Analysis of El Niño-Southern Oscillation Phenomena's Effect on the Gross Domestic Product of Western Pacific Nations

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Abstract

El Niño Southern Oscillation (ENSO) is a climatological phenomenon of the tropical Pacific Ocean which has a direct influence on the climate of western Pacific nations. This study evaluated the meteorological effects of ENSO on the economies of Indonesia and the Philippines. It was hypothesized that decreased precipitation in the western Tropical Pacific region during El Niño events causes decreases in agricultural production in the region resulting in a negative effect on a nation's Gross Domestic Product (GDP). Furthermore, during La Niña events, when precipitation increases, an increase in the nation's agricultural GDP and overall GDP is expected.

Annual GDP data were obtained from the World Bank and the Bank of Indonesia for 1960-2012. Sea surface temperatures (SST) data, in the Niño 3.4 region, were obtained from the National Climate Data Center of the National Oceanic and Atmospheric Administration (NOAA).

Data of the agricultural and total GDP of Indonesia and the Philippines had inconclusive correlations with ENSO signal data. By examining data between smaller time segments of the overall 1960-2012 timeframe, more conclusive results could not be discerned.

Indonesia's quarterly non-oil GDP for 2000-2009 was independently correlated with ENSO providing better insight on the variables' relationship during discrete ENSO phenomena. The results provided strong correlation coefficients of 0.831 and 0.624 in support of the antithesis as well as -0.421 in support of the hypothesis. An economic anomaly known as the East Asian Financial Crisis may have been the cause of the unexpected correlations however more data is needed to be certain.

Overall, the results demonstrated weak to moderate correlations between studied variables. However, more data is needed to reach substantial conclusions.

Introduction

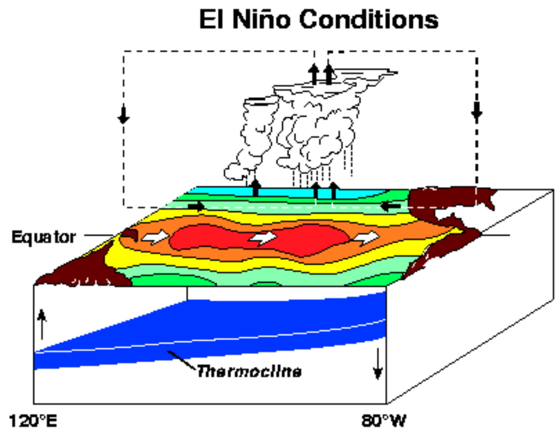


Figure 1. The illustration above demonstrates El Niño conditions; trade winds weaken and the water in the eastern Pacific Ocean warms to above average temperatures. This causes an increase in precipitation over the eastern Pacific and a decrease in precipitation in the western Pacific Ocean. Image reference: (*El Nino Conditions*, n.d.).

El Niño Southern Oscillation (ENSO) is the fluctuation of sea-surface temperatures, rainfall, air pressure, and atmospheric circulation that occurs in the equatorial Pacific Ocean (“El Niño Technical Terms”, n.d). El Niño events were first observed by fishermen off the western coast of South America. They observed that the Pacific Ocean would get warmer in December around the same time as Christmas and thus they called this phenomenon El Niño or “The Boy Child”. Scientists have confirmed the ENSO anomaly is occurring through use of satellites and weather monitoring stations that are set up throughout the Pacific Ocean (“What is the El Niño-Southern Oscillation (ENSO) in a nutshell?”, n.d). El Niño and La Niña constitute the hydro-meteorological phenomena of ENSO in which Pacific Ocean sea surface water temperatures vary from the global average (“NOAA ENSO FAQ”, n.d.). Specifically, El Niño episodes are defined as when the water temperature in the Niño 3.4 Region (5°N-5°S, 120°-170°W) varies by 0.5°C or more above the global average water temperature for five consecutive three month time intervals ("Historical El Nino/ La Nina," 2014). The same classification system is used in

