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ABSTRACT

The worst weather anomalies occurred in the latter part of the 20th century. The effects are usually assessed by multidisciplinary teams with conclusions that are often diverse. The effect of El Nino Southern Oscillation (ENSO) in Asia is characterized by testing and modeling the co-movement of the Southern Oscillation Index (SOI) and agricultural production. Johansen test for cointegration was used and a GARCH model is fitted among indicators that exhibit cointegration. The test exhibited cointegration between SOI and cereal production/yield in some Asian countries. While there is cointegration, GARCH models did not necessarily exhibit the structural effect of SOI in cereal production/yield.

A nonparametric test of causality based on the error correction model and using the bootstrap method is proposed. The method can better assess if indeed, there is causality between the time series if random shocks and similar events caused volatility or structural change in the time series.

Introduction

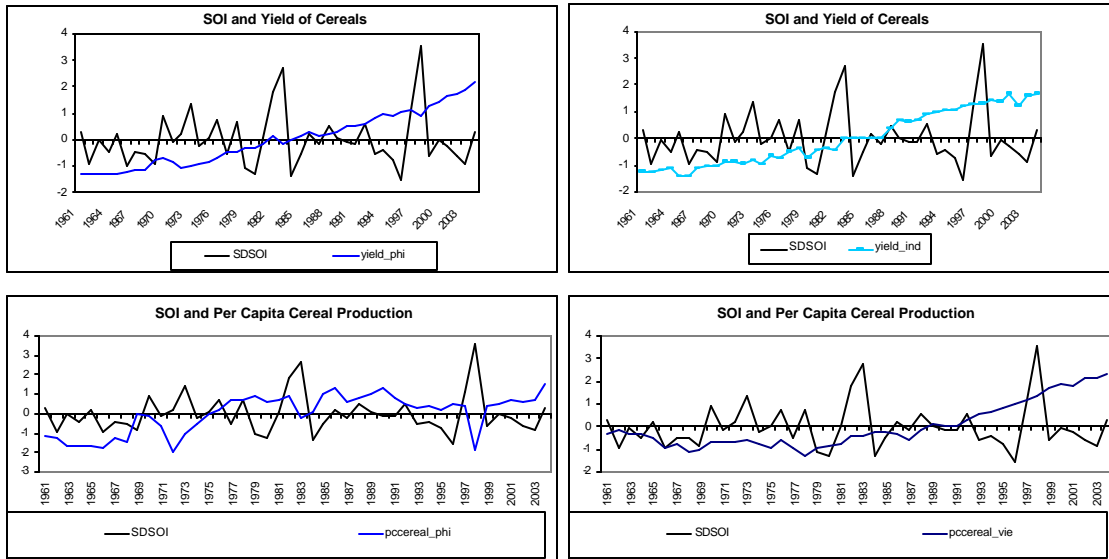
The countries around Asia are characterized by agricultural production that is highly vulnerable to weather conditions. When a dry spell hits the southern countries, massive flooding would usually hit the northern part. Fast-growing populations and limited agricultural areas motivate Asian countries to increase agricultural production through the intensive use of technology. Thus, any fluctuation in the environment can easily cause volatile movements, or to some extent, can cause structural breaks in the behavior of production time series.

Similarity of movements of two or more time series may be masked when the time series exhibit nonstationary behavior. An even more complicated masking of the relationships can occur when aside from nonstationarity, the time series also exhibit volatility and/or structural breaks. In Figure 1, the time plot between the annual standard deviation of SOI and yield per capita of cereal production of some countries are given. In times when there is high variability in SOI, both the yield and per capital production in the Philippines react prominently, yield in India react for a few episodes, while other countries' series exhibit relative robustness for some. For example, the per capita production in Vietnam does not react significantly to increases in standard deviation of SOI.

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**Figure 1: SD of SOI and Yield/Per Capita Cereal Production
Philippines, India, and Vietnam**



When there is a volatile weather condition, agricultural production can be easily affected. However, the possibility of experiencing a structural break and/or a volatile movement in either or both the SOI and agricultural production may potentially mask the movement.

In the presence of breaks or volatility, cointegration testing that assumes specific global structural and/or non-structural model may fail. The structural break usually accompanying non-stationary behavior can complicate in the breakdown of cointegration testing.

