NOTES AND CORRESPONDENCE

El Niño–Southern Oscillation Impacts on Rice Production in Luzon, the Philippines

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ABSTRACT

This study uses regression analysis to evaluate the relationships among sea surface temperature anomalies (SSTA) averaged over the Niño-3.4 region (5°N–5°S, 120°–170°W), rainfall, and rice production, area harvested, and yield in Luzon, the large island on which most Philippine rice is grown. Previous research on Philippine rice production and El Niño–Southern Oscillation (ENSO) has found negative associations between El Niño events and rice yields in rainfed systems. This analysis goes further and shows that both irrigated and rainfed ecosystems are impacted. It also compares impacts on area harvested and yield. Variations in average July–September Niño-3.4 SSTAs explain approximately 29% of the interannual variations in the deviations of total January–June (dry season) rice production from a polynomial trend for 1970–2005. In contrast, no impact was found on July–December production in either year $t$ or $t + 1$. The impact of ENSO on dry-season rice production in Luzon appears to be primarily due to changes in area harvested rather than yield. Production declines for rainfed ecosystems are relatively larger than for irrigated ecosystems: a 1°C increase in average July–September Niño-3.4 SSTA is associated with a 3.7% decrease in irrigated dry-season production but with a 13.7% decline in rainfed dry-season production.

1. Introduction

El Niño–Southern Oscillation (ENSO) is widely recognized as a significant determinant of climate variations in the Pacific Rim region and farther afield (Mason and Goddard 2001; Ropelewski and Halpert 1996, 1987). In the Philippines, El Niño events [as defined in Trenberth (1997)] are often associated with decreased rainfall, whereas the converse is typically true during La Niñas (Harger 1995). Naylor et al. (2001) also found a negative relationship between the Niño-3.4 sea surface temperature anomaly (SSTA) index and rainfall in Java, the most populous island in Indonesia. Given the importance of climate for agriculture, it is perhaps not surprising that numerous studies have demonstrated a relationship between ENSO and agricultural production in different regions around the world (e.g., Amissah-Arthur et al. 2002; Gimeno et al. 2002; Hsieh et al. 1999; Podesta et al. 1999; Dilley 1997; Hansen et al. 1996; Handler 1984).

Rice is the staple food and most widely planted crop in much of Asia, including the Philippines (Dawe 2007). Rice uses more water than other cereal crops (Bouman et al. 2007), making it potentially more vulnerable to drought. Indeed, Selvaraju (2003) found that rice production in India was more impacted by ENSO than production of the other crops he analyzed (wheat, sorghum, and legumes). Because of rice’s importance in Asia and its potential susceptibility to drought, several studies have examined the impact of ENSO on rice production in this region (e.g., Falcon et al. 2004; Selvaraju 2003; Naylor...
et al. 2001, 2002; Zubair 2002). All of these studies found negative impacts of El Niño on rice production in the specific Asian countries investigated, with the impacts varying across seasons. Although Zubair (2002) found a negative impact of El Niño on rainfall, production, and yields in one of the two main growing seasons in Sri Lanka (the yala season), the impact was positive in the other growing season (the maha season).

The studies by Falcon et al. (2004) and Naylor et al. (2001, 2002) found that the impact of ENSO was much greater on rice area harvested than on rice yield in Indonesia, but the impact of ENSO on rice area harvested was not investigated by either Selvaraju (2003) for India or by Zubair (2002) for Sri Lanka. The latter study did investigate the impacts on production and yield, but the analysis did not allow for an understanding of possible impacts on area harvested. None of the studies cited above estimated the impacts on rice production in different production ecosystems (e.g., irrigated and rainfed).

