be careful not to misinterpret short run variations as the beginning of long run trends.

One controversial aspect of using changes in correlations to measure contagion concerns how to test for statistical significance. Forbes and Rigobon (2001; 2002), for example, criticize that the simple correlation is biased in the analysis of contagion because of the presence of higher volatility in market returns in the crisis periods leads to increased correlations. Correcting for the heteroskedasticity problem, they find virtually no evidence

of contagion during the multiple crises and that the greater degree of comovement of the stock market during the crisis period may simply reflects a continuation of the trend in market interdependence. However, other researchers argue that the increase in variance is a normal part of a crisis and so adjusting for these when testing significance may not be appropriate (Baig and Goldfein, 2001).

One important issue that studies often do not address sufficiently is the length of the time periods over which correlations should be measured. Appropriate lengths can vary substantially depending on the specific issue being addressed. For example, managers of investment funds attempting to beat the market may be interested in correlations over very short time periods, while considerably longer time periods would be relevant for issues of macroeconomic policy coordination[9].

A related issue with simple correlations is that they do not distinguish long run relationships, i.e., trends, from short run movements around these trends. In general macroeconomic interdependence will have a larger impact on these shorter term movements than on the trends themselves, although of course the extent to which an economy is opened to the world economy can affect its growth rate[10]. An obvious way of dealing with this problem is to look at the correlations of deviations from trends.

b. Trend-filtered Correlations (Linear and Non-linear Trend)

The trend-filtered correlations remove the effects of medium or long term trends (linear or non-linear) and find the comovements on detrended data. Generally speaking, there are two categories of de-trending methods, linear and non-linear. For linear de-trending techniques, OLS regression is often used to estimate a linear trend-line. For non-linear de-trending techniques, the Hodrick-Prescott filter is often selected. Willett *et al.* (2011), for example, calculate both the linear detrended and HP filter detrended correlations between the growth rate of US and several EMs. Because economies such as China and India continue to have high growth rates, it is often conclude that they are little affected by the global financial crisis. When one adjusts for their high trend growth rates, however, it is found that they suffer declines on the same order as the advanced economies. Thus while simple analysis supports the decoupling hypothesis, more careful analysis finds the supports the opposite conclusion.

The HP filter smoothes data with a procedure of squared error minimization and then removes short-term fluctuations[11]. A main drawback of the HP filter is the end-point problem. The calculation puts more weight on the observations at the end of the series (Marinheiro, 2005). But if the study has relatively large numbers of observations and focus

on mostly the middle points, the biases are limited. Although the simple correlations and the static trend-filtered correlations are straightforward and easy to calculate, they are less convenient to capture high frequent time varying or dynamic characteristics of the comovements which are often shown in the fast-changing financial markets. The dynamic correlation methods can solve this problem by providing dynamic solutions.

3.1.2. Dynamic Correlations

Dynamic correlations provide time-varying correlations between economic variables. Some examples are the Dynamic Conditional Correlations – GARCH- developed by Engle (2002) and the Time Varying Coherence Functions used by Essaadi and Boutahar (2008).

a. Dynamic Conditional Correlations-GARCH

DCC-GARCH developed by Engle (2002) takes the volatility or heteroscedasticity, and autocorrelation of the variables into account to produce a time-varying calculation of correlations. It is estimated in a two-stage procedure. First, univariate GARCH models are fitted for each of the variables in the specification. Then using transformed residuals resulting from the first stage, the dynamic conditional correlation estimators are estimated[12].

This method has then been widely used in the research on contagion. For example, Wang and Thi (2006) use it to examine the impact of the 1997-98 Asian financial crises on the Chinese Economic Area (CEA) and find positive correlation coefficients of stock returns. The IMF in its 2008 Global Financial Stability Reports (IMF, 2008) uses DCC-GARCH to analyze the comovements in stock markets between the US and some global emerging market regions as a whole and find varied but overall increasing correlation levels during the past several years up to 2008. A study by Zhang (2011a) calculates dynamic conditional correlations for the stock returns of some Asian economies and the US during the recent financial crisis and finds that the correlations of Asian equity markets with the US have tended to increase over time, but that there was a decrease in correlations during the beginning of the recent crisis (7/2007-8/2008), then a substantial increase after the collapse of Lehman brothers up to late 2009 (9/2008-8/2009), and a small decrease in the later period of the recent crisis (9/2009-8/2010). Much of the decoupling debate wrongly focused on these short run changes as if they reflected changes in longer term trends.