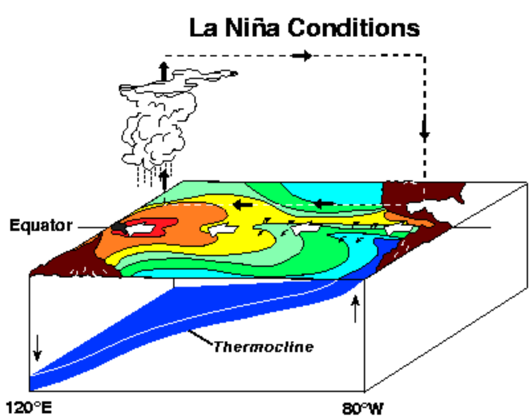


Figure 2. The illustration above demonstrates La Niña conditions; the trade winds grow stronger causing below average temperatures in the Eastern Pacific. Image reference: (*La Nina Conditions*, n.d.).

identifying La Niña episodes except temperatures must remain at least 0.5° C below the global average. Normal conditions in the equatorial Pacific Ocean are classified as ENSO neutral events ("NOAA ENSO FAQ", n.d.).

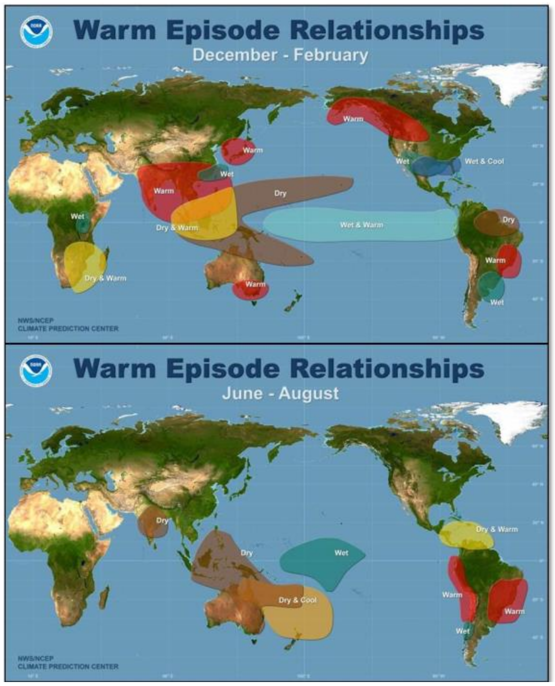


Figure 1. This map shows the relations between ENSO events and global temperature and precipitation patterns. Image references (top and bottom respectively): (*Warm Episode Relationships-DJF*, 2012) & (*Warm Episode Relationships-JJA*, 2012).

ENSO is cyclical and occurs every 2-7 years ("El Niño NASA", n.d.). Models of ocean temperatures, ocean levels, sea surface pressure, wind vectors, and salinity all contribute to better understanding and prediction of ENSO events. ENSO affects agriculture, fishing, local weather patterns, and people. Understanding ENSO is important because it is a climatic change that affects areas more than the Pacific Ocean's water temperature.

In the western Pacific, El Niño causes drought like conditions by decreasing the amount of precipitation and cloud cover. The decrease in precipitation is directly linked with agriculture production in western Pacific nations. For example, "In Indonesia, ENSO-related drought caused a cereal shortfall of millions of tons and a significant reduction in coffee and sugar production" (Gutman et al, 2000, pg. 1189). The same effect was observed in China (Zhang et al, 2008, pg. 1029). Conversely, La Niña causes an increase in the precipitation and cloud cover of nations within the region such as Indonesia (Aldrian et al, 2007, pg. 41). We postulated that decreased precipitation as a result of an El Niño event would significantly impact agricultural yields and therefore, decrease in a nation's GDP.

Methods and Materials

ENSO and SST anomalies data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Niño3.4 Index (Monthly Niño-3.4 Index, 2014). The Niño3.4 Index data are compiled with information from moorings located within the tropical Pacific Ocean as depicted in Figure 4.