Existing work on El Niño events in the Philippines has identified some evidence of negative associations between El Niño and rice yields in rainfed production systems (Lansigan 2005; Lansigan et al. 2000; Buan et al. 1996). Other work has found that agricultural communities in the Philippines suffered widespread crop losses during the 1997/98 El Niño (Dawe et al. 2009; Lopez and Mendoza 2004). None of this research has examined the impacts on rice area harvested or the possible differential impacts of ENSO on irrigated and rainfed production. Thus, one objective of this article is to further elucidate the impact of ENSO on rice production in the Philippines’ primary rice production region, the island of Luzon, by using regression analysis and analyzing the impacts on irrigated rice, which has accounted for more than 75% of production in both Luzon and the Philippines in recent years. The second objective is to contribute to the literature on the impacts of El Niño on rice in Asia by conducting a more disaggregated analysis than was done in earlier studies. In this regard, we estimate the impacts of ENSO on individual crop seasons (wet season and dry season), production ecosystems (irrigated and rainfed), and rice area harvested and yield.

Most rice production in Luzon (which includes six administrative regions: Ilocos, Cagayan Valley, Cordillera Administrative Region, Central Luzon, Southern Tagalog, and Bicol) occurs in places that are generally dominated by distinct wet and dry seasons (Akasaka et al. 2007). The wet season typically begins in May, peaks in July or August, and ends by December (see Fig. 1). The timing and quantity of wet-season rainfall are crucial determinants of rice-cropping patterns. As shown in Fig. 1, the main (wet) seasonal rice harvest lags the peak rainfall period by approximately 3 months (the growth period of the rice crop in the Philippines is 90–110 days). The dry-season crop is planted immediately after the harvest of the main crop to take advantage of the tail end of the rainy season (ratoon crops are not common in the Philippines). Rainfall can be both a blessing and a curse for the wet-season crop. Although sufficient water is needed, strong typhoons and flooding can destroy entire fields. On the other hand, water is a critical constraint for the dry-season crop. During dry years, farmers may substitute maize or other more-drought-tolerant crops for rice, or they may abandon a second crop altogether.

Nearly 60% of Philippine rice production comes from the island of Luzon, the country’s major rice production zone. The majority of Luzon’s production takes place during the wet season. However, the magnitude of the dry-season crop has more than tripled since 1970 with the use of shorter-duration varieties and additional irrigation (Dawe et al. 2006), and it now accounts for approximately 43% of annual rice production.

The proportion of rice harvested from irrigated ecosystems has increased markedly in recent years. In Luzon, irrigated rice area harvested has increased by more than 60% since 1970 and now accounts for 70% of rice area harvested during the wet season and 85% of area harvested during the dry season. About half of the irrigated acreage in Luzon is part of large irrigation systems that usually cover more than 1000 ha in areal extent, have associated water storage facilities such as dams, and are managed by the National Irrigation Administration. The other half of irrigated acreage consists of smaller communal systems that have more limited
storage capacity and are managed by groups of local private farmers. The limited storage capacity means that farmers in some irrigated systems are not well buffered against drought. Even in irrigation systems with large storage capacity, demand for water from the urban and industrial sectors during droughts can reduce the water available for agriculture (Dawe et al. 2009).

Despite the growing use of irrigation, rainfed rice production remains a vital source of income in the Philippines—in particular, for many poorer farmers (Hossain et al. 2000). Rainfed rice yields are lower than in irrigated systems because the rice plant is very susceptible to drought stress.

2. Data and methods

This study uses data on rainfall, SSTAs, and rice production (including area harvested and yield). For rainfall, we use monthly data from the Philippine Atmospheric, Geophysical and Astronomical Services Administration collected from five Luzon measurement sites (Cabanatuan, Dagupan, Laoag, Legazpi, and Tuguegarao). These sites were chosen because they are well spread across the main rice-growing zones in Luzon and have data with very few missing observations over a long period of time (1961–2005). A monthly rainfall variable was constructed as a simple average across the five sites. Quarterly rainfall averages for Luzon, which are used in later analysis, were constructed as the sum of the three monthly averages for the months in each particular quarter (e.g., October–December average rainfall is equal to the sum of average rainfall in October, November, and December).