We analyze per capita production and yield per hectare of cereals for some Asian countries in 1961-2005. We use Johansen test for cointegration between the standard deviation of the southern oscillation index (SDSOI), a global weather indicator and the cereal production indicators. We also fitted GARCH models to identify the possible episodes of volatile behavior. An evidence of co-movement between SOI variability and agricultural production will provide agriculture policy makers in Asia a tool in mitigating the possible break and/or volatility in production.

We also propose an alternative test for causality among time series that does not necessarily require stationarity. The nonparametric test for causality is based on the error correction model and using the bootstrap method.

Structural Break and Unit Root Tests

The block bootstrap has been used to develop a nonparametric method of testing for unit roots in a time series (Papadimitis and Politis, 2003). Resampling is done based on the weak assumption of dependence structure of the stationary process to derive the random walk to generate the unit root pseudo-series retaining the important characteristics of the data. The test allows for a wide class of weakly dependent processes and it is not based on any parameter assumption on the process generating the data. The procedure can accurately capture the distribution of many unit root tests proposed in the literature. Theoretical as well as empirical evidence support the conclusion that the testing procedure is a useful alternative to asymptotic distributions commonly used in econometric analysis of nonstationary time series.

(Kapetanios and Shin, 2006) proposed a testing procedure to distinguish a unit root process from a globally stationary three-regime self-exciting threshold autoregressive process. Threshold parameters are not known a priori, resulting to the misclassification of a stable non-linear process as non-stationary. The unit root tests are designed to have power against globally stationary three-regime SETAR processes. Monte Carlo evidence indicates that the proposed tests are more powerful than the Dickey-Fuller test that ignores the threshold nature under the alternative.

(Hansen, 2000) proposed a procedure that will split the sample and estimated the threshold in each segment, allowing important nonlinearities in the conditional expectation function without over-parametrization of the model. The results generalize to the case where only a subset of parameters switches between regimes and to the case where some regressors only enter in one of the two regimes. Asymptotic methods to construct confidence intervals for least-squares estimate of threshold parameters were also developed. It was noted that confidence intervals are asymptotically conservative, and it is possible that more accurate confidence intervals may be constructed using bootstrap techniques.

A parametric dummy variable-based test for event studies using multivariate regression is proposed by (Hein and Westfall, 2004). They described bootstrap alternatives,

investigated, and compared for cases where there are non-normalities, cross-sectional and time series dependencies. Independent bootstrapping of residual vectors from the multivariate regression model controls type I error rates in the presence of cross-sectional correlation, and surprisingly, even in the presence of time series dependence structures. The proposed methods not only improve upon parametric methods, but also allow development of new and powerful event study tests for which there is no parametric counterpart.

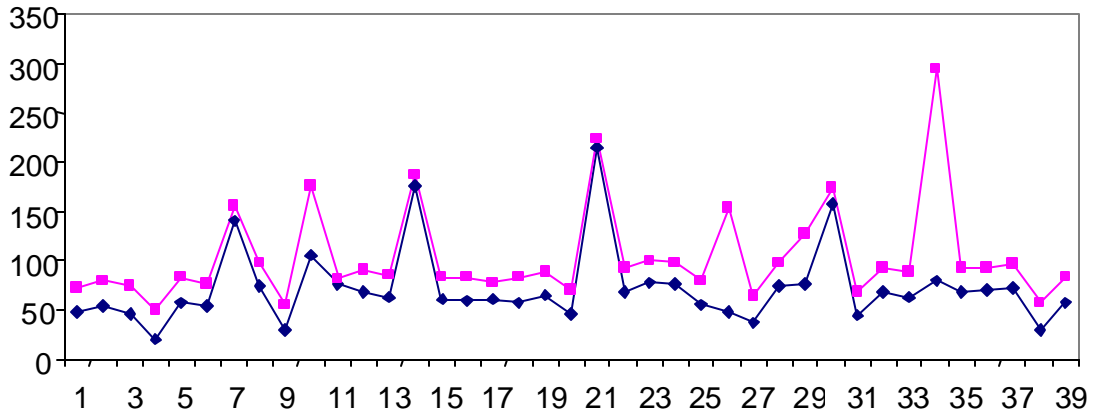
(Rapach and Wohar, 2006) examined structural stability of predictive regression models of US quarterly aggregate real stock returns over the postwar era. They tested for structural stability using Andrews SupF statistic and the Bai subsample procedure in conjunction with the Hansen heteroskedastic fixed-regressor bootstrap. They noted that the predictive ability of financial variables can vary remarkably over time.