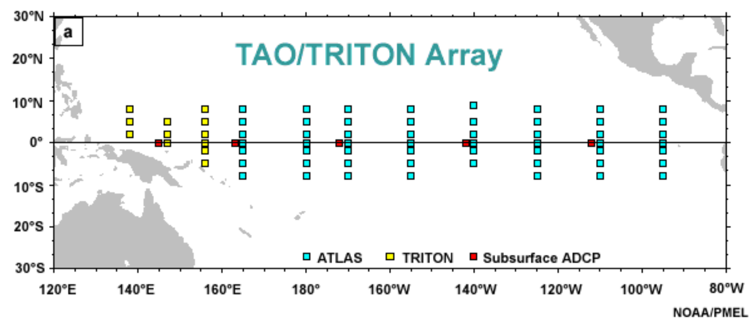


Figure 4. The TAO/TRITON Array is maintained by Japanese and United States scientists who collect information of the Pacific Ocean. The Niño3.4 Index refers to moorings located within the center of the array. Image reference: (*TAO/TRITON Array*, n.d.).

To visually depict the oscillation of ENSO events, data were compiled and graphed over the timeframe of 1968-2014 (including the whole dataset).

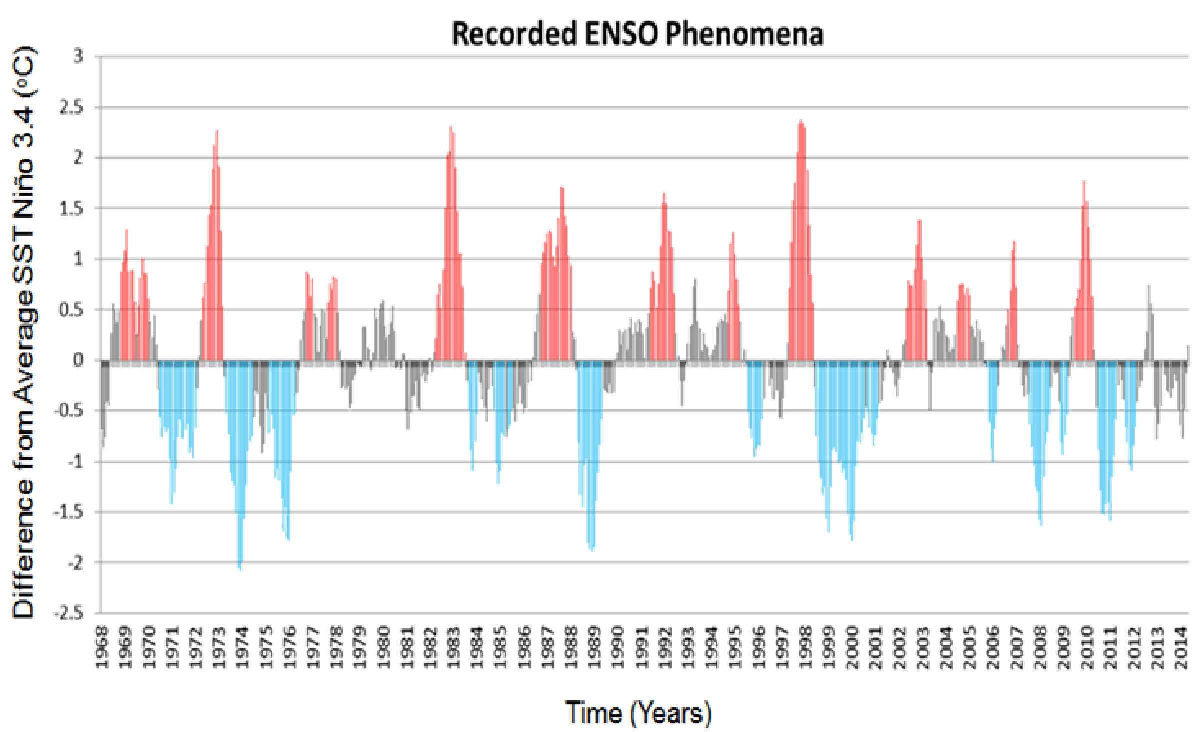


Figure 5. El Niño and La Niña events oscillate in a pattern where one occurs approximately every 2-7 years.

