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THE ECONOMIC CONSEQUENCES OF ENSO EVENTS: THE 1997-98 EL NIÑO AND THE 1998-99 LA NIÑA

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Abstract

Climate is the primary determinant of agricultural productivity. In many parts of the world, including the United States, one can trace much of the year-to-year variations in climate to the El Ni o-Southern Oscillation phenomenon. In 1997-98 the world experienced a severe El event and this is being floowed by a strong 1998-99 La Ni a. The work underlying this develops estimates of the economic consequences of these events on U.S. agriculture. Both phases result in economic damages -- a $1.5 to $1.7 billon loss for the El Niño and a $2.2 to $6.5 billion for La Ni a.. . The major conclusion is that ENSO events do impose costs on agriculture and consumers.

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Climate is the primary determinant of agricultural productivity. An important aspect of climate in terms of human well being involves the effects on agriculture of seasonal and interannual variation in temperature and precipitation. The effects of drought and flooding provide the clearest evidence of the vulnerability of agriculture and food supplies to seasonal variations in temperature and precipitation. However, less dramatic climate variations also are reflected in agricultural production, prices, and profits. In many parts of the world, including the United States, one can trace much of the year-to-year variations in climate to the El Ni o-Southern Oscillation phenomenon.

The El Ni o-Southern Oscillation (ENSO) label refers to a quasi-periodic redistribution of heat and momentum in the tropical Pacific Ocean. In broad terms, one can characterize ENSO as a varying shift between a normal phase and two extreme phases: El Ni o and La Ni a (sometimes called El Viejo). In recent years, the ability to forecast ENSO events, in particular, the occurrence of El Ni o events, has improved (Barnett et al., 1988; Cane et al., 1986, Bengtsson et al., 1993). These forecasts have potential economic value because they can stimulate actions that mitigate against adverse consequences or take advantage of potential gains from an ENSO phase.

The 1997-98 El Niño is regarded as one of the most severe in the past decade and perhaps equal to the strong El Niño of 1982-83. The physical effects of this El Niño were felt through much of the Southwestern and Eastern United States, with heavy rains and flooding throughout the winter and spring in California and Arizona and a mild, but wet winter and spring in the northeast. Preliminary evidence from weekly crop prices suggests that disruptions of certain high valued spring crops in California imposed substantial costs. For example, reductions in California strawberry marketings in the spring of 1998 resulted in losses to consumers of over $15 million compared to 1997 prices and nearly $100 million compared to the average price for the previous ten years, based on estimates of seasonal demand relationships for strawberries.

There is evidence that the waning 1997-98 El Niño is moving rapidly into a La Ni a (El Viejo) phase, with a dramatic cooling of ocean surface temperatures in the southern Pacific Ocean. Like El Niño events, La Ni a's also have specific regional "footprints" but with a reversal of the weather patterns observed during El Niño's (e.g., colder but drier winters in the western U.S.). These La Ni a events also have effects on agriculture and other sectors.

The damages associated with the recent El Niño demonstrate that ENSO events have economic consequences; recent studies show that the use of forecasts of these events has economic value (Adams et al., 1995; Costello et al., 1998; Solow et al., 1998). The agricultural values for such forecasts have been estimated to be in excess of $300 million per year (1992 dollars). However, the actual damages from a given ENSO event can be even greater. Estimates of damages from actual ENSO events can be useful to policy makers in determining first whether such events are important relative to other natural processes and second, whether the potential damages from a future event, such as the developing La Ni a, merit vulnerability reducing actions.

OBJECTIVES

The work underlying this report was designed to develop estimates of the economic consequences of the recent (1997-98) El Ni o event and to assess possible effects of the forecast 1998-1999 major La Ni a event on U.S. agriculture. Both estimates are prospective, in that the final effects of the 1997-98 El Ni o on agriculture will not be understood until final data of the 1998 harvests and yields becomes available. Similarly, the full effects of a prospective La Ni a on agriculture will not be realized for at least twelve months. However, the historical climatological record, which includes years reflecting all three ENSO phases, does provide some indications as to how weather and associated crop yield data has varied during such ENSO phases.

Historical weather and yield occurrences, measured as departures from normal (long term average) yields, are used here as a measure of the effects of the most recent El Ni o and the pending La Ni a events. In addition, modeled yield changes for such ENSO events, taken from a recent study (Solow et al., 1998) are also used. The Solow et al study involved modeled (simulated) changes and may well provide a clearer picture than historical yield deviations of the effects of weather, given that the historical data may contain effects from other factors, such as crop diseases, changes in farm programs or other non-weather phenomenon.