DCC-GARCH method has proven to be more robust than the static correlation models, especially for looking at financial variables which often face greatly changing volatility. DCC-GARCH has limitations, however. For example, the parameters of the DCC-GARCH model assume that errors are normally distributed may be greatly affected by

outliers. While the normality assumption fits the actual behavior of financial markets fairly well during calm periods, it breaks down badly during crisis periods which display much larger changes than predicted by the normal distribution. This is a major problem for many of the risk models used by the financial sector[13].

b. Time Varying Coherence Functions

The time varying coherence analysis is another example of dynamic methods of comovement analysis. Essaadi and Boutahar (2008), use this approach[14] to estimate Time Varying Coherence Functions (TVCF) for non-stationary time series to capture both degrees of comovements and their behavior in each frequency[15]. Their research finds that there is a common business cycle in East Asia, especially after the 1997-98 crises.

The main advantage of the frequency approach TVCF is that it not only detects comovement dynamics in different cycles but also identifies changes in synchronization processes at different frequencies. In addition, the frequency approach doesn't depend on any particular detrending technique and doesn't have the "end-point" problems.

3.2 Cointegration Analyses

Cointegration tests capture one aspect of the integration relationships among economies. Mathematically, if some linear combination of two or more series such as inflation in two countries has a lower order of integration, the series are considered cointegrated. Let us explain.

Empirical macroeconomic studies frequently involve variables with trends such as the money supply, price level, and aggregate economic growth and some of its components such as consumption and investment. Such series are often non-stationary. Regression of one of such variables on another would be misleading since much of the correlation would be due to common trends. Thus simple regression relationships could be spurious. To manipulate these series appropriately, the procedure of taking first differences I(1), or second differences I(2), or other transformations (such as seasonal adjustment) is used to reduce them to stationarity (Greene, 2008). Thus for example, while the price level has a strong trend, its first differ, the inflation rate, may not. Inflation may also have a strong trend than it would be differenced again.

With theory testing, an important issue with such differencing is whether the predicted relationships would still hold up in difference form. Thus while we would expect money growth and inflation to be correlated, the expected relationship between money growth and the first difference of inflation is unclear relationships.

Generally speaking, if two time series are integrated to different orders, linear combinations of them will be integrated to the higher of the two orders. If both series are each drifting upward with their own trend, then the difference between them should also be growing, with yet another trend, unless there is some relationship between those trends. For example, if the two series are both I(1), then there may be a vector of parameters such that the disturbances are I(0) (i.e., a stationary, white noise series). Intuitively, this phenomenon would imply that the two series are drifting together at roughly the same rate. If the two series satisfy this requirement, they are considered to be cointegrated (Greene, 2008).

In this case, we can distinguish the long-run relationship between the two series, that is, the manner in which the two variables move upward together, and the short-run dynamics, that is the relationship between deviations of each series from its long-run trend. If there exist cointegration relationship between two time series, transforming them to stationary data through 1^{st} difference or 2^{nd} difference procedure would hide the long-run relationship between the two time series. Thus, the cointegration test is usually used to analyze the long-run relationship between the economic variables when all the variables are found to be non-stationary (i.e., there exist unit roots).

Error correction estimation is often used to investigate the short-run interactions of the economic series such as growth rates or stock markets. As an example, Karolyi and Stulz (1996) break down the comovement of stock markets between the US and Japan into long-run and short-run linkages[16].

Cointegration tests are often used both in studies of financial and macroeconomic integration and contagion. Burdekin and Siklos (2011), for example, examine long-run cointegrating relationships for the Asian economies and the US during 1999-2010 and apply quantile regression techniques[17] to allow for variation over the spectrum of the return distributions. They find that the enormous growth of the Shanghai market in the new millennium has been accompanied by substantial integration with other regional and world market. The major advantage as well as limitation of the cointegration method is that it is only suitable to analyze the long-run relationship between non-stationary economic variables.

3.3 Panel Analyses

Panel data sets combine time series and cross section data. Thus one is able to investigate relationships both across countries and markets and over time (Greene, 2008). A

variety of different models for panel data can be constructed. Broadly, they fall into the following three categories:

1. Pooled regression: if individual effect contains only a constant term, the ordinary least squares (OLS) provides consistent and efficient estimates of the parameters.
2. Panel regression with fixed effects: individual effects can be modeled as coefficients on individual-specific binary variables. Most economists favor using "fixed effects because this form of unobserved heterogeneity can be either correlated with regressors or uncorrelated with them, just as any other regressors can be".(Greene, 2008)
3. Panel regression with random effects: some models make the strong assumption that individual effects are "random" in the sense that they must be uncorrelated with all regressors. In this form of setting, unobserved heterogeneity affects the residuals in the equation of interest.