The data on GDP were obtained from the World Bank (GDP (current US$), n.d.) which provided annual values for the Philippines and Indonesia, as well as the Bank of Indonesia (Quarterly Domestic Product by Industrial, n.d.) which included quarterly values for Indonesia. Annual values included the agricultural GDP and total GDP while quarterly values conveyed the non-oil GDP. Because we graphed ENSO as the difference from average SST, the variable displayed positive and negative values. Correlations could not adequately compare ENSO's negative/positive fluctuations with GDP's constant positive values so a percent change formula (% Change $= \frac{V_2 - V_1}{V_1}$ x 100) was used to convey the annual GDP values' percent change each year. Quarterly GDP from the Bank of Indonesia remained positive after this process because it was not only constantly positive, but also constantly increasing. To overcome this issue, the quarterly GDP data was put through a separate algorithm that inserted a polynomial trendline through the data and then calculated the accepted value minus the expected value of each data point (Figure 6).

Figure 6. Determining and using the polynomial trend line equation of $Y(x) = 720.54(x^2) - 3324.8(x) + 339480$, where x is the amount of years after 1999 within the timeframe of 2000 to 2009.

Results and Discussions

Evaluating first agricultural GDP, the graphs of Figures 7 and 8 depict ENSO's influence in the nations of the Philippines and Indonesia.

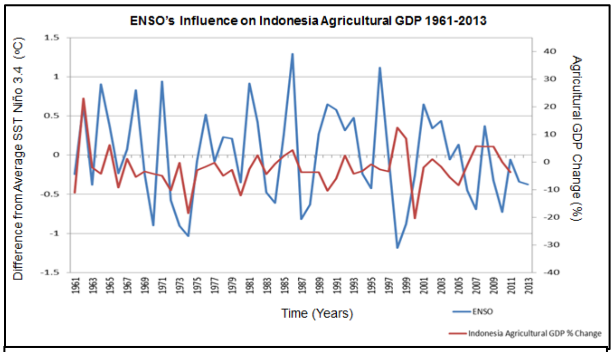


Figure 7. An overall correlation between ENSO and the Philippines' agricultural GDP of .009 conveyed no relationship between the variables.

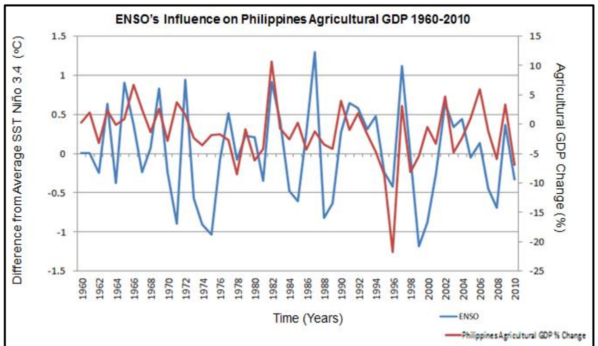


Figure 8. Overall correlations between ENSO and the Philippines' agriculture GDP demonstrated moderate support for the antithesis. Graphically, the periodicity of the graphs also conveyed that many of ENSO's peaks were reflective of the GDP's.

Believing that relationships present between the variables may not be readily apparent when including the entire timeframes in calculations, correlations were compiled for both graphs using only data from consecutive 10-year time frames.

Table 1. Correlation Coefficients of Annual Agricultural GDP of Selected Nations and ENSO

	All Available Data	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009
Philippines Agricultural GDP	.388	0.483	-0.290	-0.106	-0.098	-0.455
Indonesia Agricultural GDP	.009	-0.096	0.064	-0.008	0.004	-0.309