Less than 1% of the rainfall data were missing. When data were missing for a particular month in a particular year at a particular site, we compared two approaches for filling in the missing data. The first was to use the long-term average for that month at that site, and the second was to calculate the Luzon average for that particular month in that particular year using data from only four instead of five sites. The two time series of rainfall data generated using these alternative procedures were correlated, with correlation coefficient \( r > 0.999 \), and we elected to use the former procedure in subsequent analysis.

Data on SSTAs are averages across the Niño-3.4 region (5°N–5°S, 120°–170°W) and were obtained from the U.S. National Oceanic and Atmospheric Administration (NOAA 2006). Average SSTAs for July–September were used in the analysis, because this period occurs sufficiently prior to the dry season to allow for possible adjustments by policymakers (e.g., changes in the quantity of imports) or irrigation system managers (changes in water allocation across farms). (Estimated impacts of SSTA values on wet-season production were statistically insignificant, as noted later.)

Data on rice production, area harvested, and yield, disaggregated by ecosystem (irrigated or rainfed) and time period (January–June or July–December), were obtained from the Philippine Rice Research Institute (PhilRice 2004) and the Philippines Bureau of Agricultural Statistics (R. Recide 2007, personal communication) for the period of 1970–2005. Data for production and yield are in terms of paddy rice (rice with the husk attached to the grain). As shown in Fig. 2, the July–December semester encompasses the main (wet) seasonal crop, whereas the January–June semester corresponds to the dry-season crop.

Substantial temporal trends resulting from technological advances and land-use change are evident in the
production, area harvested, and yield data. We used a third-order polynomial to detrend production, area harvested, and yield for all six combinations of ecosystem (all, irrigated, and rainfed) and semester (January–June and July–December). Thus, for example, we regressed irrigated production in the January–June period on time, time squared, and time cubed. Figure 3 shows the actual data and the trend for all ecosystems for production, area harvested, and yield in January–June. The deviations of actual production, area harvested, or yield from the trend values were then divided by the trend value of production, area harvested, or yield in each year to generate a percentage deviation from trend [(actual – trend)/trend]. These percentage deviations from trend are the dependent variables in our regressions.

We divide the difference between the actual value and the trend value by the trend value because area harvested and yield changed substantially from 1970 to 2005. It is likely that ENSO will impact a percentage of area harvested and yield when those variables change substantially over time, not an absolute number of hectares or a constant number of tons per hectare. Such a procedure is common in the literature that uses data spanning many years (e.g., Selvaraju 2003; Zubair 2002; Handler 1984).

3. Relationships between Luzon rainfall and ENSO

We separately regressed average Luzon rainfall for each of the four quarters on average July–September Niño-3.4 SSTA values. The coefficient on the SSTA variable was negative and statistically significant at significance level \( p < 0.01 \) for both average October–December rainfall in the same year (year \( t \)) and average January–March rainfall of the following year (year \( t + 1 \)), with \( r^2 \) values of 0.35 and 0.40, respectively. The coefficient on the average July–September Niño-3.4 SSTA value was also negative with average April–June rainfall of the following year (year \( t + 1 \)) as the dependent variable but was significant only at \( p < 0.10 \) (\( r^2 = 0.10 \)). The coefficient on the SSTA value was positive with July–September rainfall in the same year as the dependent variable but was not statistically significant (\( r^2 = 0.07 \)).

4. Relationships between Luzon rainfall and rice production, area harvested, and yield

Regressions of rice production and rice area harvested (as proportional deviations from a polynomial trend) in January–June of year \( t \) on average rainfall in the preceding October–December (year \( t - 1 \)) resulted in statistically significant positive coefficients at \( p < 0.05 \) for production and \( p < 0.01 \) for area harvested. One possibility consistent with these associations is that more rainfall encourages more planting, leading to an impact on area harvested (and production) about 3 months later. Irrigated and rainfed area harvested in January–June of year \( t \) (again as proportional deviations from a polynomial trend), when examined separately, each show a statistically significant positive correlation with October–December rainfall of year \( t - 1 \).

