Actuarial Implication of Structural Changes in El Niño-Southern Oscillation Index Dynamics

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Catastrophic rain and floods are most important catastrophic risks endured in Piura, Peru’s richest agricultural region associated with region El Niños caused by high sea-surface temperature anomalies. During positive Niño, rain increase in intensity, duration, and spatial extent (crop yield) can mean losses more than 40 times large than average. Expected to increase catastrophic weather risks that impact agriculture, public health, and insurance. El Niño-Southern Oscillation index is the most highly correlated with economic losses of Peru, is the most highly correlated with catastrophic risks endured in Piura, Peru’s richest agricultural region, Piura. High pressure system develops over west Pacific, relaxes trade winds, reduces upwelling of cold water and raises water temperatures in east Pacific, causes above normal rainfall in coastal Peru 

El Niño to Blame?

Design an El Niño-Southern Oscillation Index Insurance for Floods

Step 1: Choosing an Index

- Choose an index which is highly correlated with economic losses due to catastrophic floods evaluated via Quantile
- Among four Niño index regions, Niño 1+2 index, just off coast of Peru, is the most highly correlated with CORPAC Piura precipitation

Monthly El Niño 1+2 Index with 5 breaks, 1856-01-2010

Step 2: Modelling El Niño Index

- Is El Niño Changing?
- Testing for structural changes using Bai and Perron approach estimates number and date of shifts in the data generating process within a linear model allows for serial correlation and heteroskedasticity in the errors across time periods
- Bai and Perron approach indicate breaks at 1957-01, 1965-12, 1976-01, 2004-04, consistent with climatic literature if heteroskedasticity in the errors process within a linear model

Multiple structural break tests and estimated break dates

Step 3: Modelling El Niño Index

- Statistical Models
- Conditional variance of El Niño 1+2 index has increased over time
- In-sample fit via AIC & SIC: 1856:01-1952:04
- Out-of-sample forecast via Mean Square Error: 2010:01-2010:12
- AR(2) - GARCH(1,1) model and least square estimation method is applied to compute fair premium rates
- Expected indemnity = 

\[
\text{Expected indemnity} = \text{Expected loss} \times \text{coverage}
\]

Given QMLE parameters from the model, Monte Carlo simulation method is applied to generate the data and thus compute fair premium rates

<table>
<thead>
<tr>
<th>AR(2)</th>
<th>AR(2) - GARCH(1,1)</th>
<th>AR(2) - FIGARCH(1, 1)</th>
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<tr>
<td>1.23</td>
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Step 4: Rating El Niño Index Insurance

- The design of the contract is based on proportional indemnity schedule
- The expected indemnity that would be paid per unit of coverage is expected indemnity

Summary and Conclusion

Support the actuarial analysis of a proposed El Niño-Southern Oscillation Index insurance for Peru

<table>
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<tr>
<th>Months</th>
<th>1</th>
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<td>1</td>
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</tbody>
</table>

El Niño events becoming more volatile since the mid 1970s

The results of multiple structural change tests proposed by Bai and Perron (1998, 2003) imply standard deviation of El Niño 1+2 index is changing over time

Three statistical time-series model of El Niño 1+2 index are examined and compared through in-sample fits and out-of-sample forecasts

- For in-sample fits, AR-GARCH and AR-FGARCH models that allow disturbance variance to vary over time outperform linear AR model
- At short forecast horizons, out-of-sample forecasts from the linear AR(2) model are superior than AR(2)-GARCH(1, 1) and AR(2)-FIGARCH(1, d, 1) model
- As the forecast horizon increases, AR(2)-GARCH(1, 1) model and AR(2)+FIGARCH(1, d, 1) model outperform the linear AR(2)

The premium rate estimates based on such time-varying asymmetric model could be too low and the insurer would therefore expose to underwritten underwriting risk and ultimately the index insurance market would collapse