Climate Change Effects on Brazilian Agricultural Land Use—Cross-Sectional Panel Model with Census Data

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Outline

- Motivation
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- Model
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- Data
- Results
  - Estimation
  - Simulation
- Conclusions
- Extensions
Motivation

- Quantify climate change effects on the agricultural economy.
  - Project impacts on farm profits.
    - www.ipea.gov.br
    - www.nemesis.org.br
    - www.ipeadata.gov.br
- Land use feedback linkage for models that project future climate change.
Motivation – Feedback Linkage

- Deforestation $\rightarrow$ 2\textsuperscript{nd} largest global source of CO$_2$
- Elsewhere:
  - $\Delta$ land use $\Rightarrow \Delta$ land cover
  - $\Delta$ land cover $\Rightarrow \Delta$ climate
- Current project:
  - $\Delta$ climate $\Rightarrow \Delta$ land use
Past Results

  - $\uparrow$ 1°C; $\uparrow$ 3% rainfall:
    - land values $\downarrow$ 1.2%
    - natural forest $\downarrow$ 2%

- Timmins (2003)
  - GCM spatially differentiated climate change
    - natural and planted forest $\uparrow$
Model – Theory

- Climate $\rightarrow$ (profits) $\rightarrow$ land conversion

- Regression analysis
  - Depvar = ARALT: proportion of municipio area unused in agropastoral activities
    - annual or perennial cropland
    - planted pasture
    - planted forest
    - short-term fallow
  - Assumption: Spatial variation in climate mimics temporal variation
  - Estimated with Agricultural Census data
  - MCA-level cross-sectional model
    - Excluded non-representative and metropolitan MCAs
BRASIL

Areas Minimas Comparáveis entre 1997 e 1970

Divisão Municipal 1997

MCAs
1970
1975
1980
1985
1995/96

Elaboração: IBGE/DIMEC utilizando Matriz Municipal Digital do Brasil 1997 (IBGE/DGC/DIMAC)
Model Estimation – Logistic Specification

\[
\log\left(\frac{\text{ARALT}_i}{1 - \text{ARALT}_i}\right) = \alpha + \beta T_i + \delta T_i^2 + \gamma P_i + \phi P_i^2 + \eta T_i P_i \\
+ \tau T_i E_i + \varphi P_i E_i + \sum_c \lambda_c Z_{ic} + e_i
\]

- \(\text{ARALT}_i\) = altered area per hectare of establishment area;
- \(T_i\) = temperature (°C);
- \(P_i\) = precipitation (mm);
- \(E_i\) = Erosion limitation;
- \(Z_{ic}\) = edaphic, geographic, and socio-economic control variables;
- \(e_i\) = error term;
- \(\alpha, \beta, \delta, \gamma, \phi, \eta, \tau, \varphi, \text{ and } \lambda_c\) = parameters to be estimated.
Climate enters the model in 3 different steps:
1. to estimate the land use model.
2. to predict the current amount of converted land.
3. to project amount of converted land under climate change.

The impact of climate change on ARALT (the amount of converted land) is calculated as the difference between projected and predicted.
Climate Data

- Base climatology:
  - Climate Research Unit (CRU)
    - 10 minute (~20km) interpolated grids intersected with AMC boundaries
  - 30-year averages (1961-1990)
    - temperature (°C)
    - precipitation (mm/month)
  - Seasonal specification
    - December, January, February
    - March, April, May
    - June, July, August
    - September, October, November
Average Temperature - MAM
Average Temperature - JJA
Average Temperature - SON
Average Precipitation – DJF
Average Precipitation – MAM
Average Precipitation – JJA
Average Precipitation – SON
Climate Change Data

- General Circulation Model (GCM) projections
  - Wagner Soares, CPTEC
  - Projected timeslices
    - 1961-1990
    - 2020s
    - 2050s
    - 2080s
  - 5 GCMs
    - HadCM3
    - CCCma
    - CCSR/NIES
    - CSIRO
    - GFDL
  - Intersected grids with MCAs

Projected climate change = observed (CRU) base + modeled anomaly
Climate Data – Modeled 1961-1990
Climate Data –
5-model average of 2020s, 2050s, and 2080s temperatures
Climate Data –
5-model average of 2020s, 2050s, and 2080s anomalies
Geographic Data – Soils

- 1:5,000,000 digital maps of Brazilian soils (Embrapa)
  - Erosion
    - PERO1 = 7.5 - 15% inclinação
    - PERO2 = 30 - 45% inclinação
  - Proportion of município in each of 12 categories of soil type
  - Proportion in 5 categories of soil quality
Soil type – 1:5,000,000
Geographic Data

- PALT = proportion of município in each of 7 classes of altitude.
- DSHOR = linear distance to the sea
- DEN_TIND = proportion of município in indigenous reserves
- DEN_UCI = proportion of município in protected areas (integral)
- DEN_UCS = proportion of município in protected areas (sustainable use)
Results: Logistic Estimation of Converted Land

- Adj. R-square = 0.78
- 24 out of 28 climate variables are significant
- F-tests find all variable groups to be significant
Results: Logistic Estimation of Land Use

"Exogenous Model" -- AMC-level -- Panel:1970, 75, 80, 85, 95/96 -- Weighted by municipio area

Dependent Var = ARALT: Proportion of municipio converted to agricultural use

<table>
<thead>
<tr>
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<th>Coefficient</th>
<th>N.Obs.</th>
<th>F-value</th>
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*significant at Pr>T=0.10, **significant at Pr>T=0.01
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*significant at Pr>T=0.10, **significant at Pr>T=0.01
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Simulation of Land Use

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<th>Region</th>
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<th>% Change – 2080s</th>
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<tr>
<td>Brasil</td>
<td>51</td>
<td>83</td>
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Un-Weighted

% Change in Area Under Agropastoral Activities

% Change

Error

CHANGE

-57.31 - -23.00
-22.99 - 0.00
0.01 - 75.00
75.01 - 135.00
135.01 - 204.00
204.01 - 306.00
306.01 - 520.00
520.01 - 945.00
945.01 - 1999.00
1999.01 - 1650.98
Conclusions

- Evidence suggests the possibility that climate change may dampen deforestation in the Amazon and frontier areas, potentially causing a negative feedback into the greenhouse effect.

- Care must be taken with any econometric analysis where cross-section is taken over non-uniform units of observation.
Extensions – Land Use Model

- Control for spatial autocorrelation and heteroskedasticity
- Instrument for transportation costs and other endogenous RHS variables
- Joint estimation of 7 land use categories separately
Extensions – Productivity Model

- Hedonic land value
- Fixed effects
- Profits
- Ag GDP
- Best use land value function (hedonic)
  - Controls for non-time varying effects
    - Time: Isolates the effects of single-year climate on single-year profits.
  - Includes more variance in observations