The relationships between rainfall and yield are weaker than for area harvested. A regression of yield (as proportional deviation from a polynomial trend) in January–June of year \( t \) on average rainfall in the preceding October–December (year \( t - 1 \)) gave a statistically significant positive coefficient (\( p < 0.01 \)) only in rainfed systems. The same coefficient in irrigated systems was negative and was not statistically significant.

5. Relationships between ENSO and rice production, area harvested, and yield

As shown above, strong correlations exist between average July–September Niño-3.4 SSTA values and October–December rainfall, and October–December rainfall is in turn correlated with rice production, area harvested, and yield in January–June (of the following year). These results illustrate a plausible chain of events that lead to an impact of ENSO on rice production, area harvested, and yield. For applied researchers and policymakers, the “direct” impact of ENSO on rice production, area harvested, and yield is likely to be of interest because the use of July–September Niño-3.4 SSTA as a predictor rather than October–December rainfall offers more lead time before the realization of January–June production, area harvested, and yield. Thus, in this section, we report the results of regression analysis with July–September Niño-3.4 SSTA values in year \( t \) as the independent variable and rice production, area harvested, and yield (as proportional deviations from a third-order polynomial trend) in January–June of year \( t + 1 \) as the dependent variables. (Results from a first-difference model give similar results. Results of \( f \) tests fail to reject symmetry between El Niño and La Niña events).

Positive Niño-3.4 SSTA values in July–September are associated with statistically significant declines in rice production and area harvested (for all ecosystems combined) in the following January–June semester (the top third of Table 1). For each degree increase in July–September SSTA, rice production in Luzon during the January–June semester declines by 5.1% of its trend value, whereas area harvested decreases by about 4.0% relative to its trend value. The coefficient estimate on yield is not statistically significant.
FIG. 3. Actual and third-order polynomial trend values for rice (a) production (million tons of paddy rice), (b) area harvested (thousand hectares), and (c) yield (tons of paddy rice per hectare) from 1970 to 2005 for Luzon.
Table 1. Value of July–September SSTA coefficients and $r^2$ for regressions of rice production, area harvested, and yield (as proportional deviations from a third-order polynomial trend) in January–June, year $t + 1$ (for all ecosystems, irrigated, and rainfed) on average July–September Niño-3.4 SSTA value in year $t$ (1970–2005; standard errors in parentheses).

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>SSTA coef</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>-0.051 (0.014)*</td>
<td>0.29</td>
</tr>
<tr>
<td>Area harvested</td>
<td>-0.040 (0.009)*</td>
<td>0.35</td>
</tr>
<tr>
<td>Yield</td>
<td>-0.014 (0.011)</td>
<td>0.04</td>
</tr>
<tr>
<td>Irrigated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>-0.037 (0.015)**</td>
<td>0.15</td>
</tr>
<tr>
<td>Area harvested</td>
<td>-0.030 (0.008)*</td>
<td>0.28</td>
</tr>
<tr>
<td>Yield</td>
<td>-0.010 (0.012)</td>
<td>0.02</td>
</tr>
<tr>
<td>Rainfed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>-0.137 (0.034)*</td>
<td>0.33</td>
</tr>
<tr>
<td>Area harvested</td>
<td>-0.090 (0.025)*</td>
<td>0.28</td>
</tr>
<tr>
<td>Yield</td>
<td>-0.060 (0.018)*</td>
<td>0.24</td>
</tr>
</tbody>
</table>

* Statistically significant at 1% level.
** Statistically significant at 5% level.