The yield changes for El Ni o, Normal and La Ni a events arising from both the historical record and model simulations are used as input into an economic model of the U.S. agricultural sector. This model is used to estimate the effects of the ENSO events on prices, crop supplies and the welfare of consumers and producers. Procedures underlying this simulation of ENSO events, including data and the economic model, are discussed in more detail in the next section. The following section presents results of these simulated ENSO events. Implications and conclusions of these estimates are presented in the final sections of this report.

DATA AND MODELS

This assessment of the damages from ENSO events involves a two stage process. In the first stage, the consequences of the changes in weather patterns due to ENSO phases on crop yields are measured using estimates from both crop biophysical simulation models and historical yield data. The second stage incorporates these yield differences into an economic model in order to assess the aggregate economic damages of ENSO events.

Crop Yield Changes

The first set of yield estimates are taken from Solow et al. and are based on output from a crop simulation model. Specifically, estimates of the yield implications of weather changes from each ENSO phase for eight field crops (corn, wheat, soybeans, cotton, barley, sorghum, oats and hay) were developed using a mathematical model called Erosion Productivity Impact Calculator (EPIC -- Williams et al., 1984; Williams et al., 1989). EPIC has been used in numerous studies for a variety of purposes and has gained popularity across disciplines in agriculture. EPIC has been shown to provide reasonable simulations of crop yields in previous ENSO studies (Bryant et al., 1992). Details of the EPIC application to ENSO events can be found in Adams et al. and Solow et al. Specific yield data are reported in Solow et al. and Legler, Bryant and O'Brien.

The second approach to estimating yield consequences of ENSO phases is based on twenty-five years (1972-1996) of crop yield data for all crops included in the economic model (the eight listed above plus citrus and some minor crops). The yield data are taken from USDA publications, including *Agricultural Statistics* (various years). These yield data are first detrended (to remove effects of technological change and acreage shifts on yields) and then yield estimates are projected for each year. In turn, the deviations between the projected and actual yields are recorded as a percentage change from the projected. Finally these deviations were applied to the 1997 yield projection to obtain a joint probability distribution across 63 US regions based on the 25 historic weather events. This distribution reflects, among other factors or influences, the variation due to the weather including the ENSO phase.

Economic Modeling Procedures

The yield distributions, from both the EPIC estimates and historical data, are used in defining the economic model used in this assessment framework. Specifically, the changes in yields are used in an economic model of the U.S. agricultural sector, identified as the Agricultural Sector Model or ASM (see Chang and McCarl, 1992, for details) within a stochastic framework (Lambert et al). This economic model provides the mechanism for translating the physical (yield) effects of ENSO changes into economic effects, including net changes in economic welfare, as well as changes in supply and prices for major agricultural commodities. Variants of this model are used in Adams et al., Solow et al., and a number of other assessments of the consequences of environmental change.

The economic model is a price endogenous model formulated as a mathematical programming problem (McCarl and Spreen). The model represents production and consumption of 30 primary agricultural products including both crop and livestock products. Processing of agricultural products into 12 secondary commodities also is included. Prices for these commodities are determined endogenously for both national and international (export) markets. The model maximizes the sum of the area under the demand curves but above the price (consumer surplus) plus the area above the supply curves but below the price (producer surplus) for these commodities. One can interpret changes in this area as a measure of the economic welfare equivalent of the annual net income lost or gained by agricultural producers and consumers as a consequence of crop yield or other changes, expressed in 1997 dollars. Both domestic and foreign consumption (exports) are included.

The model takes regional level responses and aggregates these to national level responses. Specifically, producer-level behavior is captured in a series of technical coefficients that portray the physical and economic environment of agricultural producers in each of the 63 homogeneous production regions in the model, encompassing the 48 contiguous states. The analysis also considers irrigated and non-irrigated crop production and water supply relationships. Availability of land, labor, and irrigation water is determined by supply curves for each input. Farm-level supply responses generated from the 63 individual regions are linked to national demand through the objective function of the sector model, which features demand relationships for various market outlets for the included commodities.

Certain assumptions and procedures are required to use ASM to estimate economic damages from forecasts of ENSO events: (i) The base economic model is keyed to 1990 economic, agriculture, and environmental conditions. (ii) The EPIC yield forecasts and selected historical yield deviations are assumed to reflect accurately the consequences of the 1997-98 El Niño and the 1998-99 La Ni a. As noted above, the yield changes measured by historical records reflect all sources of yield variation, not just the ENSO-specific influences. The EPIC forecasts, to the extent that they are tailored to specific weather conditions associated with ENSO phases, are expected to more accurately reflect such events. Taken together, however, both sets of yield changes are believed to provide valid evidence of the consequences of these ENSO events on the agricultural economy of the U.S.