The major difference between fixed and random effects is whether the unobserved individual effect embodies elements are correlated with the regressors in the model, not whether these effects are stochastic or not. The fixed effects estimator of the slope parameters is consistent even if the true model is pooled or with random effects, because the fixed effects model allows individual effects to be correlated with other explanatory variables but it does not

require the variables to be correlated. The random effects model is not consistent if the true model is fixed effects model, because the random effects model imposes "no correlations between the individual effect and the other explanatory variables" (Greene, 2008). In addition, the random effects model allows the identification of the marginal effects of time-invariant regressors to avoid "perfect multicollinearity" when the fixed effects model is applied, because the individual effect is just a shock in the random effect model, but the estimates are consistent only if the strong assumptions underlying the random effects are valid (i.e., no correlations between the individual effect and the other explanatory variables).

Yeyati (2011) provides an example of the use of pooled panel regression to investigate the decoupling of the main emerging markets from the advanced economies in both financial and real terms. The panel regressions for the annual growth rate of country's cyclical output (relative to a log linear GDP trend) on the G7 and Chinese cycles for the periods of 1993-99 and 2000-Q3 2010 show that the growth of some emerging markets are becoming less coupled with the advanced economies and more coupled with China.

Baur and Fry (2008) apply a panel fixed time effects model to equity returns for eleven Asian economies during the Asian crisis of 1997-98 and find that interdependencies are substantially more important than contagion during the crisis. The fixed time effects are

interpreted in comparison to a base period and are assumed to reflect contagion. Actually, the fixed time effects can capture movements across all asset markets that are not explained by regional or global factors. Baur and Fry address that system-wide contagion exists if the value of the fixed time effect is greater than a threshold based on conventional (99 percent) significance levels.

Using high significance requirements is certainly correct for scientific analysis where we should require strong evidence to accept a hypothesis. From a policy perspective, however, such stringent requirements are questionable. They implicitly assume no contagion as the base presumption. Significance from the standard types of tests at say the 30% level would still suggest that the odds were 70 to 30 that there was some contagion and policy makers would not have the luxury of waiting for a larger number of observations before making decisions.

The IMF (2008) in its Financial Stability Report investigates the spill-over effects in equity markets from the advanced economies to emerging market economies from May 2008 to January 2011 using a fixed effect panel analysis. The estimation on Asian equity markets, for example, suggests that the global factors are statistically significant: equity prices are positively associated with global excess liquidity and negatively with credit and market risk prime. For domestic factors, GDP growth, an expected exchange rate appreciation, and an increase of

market capitalization have positive effects on equity prices, while interest rate differentials have a negative effect.

The fundamental advantage of panel analysis over a cross section is that researchers have great flexibility in modeling differences in behavior across individual units and their dynamics. Of course panel analysis requires a larger set of variables than correlation or cointergration tests

3.4 Vector Auto-regression (VAR) Analyses

VAR analysis takes endogeneity of different economic variables into account when investigating interdependencies among economies. It analyzes the dynamic impact of random disturbances and describes the evaluation of a set of endogenous variables in the system as a linear function of their past evolution[18]. VAR models are usually presented with impulse response functions that measure the effects of the different shocks in one variable on the other variables, and variance decompositions that measure the relative importance of the different shocks to the variation in the different variables. Granger causality tests are often used in the VAR analysis to decide the endogeneity of the variables. These disclose statistical but not necessarily behavioral causality.

Kim, Lee, and Park (2009), for example, investigate the degree of real economic interdependence between nine emerging Asian countries and major industrial countries including

Japan and the US. They document the evolution of macroeconomic interdependence for the emerging Asian economies through changing trade and financial linkages at both the regional level and the global level. They apply a panel VAR model to estimate the degree of real economic interdependence measured by aggregate output growth rates before and after the 1997-1998 Asian Crises. Their empirical findings show that real economic interdependence increased significantly in the post-crisis period, indicating "recoupling", rather than decoupling.

The IMF in its WEO report (IMF, 2007) also uses the VAR method to examine the spillover of the US to other 130 economies in GDP and finds that in general, the spillovers from growth in the US are significantly higher in the post-1987 half of the sample (1970 to 2005). This suggests that perceived large declines in the macroeconomic importance of the United States have been overstated and that the rapidly increasing trade intergration in many regions has not undercut the importance of global interdependence.