The second and third parts of Table 1 display the regression coefficients for the July–September SSTA variable when production, area harvested, and yield are disaggregated into irrigated and rainfed ecosystems. Rainfed ecosystems are more vulnerable to El Niño, as shown by the larger percentage declines in production, area harvested, and yield from a 1°C increase in average July–September Niño-3.4 SSTA as compared with the comparable coefficients in irrigated ecosystems. In both ecosystems, area harvested is affected more than yield is, as shown by the fact that the coefficients on area harvested (3.0% in irrigated and 9.0% in rainfed) are larger than the coefficients on yield (1.0% in irrigated and 6.0% in rainfed).

We also regressed July–December rice production, area harvested, and yield on average July–September Niño-3.4 SSTA values. None of the coefficients on SSTA were statistically significant, for the crop either before or after the ENSO-impacted January–June season. Further, July–December rice production in year $t$ was regressed on Niño-3.4 SSTA values for each month from September of year $t - 1$ to December of year $t$. None of the SSTA coefficients were statistically significant in any of these regressions. We do not report those results for reasons of space.

6. Discussion

Previous research on Philippine rice production and ENSO focused on rice yields and found negative associations between El Niño events and rice yields in rainfed systems (Lansigan et al. 2000). Our analysis goes further and shows that both irrigated and rainfed systems are affected by El Niño, although they are affected differently. In irrigated systems, the decline in production is largely due to decreases in area harvested. Faced with low rainfall during the end of the rainy season, it appears that farmers in irrigated ecosystems abandon or substitute away from a January–June rice crop. Those farmers who do plant are protected from substantial yield decreases by the availability of stored irrigation water. Farms in rainfed systems are less buffered against drought stress, which may explain why they suffer from larger declines in yields than do farms in irrigated ecosystems. In addition to the yield impacts, farmers in rainfed systems also take land out of rice production in response to El Niño events. In fact, the impact in rainfed systems of a 1°C change in July–September SSTA on area harvested of 9.0% is greater than the impact on yields of 6.0%.

The result that the impacts on area harvested are larger than the impacts on yield is consistent with the results in Indonesia reported by Falcon et al. (2004) and Naylor et al. (2001, 2002). Other studies on Asian rice for India (Selvaraju 2003) and Sri Lanka (Zubair 2002) did not consider impacts on area harvested, and they may be missing an important mechanism by which ENSO has an impact on rice production.

The disaggregation into rainfed and irrigated systems is important if policymakers and planners are to respond appropriately. For example, if only rainfed systems are impacted by ENSO, there would be little need to involve irrigation system managers in planning a response. As another example, there may be a case for designing insurance mechanisms that are preferentially targeted to farmers in rainfed ecosystems, given that these farmers are much poorer than rice farmers in irrigated ecosystems (e.g., IRRI 2006) and are also more vulnerable to drought. In other words, it is important for planning purposes to know how ENSO affects rice production (e.g., through area harvested, yield, or both) and which groups of farmers are most affected.

In the Philippines, ENSO has larger impacts on dry-season production than on wet-season production. This contrasts with both Indonesia (Falcon et al. 2004; Naylor et al. 2002, 2001) and India (Selvaraju 2003), where the largest impact is on main (wet) seasonal production. If an El Niño event leads to a production shortfall in the dry season, the government will need to carefully manage rice imports from the world market. This is because stock levels are on average 16% lower in April at the end of the dry season than they are in December at the end of the main (wet) season [based on analysis of data for 1990–2002 from the National Food Authority (various staff 2005, personal communication)]. A large shock to already low stock levels will make the rice economy more vulnerable to
price increases that adversely affect the poor, who spend a larger portion of their income on rice than do wealthier members of society (Dawe et al. 2006). Indeed, a recent study by Dawe et al. (2009) shows that there have been several large increases in Philippine rice prices in the aftermath of El Niño events, although this outcome was avoided in the most recent severe El Niño of 1997/98 through appropriate management of imports and stocks.

In conclusion, it is important whenever possible to disaggregate ENSO impacts by season, by ecosystem, and according to area harvested and yield. Such disaggregation will enable the possibility of more effective responses to mitigate and adapt to the impact of ENSO.

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