(Kim and Kim, 1997) used a fad model with Markov-switching heteroskedasticity in both the fundamental and fad components (UC-MS model). They examined the possibility that the 1987 stock market crash was an example of a short-lived fad. The conditional variance implied by the UC-MS model captures most of the dynamics in the GARCH specification of stock return volatility. Unlike the GARCH measure of volatility, the UC-MS measure of volatility is consistent with volatility reverting to its normal level very quickly after the crash.

Nonparametric Test of Causality

Consider two simulated time series in Figure 2. One time series is derived from the other, thus, the population correlation exists (cointegrated). A time trend and some shocks were included in the time series. Globally, the two time series may exhibit parallel movement. However, if analysis will focus on specific subset periods (the usual case when relying on available realization of the time series), the series may not exhibit parallel movement, or when formally tested, the analysis may conclude that the two series are not cointegrated.

Figure 2: Simulated Time Series



In the presence of shocks or drifting among the time series, a structural change (whether in terms of additive or innovative shocks) may contaminate the test on whether they move along the same path or not (cointegrated). We propose a nonparametric bootstrap procedure in verifying whether there is causality between two time series. Consider the error correction model:

$$y_t = \alpha x_t + \beta dy_{t-1} + e_t \quad (1)$$

The error correction term (βdy_{t-1}) is equivalent to an infinite order linear filter that actually accounts for the effect of the entire history of the time series to the most recent value. This term is expected to have 'sufficient' forecasting capability for y_t . Thus, if θ may also appear to be significant, then it only proves the existence of causality, i.e., x_t causes y_t .

When there are random shocks or a volatile behavior in equation (1), estimation of the parameters (done in cointegration testing) may be seriously affected. The significance of the effect of the terms in the right-hand side of equation (1) can be masked. Our proposal is to take a sub-sample of the time series of length $b < T$ (total length of the time series) and fit model 1. The first b observations in the time series constitutes the first subset, deleting the first and adding the next observation will form the second subset, and so on. The Monte Carlo mean and variance of the bootstrapped estimates of θ provides the information needed in the nonparametric test for causality. The bootstrap confidence interval that contains 0 imply non-causality, while if the interval is entirely in the positive or negative range, provides evidence of causality between the two time series.

ENSO and Agricultural Production in Asia

The SOI that is measured monthly was aggregated into annual indicators. Several aggregation strategies were considered. However, the standard deviation for the year seemed to have captured the volatile weather behavior that can affect agricultural production more efficiently. Johansen test for cointegration between the standard deviation of SOI (SDSOI) and agricultural production indexed by per capita production and yield per hectare. Some countries were chosen from the different Asian regions namely:

Southeast Asia: Philippines, Thailand, Malaysia, Indonesia, and Vietnam

South Asia: India, Bangladesh, and Nepal

East Asia: South Korea and PR China

Pacific: Papua New Guinea and Fiji

Central Asia: Pakistan

The results indicated that each of the variables (per capita cereal production and yield per hectare) are cointegrated with SDSOI. It is noted that some show only one cointegrating vector while others indicate more than one.

When the two indices of agricultural production were modeled with SDSOI following AR and GARCH errors for the countries listed above, only per capita cereal production is significantly related with SDSOI for Philippines, Thailand, Papua New Guinea, Fiji and Pakistan.

Only Vietnam's yield of cereal production per hectare is significantly influenced by SDSOI. For Fiji, yield of cereal production per hectare seems to be influenced by SDSOI also, but is already captured by the GARCH representation, forcing a nonsignificant SDSOI.

While yield per hectare move along with SDSOI, this may be caused by the same volatility model (ARCH/GARCH) that govern both series. The erratic behavior in cereal yield may have been caused by some other factors, and not necessarily by weather. This may also be interpreted that some yield-enhancing policies in Asia may have dominated over weather volatility and/or there are measures that can potentially mitigate adverse effect of weather towards agriculture.

