A Structural Dynamic Land Use Model for the Amazon Rainforest

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Introduction – Motivation

- Deforestation is a matter of global concern
- The Amazon rainforest is the world's most extensive rainforest

- A critically important ecosystem
- Approximately 20% of the Brazilian Amazon was deforested by 2016

Introduction – Motivation

- Widely agreed that land use decisions respond to economic incentives
- Yet, surprisingly little is known about the elasticity of deforestation to commodity prices
- Land use responses also matter for several policies of interest:
  - agricultural policies
  - conservation policies
  - investments in infrastructure

Introduction – This Paper

In this paper, we aim to:

1. Estimate the elasticity of deforestation with respect to agricultural prices for the Brazilian Amazon
2. Investigate how improvements in transportation infrastructure affect deforestation (through effects on local prices)

Introduction – This Paper

- Assemble rich new panel data set for 2001-2012
- Structural dynamic land use choice model for farmers in the rainforest
  - Farmers balance clearing costs against discounted future returns to agriculture
  - Static or myopic models likely underestimate long-run land use responses (Scott (2013))
- *Very Preliminary Results*

Related Literature

- Empirical Land Use Models:
  - Chomitz and Gray (1996), Kaimowitz and Angelsen (1998), Stavins (1999), Pfaff (1999), Bell and Irwin (2002), Nelson and Geoghegan (2002), Andersen et al. (2003), Chomitz and Thomas (2003), Lubowski, Platinga and Stavins (2006), Pfaff et al. (2007), Weinhold and Reis (2008), Brady and Irwin (2011), Mason and Platinga (2013), Scott (2013), Assuncao, Mobarak, Lipscomb, and Szerman (2016), Souza-Rodrigues (2017).
- Monitoring Efforts/Institutions in the Amazon:
  - Assuncao and Rocha (2013),Assuncao, Gandour and Rocha (2013), Hargrave and Kis-Katos (2013), Arima et al. (2014), Cisneros, Zhou and Borner (2015), Andrade and Chagas (2016), Burgess, Costa and Olken (2016).
- Payments for Ecological Services Programs:
  - Alix-Garcia, Shapiro and Sims (2010), Pattanayak, Wunder and Ferraro (2010), Simonet et al (2016), Wong et al (2016).

Outline

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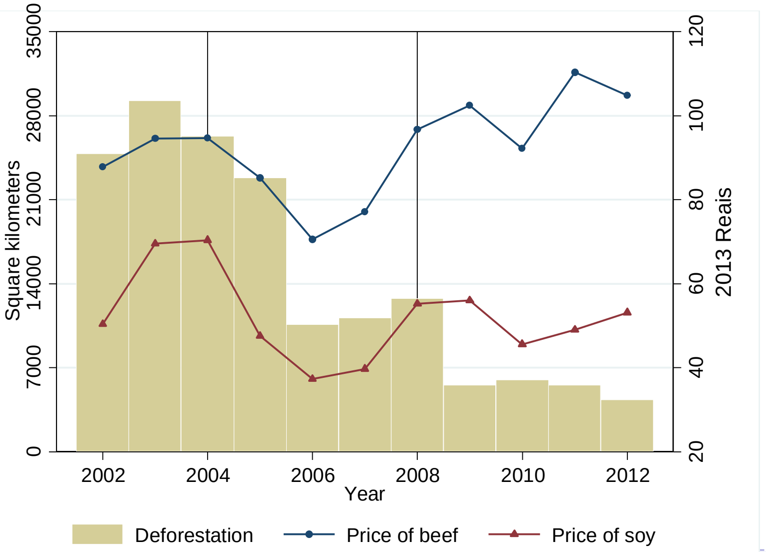
Institutional Background and Data

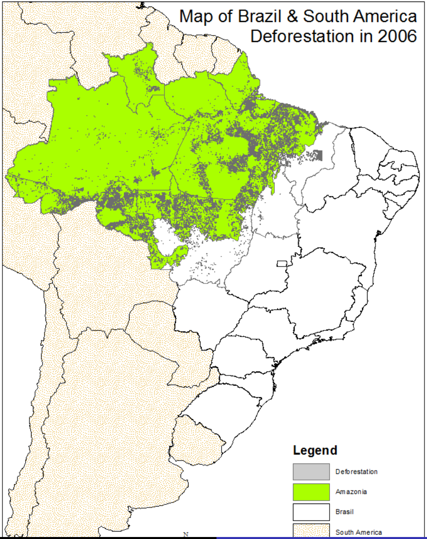
Spatial merge of:

1. Land use from TerraClass (extrapolated to 2000 to 2015)
   - correct misclassifications based on a HMM approach (Torchiana, Rosenbaum, Scott and Souza-Rodrigues (2017))
2. Local prices from
   - prices at port $\pm$ transportation costs
3. Yields, Rural wages, Fertilizers, other costs
4. Monitoring efforts (fines data, priority list)
5. Topographical info from NASA's Shuttle Radar Topography Mission database, Soil categories from GAEZ