Using a structural VAR in the Generalized Method of Moments model[19], Angkinand, Barth, and Kim (2010) find an increase in interdependence between advanced country stock market returns over time and that the spillover effects from the United States to other industrial countries are particularly large during the recent financial crisis. A study by Zhang (2011b) investigates the impact of US stock market movements on Asian markets during the recent

financial crisis using VAR analysis and finds that global factors, especially the US equity market, also effect Asian equity markets more strongly during the crisis.

The major advantage of the VAR method is that it analyzes the effects of shocks allowing for interactions among variables and provides dynamic estimates. The VAR method provides a systematic approach to imposing restrictions[20] and to define endogeneity among variables and capture relationships which are often hidden to standard procedures such as OLS regressions. A limitation of the method is that the robustness of the VAR estimations depends on a plausible setup on the endogenous assumptions among variables. Another limitation of the VAR approach is that as it has to be estimated with limited number of variables, all effects of omitted variables will be in the residuals. This may lead to major distortions in the impulse responses, making structural interpretations more difficult.

3.5 Dynamic Factor Analyses

Dynamic factor analysis is a technique used to detect common patterns in a set of time series and relationships between these series and explanatory variables[21]. Taking the model used by Kose *et al.* (2008) as an example, dynamic factor analysis characterizes the degree of synchronization over time in various dimensions (global factor, regional factors, country factors, and idiosyncratic factors) without making strong identifying assumptions to disentangle different

types of common shocks[22]. The dynamic relationships in the model are captured by modeling each factor and idiosyncratic component as an autoregressive process. This simultaneously picks up in a flexible manner, the contemporaneous spillovers of shocks as well as the dynamic propagation of business cycles without putting a priori restrictions on the structure of the propagation mechanism or the directions of spillovers[23]. A surprising conclusion of their analysis is that contrary to what would be expected from increased globalization, the global factor was less important in the second period.

Li (2011) adds additional macroeconomic variables such as exports and imports to Kose *et al.*'s model and also finds that the world factor has become less important in explaining the macroeconomic fluctuations from sub-period 1961-1984 to sub-period 1985-2007. Li also finds that contrary to perceptions of increased regionalization, regional factors do not play an important role in explaining aggregate volatility except for consumption. The explanatory power of country factors increases as variances are driven more by country and idiosyncratic factors than by the world factor[24]. This conflicts with the results from studies of output growth fluctuations. The cause of these differences is an important area for further research.

A static factor model provides a description of the variance-covariance matrix of a set of random variables, while a dynamic factor model provides a description of the inter-periods

correlations. Therefore, the dynamic factors can describe contemporaneous and temporal covariance among the variables (Kose *et al.*, 2008).

Compared with correlation approaches, an important advantage of the dynamic factor model is that it allows for the separation of idiosyncratic components and common comovements of global, regional, country-specific and idiosyncratic factors. It is well suited to investigate the degree of region-wide comovements and to study the joint properties of fluctuations in output and its components. However, the disadvantage of dynamic factor models is that they need relatively long time series and it is easy to lose degrees of freedom. In addition, it cannot be used to analyze bilateral comovements between concerned countries.

4. Concluding Remarks: The Consistency of Measurements

Empirical studies of financial and economic interdependence have provided considerable useful information. For example, they find that most national economies and financial markets are substantially influenced by international influences, but also that these are generally not as strong as to completely dominate the national performance. Often such studies find that reality lies well within the range of the extreme popular opinions offered about such issues as decoupling and recoupling and contagion. However, there is still considerable disagreement among experts about the strengths of some important forms of interdependence.

It’s not surprising that different studies often don't exactly agree. More troubling is that they sometimes fundamentally disagree. In part this is no doubt because some experts have strong beliefs about the nature of certain relationships and interpret their results in this light. But we also find that not only the use of different sets of countries and time periods but also different estimation techniques sometimes yield substantially different conclusions[25].

The differences in results from different data sets should remind us that economic relationships are generated by the behavior of human beings and thus can vary from one situation to another. While we are able to capture some fairly strong regularity, these often don't have the consistency of the physical laws of nature. The differences from identical data sets resulting from different estimation techniques such as were illustrated at the end of the previous section need to be the focus of extensive research. In the meanwhile where alternative approaches have been recommended we should check the sensitivity of the results to the different methods. Obviously we should have more confidence when the results of doing this roughly agree than when they differ substantially.

