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Spectral and Statistical Modeling in Crop Insurance: Evidence from Brazil

by

Vitor A. Ozaki

Professor, Department of Economics, Business and Sociology, University of Sao Paulo av. Padua Dias, 11, Agronomia, Piracicaba, Sao Paulo, Brazil, 13418-900. Contact: +55 19 3429-4444/FAX: +55 19 3434-5186. Email: vitorozaki@gmail.com

and

Rogério C. Campos

Professor, Department of Rural Engineering, Federal University of Pelotas.

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SPECTRAL AND STATISTICAL ANALYSIS IN CROP INSURANCE: EVIDENCE FROM BRAZIL

Vitor A. Ozaki[1] and Rogério C. Campos[2]
[1] University of São Paulo; [2] Federal University of Pelotas
Risk and Insurance Research Group – GESER /BRAZIL

INTRODUCTION

As any insurance, crop insurance contract includes two key parameters: the premium rate and the indemnity. The methodology for calculating the premium rate is fundamental to avoid information asymmetry problems, while methods for monitoring the insured crop area can be useful to measure and control losses. Usually, uncertainties about the cash flow of companies in a contingent market are high. According to this study, these uncertainties can be reduced through alternative pricing methods based on Bayesian hierarchical models and crop monitoring through spectral analysis of remote sensing images. The methodology proposed in this study allows for a better understanding of the temporal and spatial dynamic of the cash flow of economic agents in the crop insurance market in Brazil at municipality level. The results show that fair premium rates can be precisely estimated using the pricing methodology proposed here and that geotechnology brings significant improvements in quantifying crop losses.

METHOD FOR QUANTIFYING CROP LOSSES

In this study, images from the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor were used to quantify the biomass of the crop accumulated throughout the soybean cycle. First, the municipalities covered by the study were mapped out based on a spectral-temporal differentiation of targets in a temporal series of MODIS images in the 2007-2008 harvest. The result is a map that divides the municipalities into the following categories: (i) agricultural non-soybean area, (ii) soybean area, and (iii) non-agricultural area. Next, reflectance images were used to generate a set of NDVI (B820 – B660/ B820 + B660) images in which we estimate the biomass based on the accumulated index in the next crop cycle (2008-2009). In the study, the soybean yield data was related to the vigor data through a linear regression model. Using yield as a dependent variable, the adjusted model was then applied to the vigor data, resulting in yield information pixel by pixel. The adjusted model was used to estimate crop yield based on the biomass in each pixel. All estimated yield (y) were compared to each insured yield level (yc), given by the multiplication of all coverage levels (50, 55, 60, 65, 70%) by the average municipality yield in the last five years preceding 2009. A loss index given by (yc - y)/yc was then calculated. In this case, when the estimated yield in each pixel is less than the insured yield, there is a loss situation (claim) and an amount of indemnity is due.

PRICING AGRICULTURAL RISKS

Yield Y is forecasted two steps ahead. Therefore, considering the average μ_{it} as identical to E(Y_{it}), where *i* refers to the spatial variable and *t* represents the temporal variable, such that *i* = 1, 2, ... ,*S*, *t* = 1, 2 , ..., *T* and Y_{it} represents yield in municipality *i* in time *t*. The objective will be that of modeling the average, so that μ_{it} reflects, in general, the covariates, the temporal effect, the spatial variation of crop yield and the spatio-temporal effect. Among all the proposed models, the best model is given by:

$$y_{i,t} \sim N(\mu_{i,t}, \tau)$$

$$\mu_{i,t} = \rho_i y_{i,t-1} + \beta_{1i} + \beta_{2_i} t^* + \delta_{1i} x_{i,t} + \varepsilon_{i,t}$$

With a priori distributions given by:

$$\rho_i \sim N(\mu^\rho, \tau^\rho),\ \beta_{1i} = \varphi_{1i} + \nu_1,\ \beta_{2i} = \varphi_{2i} + \nu_2,\ \varphi_{1i}; \varphi_{2i} \sim CAR(\mu_i, \sigma^2 / \mathrm{n}_i)$$

Normal prior distributions for $\nu_1, \nu_2, \delta_{1i}, \mu^\rho$ and precision equal to 10^{-6} and prior Gamma-Inverse distributions for τ, τ^ρ

DATA

The data for crop yield, in kilograms per hectare, were the ones disseminated by the Brazilian Institute for Geography and Statistics (IBGE) from 1997 through 2009. Information for accumulated rainfall was provided by the National Water Agency (ANA) for the period between the second fortnight of January and the first fortnight of March, a critical period for soybean crops in the region covered by the study. The crop insurance analyzed in this study covers the rural credit. The data for rural credit per municipality is provided by the Central Bank, in millions of dollars (US$), for the 2008-2009 harvest year. The region covered by the study comprises twelve municipalities in the state of Paraná, highlighted in dark gray (figure 1).

RESULTS

As expected, the results show that the higher the coverage level, the higher the loss

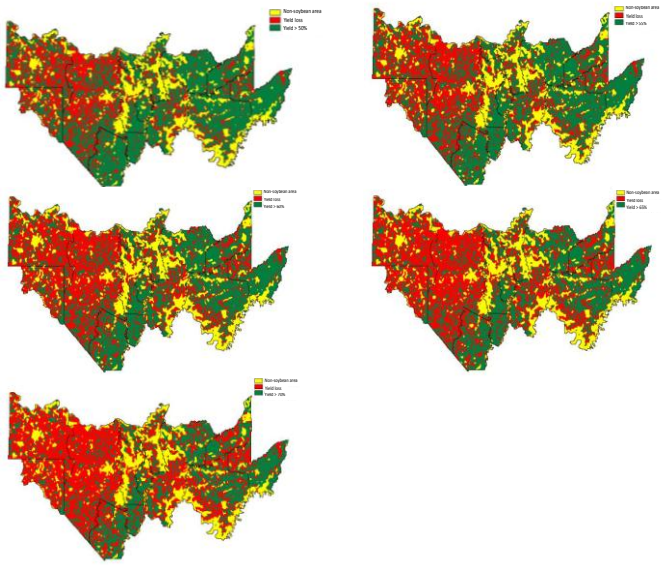

Figure. Loss maps - level of coverage of 50 % (a), 55% (b), 60% (c), 65% (d), 70% (e).

CONCLUSION

This study contributes to a better understanding of the dynamic of crop losses, as well as of their implications for the insurance market and credit agents, apart from using an alternative pricing approach. Using satellite images, it is possible to locate soybean crop areas and to quantify losses during the harvest season. Finally, the development of crop insurance in Brazil requires improvements in the climate-related and spectral information available to the public and private sectors. The more disaggregated information is available in high detail, the greater the possibility of offering products that can meet the expectations of farmers and economic agents involved in agribusiness.