RESULTS

The two phase assessment procedure defined above constitutes a set of “experiments” to measure the potential consequences on U.S. agriculture of as yet unrealized events (the final effects of a major El Niño in 1997-98 and a possible La Ni a in 1998-99). These experiments provide an indication of how two strong ENSO events may affect the aggregate (national level) welfare of the agricultural sector.

The results from these experiments reflect a range of weather and yield conditions. For example, the yield and subsequent economic consequences elicited here reflect historical frequencies of each phase. To capture these, the economic model is run (solved) under a series of uncertain events (3 in the EPIC analysis and 25 in the “historical” yield case) based on the long run probability of these events occurring. These sets of model runs are used to determine average or “normal” conditions from which the El Niño and La Ni a economic effects will then be inferred. In the EPIC-based analysis, the El Niño and La Ni a results do not correspond to a particular year; rather, they represent the weather and resultant yield changes for years identified by each phase. In the “historical yields” case, two time periods from the twenty-five year record are used to portray possible effects; 1982-83 for the El Niño and 1988-89 for La Ni a. The economic consequences under this latter approach are measured as departures from the “normal” phase (neither El Niño nor La Ni a).

The results of these experiments are provided in Tables 1 and 2. In Table 1, results from the EPIC-based simulations of each ENSO phase or event are reported. As is evident from the table, both phases result in economic damages relative to the Normal phase or case (of -$1.5 for El Niño and -$6.5 billion for La Ni a, respectively). For the historical case, both ENSO phases again show losses (economic damages) although of a smaller magnitude. Here, the economic damages of El Niño and La Ni a are $1.7 and $2.2 billion, respectively. While the results of the EPIC-based analysis are greater, it is notable that these events translate into economic damages for agriculture under both sets of assumptions regarding yield changes. It is also worth noting that the optimization nature of the economic model used here results in estimates that reflect some internal actions (such as changes in crop mixes) to offset or mitigate against the negative consequences of the changes in yields. Thus, the estimates are lower bounds on damages.

The overall implication of these findings regarding ENSO phases is not surprising; extreme events, whether they be El Niño or La Ni a's, have adverse consequences for agriculture (at the national level). To the extent that some of these agriculture effects can be mitigated or offset by planning, there is value in forecasting such ENSO phenomenon. Previous studies have confirmed the value of such forecasts.

Table 1. Estimates of the 1997-98 the El Niño and a Strong La Ni a, Using Simulated Yield Changes.

ENSO Event	Economic Consequences[2] (millions of 1990 dollars)
1997-98 El Niño[1]	-2,543
La Ni a[1] (strong event)	-6,455

[1] The weather patterns used as inputs to the EPIC model reflect or simulate a “strong” ENSO event.

[2] Economic consequences (damages) reported here are measured against an average or “base case” derived by using historical frequencies of all three ENSO phases.

Table 2. Estimates of the 1997-98 the El Niño and a Strong La Ni a, Using Historical Yield Changes.

ENSO Event	Economic Consequences[2] (millions of 1990 dollars)
1997-98 El Niño[1]	-1,739
La Ni a[1]	-2,247

[1] The historical analogue used to represent the 1997-98 El Niño is the 1982-83 El Niño.

[2] The historical analogue used to represent the 1997-98 La Ni a is the 1988-89 La Ni a.

CONCLUSIONS

ENSO events have varying effects on temperature and precipitation across agricultural regions of the U.S. For some regions, these changes in seasonal weather may be beneficial. However, for other regions the effects can be dramatic and severe, such as the floods in the southwest during the spring of 1998. These sets of effects translate into economic effects if crop yields are reduced (or increased) from expected or “normal” levels..

The results of the experiments performed here indicate that overall, the effects of both extreme ENSO phases are negative for U.S. agriculture. Measured as departure from normal (non El Niño or La Ni a) yields, the consequences vary from approximately $1.5 billion to $6.5 billion in losses. The range reflects assumptions concerning how yields are estimated and whether it is an El Niño or La Ni a event. The estimates reported here must be viewed in the context in which they are generated. As estimates from a modeling exercise, the numbers reflect a series of embedded assumptions and are conditional on the quality of data used in the economic modeling and in the generation of the yields used to capture the various ENSO phases. The major conclusion is that extreme weather events, such as the ENSO events, do impose costs on agriculture and consumers. The magnitude of these cost estimates support concerns over the likely increase in extreme weather phenomenon under a warming global atmosphere.

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