Notes

1. See the analysis and references in Sula and Willett (2009) and the companion paper in part one of this special issue by Efremidze *et al.* (2011).
2. See, for example, the general discussion of OCA criteria and references in Willett (2003a; 2003b) and applications to Asia and Europe in Willett, Permpoon, and Srisorn (2010) and Willett, Permpoon, and Wihlborg (2010).
3. For analysis and references see Willett, Liang, and Zhang (2010).
4. For further more discussion and references please see Liang and Willett (2008).
5. See, for example, Willett *et al.* (2005) and Eichengreen *et al.* (1996).
6. Some of the other techniques used are probit analysis for studying the probability of effects of the spread of crises (for an example see Angkinand, Chiu, and Willett (2009)) and principal components analysis for identifying the common factors of the spread of the crisis (for detailed analysis, see Rigobon (2001)). They are not necessarily completely exclusive from methods we discuss in this paper though. For example, the probit method is often used in panel analysis.
7. The mathematical presentation of the simple correlation is as the following:

$$\rho_{X,Y} = corr(X,Y) = \frac{cov(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_x)(Y-\mu_Y)]}{\sigma_X \sigma_Y}$$

   Where X and Y are two variables of which the relationship is to be evaluated, μ_X and μ_Y are expected values for X and Y respectively, σ_X and σ_Y are their standard deviations, and E is the expected value operator.
8. See Willett, Permpoon, and Srison (2010) and Zhang (2011a).
9. For stock markets it is important to consider whether they should be measured in dollars or the domestic currency for the specific question being investigated. For example, for portfolio allocations by US investors the dollar value is most relevant while for looking at the sensitivity of a foreign market to a US shock the domestic currency value is more relevant.
10. For an application to the measurement of business cycle correlations and their implications for OCA analysis see Willett, Permpoon, and Srisorn (2010).
11. For discussion of how the HP filters are estimated, see appendix A of the longer version of this paper that appears on the Web site of the Claremont Institute for Economic Policy

Studies: http://www.cgu.edu/pages/1380.asp. For evaluation of the HP filter, see Ravn and Uhlig (2002).

12. See appendix B in the longer version of this paper.
13. For more evaluation of DCC-GARCH, see Engle and Sheppard (2001) and Vargas (2006).
14. The frequency approach is based on time varying coherence to detect endogenously structural changes in the comovement process. This method not only detects comovement dynamics in different cycles, but also tests if these countries tend to be more synchronized or not. The coherence is interpreted as the squared linear correlation coefficient for each frequency of the spectra of two series. When calculating the time varying coherence, they employ the Bai and Perron test (1998) to determine endogenously break dates because the choice of this type of model is motivated by TVCF characteristics.
15. For more econometric details of the TVCF analysis, see Essaadi and Boutahar (2008).
16. The short-run effects are measured by a vector-correction model and the long-run effects are measured by conintegration tests, for example, the Johansen procedure (Johansen, 1991).
17. While standard OLS assumes a simple linear relationship among the variables, quartile analysis allows the estimation of different coefficients for different parts of the distributions.
18. The reduced form presentation of the VAR model is as the following:

$$Y_t = c + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + e_t$$

where Y_t is a set of k time series variables: $Y_t = (Y_{1t}, Y_{2t} \ldots Y_{kt})'$, the A_i s are k x k matrices of coefficients, c is a kx1 vector of constants, p is the order or lag of the model, and e_t is a kx1 vector of error terms – the e_t s are serially uncorrelated but may be contemporaneously correlated.

19. Generalized Method of Moments (GMM) is a generic method to estimate parameters when the full shape of the distribution function of the data is not known and the parameters of interest are finite-dimensional.
20. The restrictions define the endogenous relationship among variables and can be realized by multiplying a control matrix determining the order of the effects.
21. More applications of factor analysis can be found in studies by Otrok and Whiteman (1998), and Bernanke, Boivin, and Eliasz (2005).

22. The pioneering use of this approach to attempt to distinguish real versus nominal shocks is by Blanchard and Quah (1989).
23. For technical details see appendix C of the longer version of this paper.
24. Li also finds that regional factors and country factors also play a more important role in explaining gross import fluctuations than in explaining gross exports (Li, 2011).
25. Of course they also often find similar results. For example both Li (2011) and Zhang (2011a) find that the use of linear versus HP trends makes little difference in their studies of macroeconomic and stock market interdependencies.

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