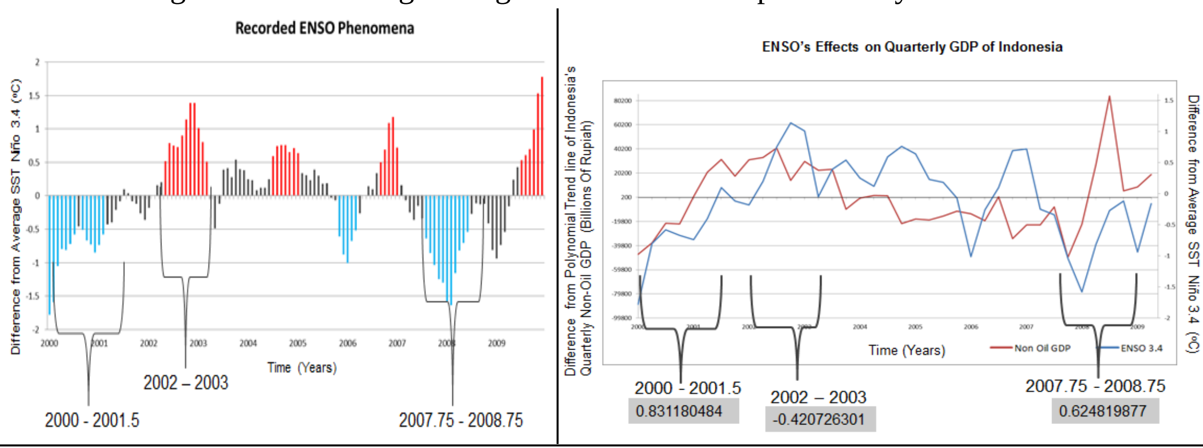
Philippines' correlations of the decades yielded significant values such as .483 and -.455 in support of both the antithesis and hypothesis implying that relationships could vary between years and therefore mitigate overall correlations. Ultimately, the data remained inconclusive. Within Indonesia's data, correlations remained much less significant. Indonesia also had years that varied from positive to negative correlations however the positive values of Indonesia did not consistently occur at the same as those of the Philippines.

Table 2. Correlation Coefficients of Annual Total GDP of Selected Nations and ENSO

	All Available Data	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009
Philippines Total GDP	-0.110	0.454	-0.669	-0.059	0.475	-0.340
Indonesia Total GDP	-0.302	N/A	-0.290	-0.106	-0.098	-0.455

Total GDP data correlations provided varied results. The Philippines had moderate correlations supporting both the hypothesis and the antithesis. Indonesia's results were weak however they were all concurring in support of the hypothesis.

The final test we conducted analyzed the relationships present within the timeframes of discrete ENSO phenomena. These timeframes were delineated by the graph of Figure 9 which was taken as a section from Figure 5's graph. Figure 9 was used to identify several major ENSO events within the 2000-2009 timeframe and Figure 10 was used to determine the GDP of Indonesia during these times using the higher resolution data provided by the Bank of Indonesia.



Figures 9 & 10. These graphs demonstrate the process of taking timeframes of ENSO events from the bar graph and correlating data from the line graph within those timeframes.

Results from the discrete ENSO event analysis yielded very strong correlations of .831 and .625 in support of the antithesis as well as -.421 in support of the antithesis. While they are not all negative or all positive, their magnitudes convey definite strong relationships between the variables during El Niño and La Niña events.

Conclusions

This study provided weak to moderate correlations present between ENSO and overall/agricultural GDP values. Moderate to strong correlations were determined within the timeframes of discrete ENSO events. Within both analyses, determined correlations were both positive and negative therefore supporting the hypothesis as well as refuting it. While these correlations are indicative of relationships between the variables, the findings remain overall inconclusive and more work must be done to amply determine what is causing such strong correlations in different directions.

An issue encountered within this study was varying times between data points. The cause of more significant correlations being determined by ENSO and data of the Bank of Indonesia rather than ENSO and data of the World Bank was likely the timespan between their data points. The World Bank's annual GDP data lacked the resolution to demonstrate correlations resulting from ENSO events that only last several months to a few years. More data points allowed for analysis of the timeframes of discrete ENSO events leading to clearer correlations and better understanding. When limiting timeframes to analyze, such as when agricultural GDP was analyzed by decade, non-existent correlations may have been observed. For this reason, all correlations we calculated contained a minimum of eight data points. More conclusive results may have been obtained by altering the amount of data to be considered per correlation. Data with better resolutions such as quarterly GDP instead of annual GDP provides better insight on the relationships of the variables within small timeframes without jeopardizing the validity of the data.

Future Work

More data is required within the timeframes of discrete ENSO phenomena. These timeframes displayed the strongest relationships within this study and provide a promising avenue to propagate future research. An additional interest of this research group is exploring ENSO's effect on the economies of eastern Pacific nations.

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