El Niño Southern Oscillation Impacts on Crop Insurance

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Motivation: ENSO

- The U.S. drought of 2012 has served as a global reminder that extreme weather events do occur.
- Extreme weather events are “teleconnected” with El Niño Southern Oscillation.
- If the frequency and intensity of ENSO anomalies increase parallel to climatic change extreme weather events are more likely in the future.

Motivation: Crop Insurance

- The underlying assumptions of the actuarially fair area-based crop insurance programs are that: (i) yield distributions are “properly” determined; and (ii) agents have no superior information about the determinants of this distribution.
- However, when the assumptions are violated the rates may no longer be actuarially fair and possibilities of mis-priced premium rates emerge.

Main Findings

1. Extreme ENSO events alter cotton yield distributions in the Southeastern U.S., and these impacts translate into economically meaningful effects on crop insurance premium rates.
2. Commercial insurers can use publicly available information to determine if government-set premium rates are mis-priced, and in turn extract economic rents via the federally mandated Standard Reinsurance Agreement.

The ENSO Impact on Indemnities

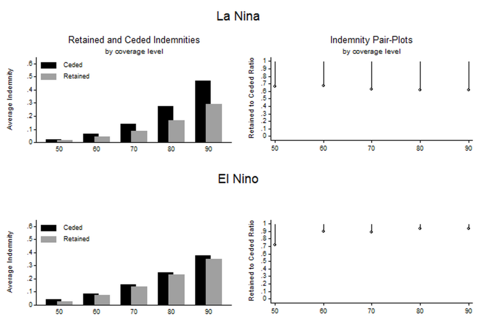

Figure : Indemnities for ceders: Western Cotton Belt

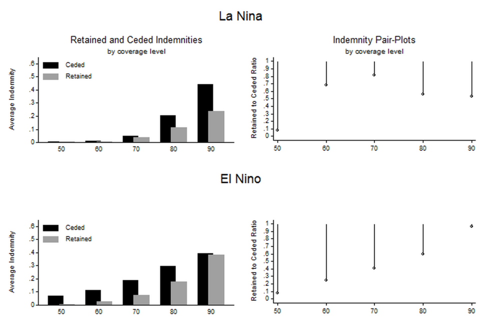

Figure : Indemnities for ceders: Eastern Cotton Belt

Notes: The first column reports acreage-weighted indemnities across counties for the repeated game of insurance selection. The second column presents pair-plots of these indemnities for ceded and retained policies. Each pair-plot is a simple ratio of the rate for retained polices over the rate for ceded policies.

Conclusions

This research contributes to the burgeoning scientific literature linking climatic phenomena to insurance program-design and decision-making. The main conclusions are:

- there are more than just mean ENSO effects on crop yields, which in and of itself suggests premium rate deviations across ENSO events.
- opportunities to cede mis-priced policies back to the U.S. government do exist for area-triggered cotton insurance products.
- future work might consider whether these results extend to other crops and/or farm-based products.

Empirical Framework

The regression based model for the $j = 1, 2, 3$ raw moments of the cotton yield distribution is:

$$y^j_{it} = \alpha_{ij} + \beta_{j1} lo_{ijt} + \beta_{j2} md_{ijt} + \beta_{j3} hi_{ijt} + \beta_{j4} pc_{it} + \beta_{j5} pc^2_{it} + \beta_{j6} nino_t + \beta_{j7} nina_t + \beta_{j8} trd_{it} + \varepsilon_{ijt} \quad (1)$$

For an arbitrary county i and regime r, the maximum entropy distribution is defined by:

$$f^*_{ir} = \arg\max_f - \int f(y) \ln f(y)\, dy \quad (2)$$

subject to the moment constraints

$$\int f(y)\, dy = 1 \quad \text{and} \quad \int \ln(y)^j f(y)\, dy = \mu^r_{ij}, \quad j = 1, \ldots, 3 \quad (3)$$

The associated Lagrangian for this maximization problem is:

$$\mathcal{L} = - \int f(y) \ln f(y)\, dy - \gamma_0 \left[\int f(y)\, dy - 1 \right] - \sum_{j=1}^{3} \gamma_j \left[\int y^j f(y)\, dy - \mu^r_{ij} \right] \quad (4)$$

and the implied solution is the maximum entropy density:

$$f^*_{ir}(y) = \frac{1}{\psi(\gamma^*_{ir})} \exp\left[-\sum_{j=1}^{3} \gamma^*_{ijr} y^j \right] \quad (5)$$

$$\text{where} \quad \psi(\gamma^*_{ir}) = \int \exp\left[-\sum_{j=1}^{3} \gamma^*_{ijr} y^j \right] dy.$$

The impact of El Niño (La Niña) on mean yields is measured as the percentage change in the mean of the El Niño (La Niña) regime relative to the mean of the La Nada regime. We use the estimated coefficients from the first moment equation and calculate mean impacts for each county i according to:

$$I^r_i = 100 \times \frac{(\hat{\alpha}_{i1} + \hat{\beta}_{1s}\bar{\mathbf{x}}^r_i) - (\hat{\alpha}_{i1} + \hat{\beta}_{1s}\bar{\mathbf{x}}^{nada}_i)}{\hat{\alpha}_{i1} + \hat{\beta}_{1s}\bar{\mathbf{x}}^{nada}_i} \quad (6)$$

where the $\bar{\mathbf{x}}^r_i$ are county-specific predictors under each regime, and where $r \in \{nino, nina\}$. The performance of the insurance company’s decision rule is evaluated using the realized yield observations y_{it}, such that:

$$indem_{itc} = \max\left\{ \frac{\tilde{y}_{it} - y_{it}}{c}, 0 \right\}, \ t = 1, \ldots, 38, \ c \in \{50, 60, 70, 80, 90\} \quad (7)$$

where the yield guarantee $\tilde{y}_{it} \equiv \hat{y}_{it} \times c$ is constructed using the fitted value $\hat{y}_{it}$ from the trend regression.

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