Severe volatility in cereal production usually occurred in 1999 in many Asian countries. The worst El Nino episode in recent history was noted to be the one that occurred in 1998, and immediately the year after, La Nina was observed, resulting to a highly erratic movement of per capita cereal production. There are also some evidence that the El Nino

episode in the early 70's could have contributed in the volatility of cereal production but whose magnitude is negligible compared to the impact of the 1998 El Nino jointly with the 1999 La Nina episodes.

Nonparametric Assessment of Comovement of ENSO and Agricultural Production

The proposed nonparametric test for causality is applied to Philippines, Vietnam and Indonesia. In the Johansen test, both the per capita cereal production and yield per hectare are cointegrated with SDSOI for these three countries. Per capita cereal production in the Philippines and yield per hectare in Vietnam are also significantly influenced by SDSOI.

The error correction model (ECM) in equation 1 was fitted for all observations from 1961 to 2004. The results are summarized in Table 1. Note that only the coefficient for Philippines (both indicators) is significant. The global behavior of the ECM is sufficient to explain agricultural production and that the shocks observed in SDSOI is not necessarily reflected in the behavior of cereal production.

Table 1. Coefficient of SDSOI in the ECM (1961 -2004)

Indicator	Coefficient	Standard Error
Per Capita Cereal Production, Philippines	-2.4108s	0.7989
Yield Per Hectare, Philippines	-129.5278s	42.7791
Per Capita Cereal Production, Vietnam	0.9659ns	0.9674
Yield Per Hectare, Vietnam	83.8174ns	75.2400
Per Capita Cereal Production, Indonesia	0.1211ns	0.7962
Yield Per Hectare, Indonesia	-98.47ns	54.25

The nonparametric test of causality is implemented by extracting a 10-year time series from the total time series from 1961 to 2004. The bootstrap estimates for the coefficient of SDSOI are summarized in Table 2. Note that all the bias-corrected confidence intervals does not contain zero, indicating that significance of the coefficient can be concluded. The test indicates that cereal production moves along the same path as SDSOI, that SDSOI causes effect on cereal production, and that the ECM can adequately explain the dynamics in which SDSOI affects cereal production. The nonparametric test and Johansen's test for cointegration are in agreement that cereal production and SDSOI move along the same path. However, unlike the ARCH/GARCH model who failed to account for the structural relationship, the ECM can confirm that indeed SDSOI had adverse effect on

Philippines' cereal production, but a mild positive effect on Vietnam's cereal production. Indonesia is adversely affected in terms of per capita production, but yield is affected positively.

Table 2. Bootstrapped Coefficient of SDSOI in the ECM (10-Year Subset)

Indicator	Coefficient	Bias	Bias-Corrected Interval
Per Capita Cereal Production, Philippines	-1.3407	-0.0117	-2.2020 -0.5059
Yield Per Hectare, Philippines	-99.1727	-0.7195	-130.5627 -65.5580
Per Capita Cereal Production, Vietnam	2.5958	-0.0127	1.4066 4.1277
Yield Per Hectare, Vietnam	246.5453	-1.8747	125.5080 399.0853
Per Capita Cereal Production, Indonesia	1.0896	0.0294	0.1803 2.5242
Yield Per Hectare, Indonesia	-125.1115	1.4121	-180.5600 -81.5413

Concluding Notes

The weather disturbances indicated by the standard deviation of SOI (SDSOI) move along the same path as per capita cereal production and yield per hectare in some Asian countries. However, in the ARCH/GARCH model, causality may only be ascertained for per capita production of selected countries. The erratic behavior in cereal yield may have been caused by some other factors, and not necessarily by weather. This may also be interpreted that some yield-enhancing policies in Asia may have dominated over weather volatility and/or there are measures that can potentially mitigate adverse effect of weather towards agriculture.

A nonparametric procedure can be used to simultaneously test co-movement between two time series and estimate the causal dynamics that exist, if any through the error correction model. Application of the method to three countries indicated that co-movement/causality can be tested and structural relationship simultaneously tested though a bootstrap procedure.

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