Institutional Background and Data



Institutional Background and Data



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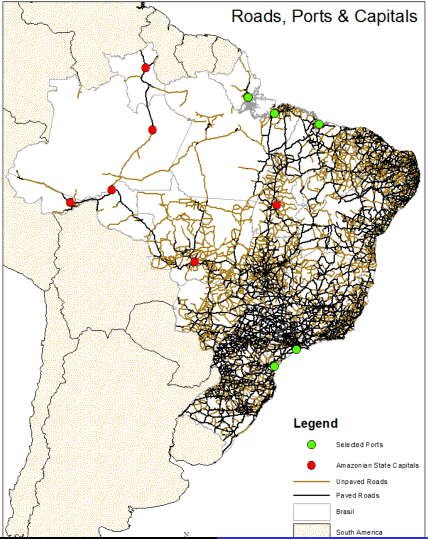

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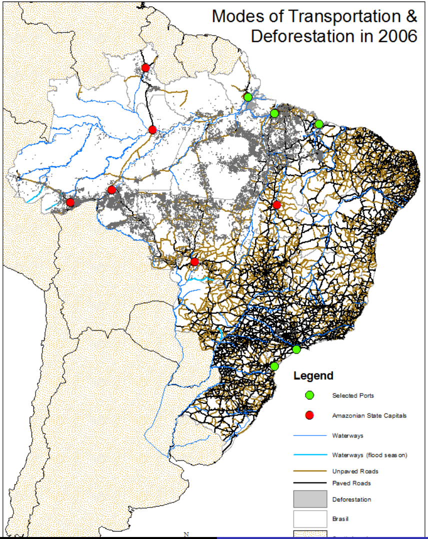

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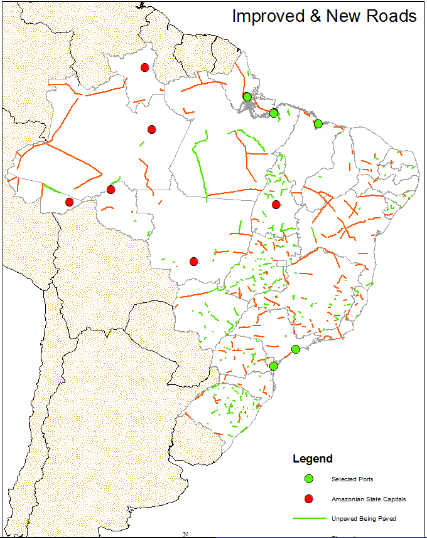


Outline

Model

- Choice set: $\{forest,\ agriculture\}$
  - agriculture includes pasture and cropland (soy, corn, rice, beans, etc)
  - exclude: urban land, protected areas, and water
- Field state:
  - field characteristics z_{im}: e.g. location, slope, altitude, soil
  - field's past usage k_{imt}.
  - market level variables ω_{mt}: e.g. crop prices, monitoring efforts

Model

- Profits

$$\pi(a, k, \omega, z) = \theta_0(a, k, z) + \theta_1 R(a, w, z) + \xi(a, k, \omega, z) + \varepsilon(a)$$

where

  - $R(a, w, z)$ observable component of expected returns
  - $\xi(a, k, \omega, z)$ unobservable component of expected returns
  - $\varepsilon(a)$ i.i.d. logit errors

- Parameters of interest:
  - switching costs, $\theta_0(a, k, z)$
  - slope θ_1

- Normalization: $\pi_{forest} = 0$
(Kalouptsidi, Scott, Souza-Rodrigues (2017a))

Model

- Using an Euler Equation Approach for discrete choice models, we can show that:

$$Y_t(z) = \alpha_1 + \theta_1 R(z, w_t) + \xi(z, w_t) + e_t^V(z)$$

where

$$Y_t(z) \equiv \ln\left(\frac{p_t(def|forest, z)}{1 - p_t(def|forest, z)}\right) + \beta \ln\left(\frac{p_{t+1}(def|def, z)}{p_{t+1}(def|forest, z)}\right)$$

and $e_t^V(z)$ is an expectational error term

(Scott (2013), Kalouptsidi, Scott, Souza-Rodrigues (2017b))

- Estimate model parameters using a linear regression framework

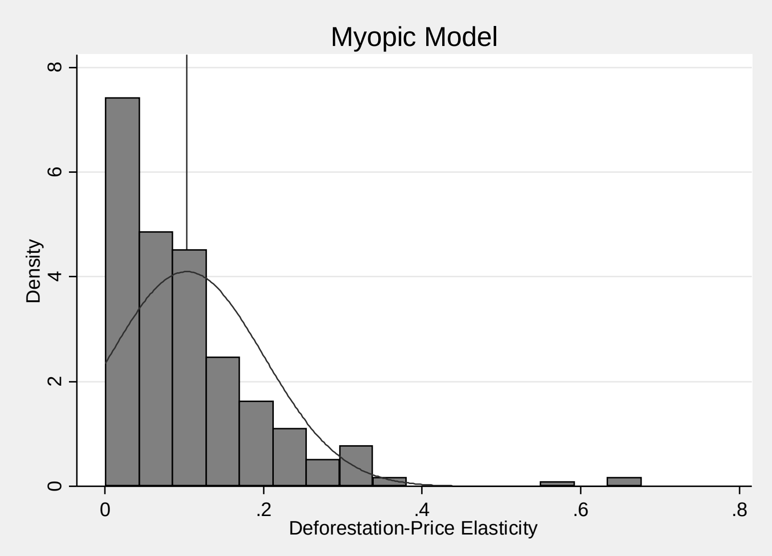
Outline

Preliminary Empirical Results

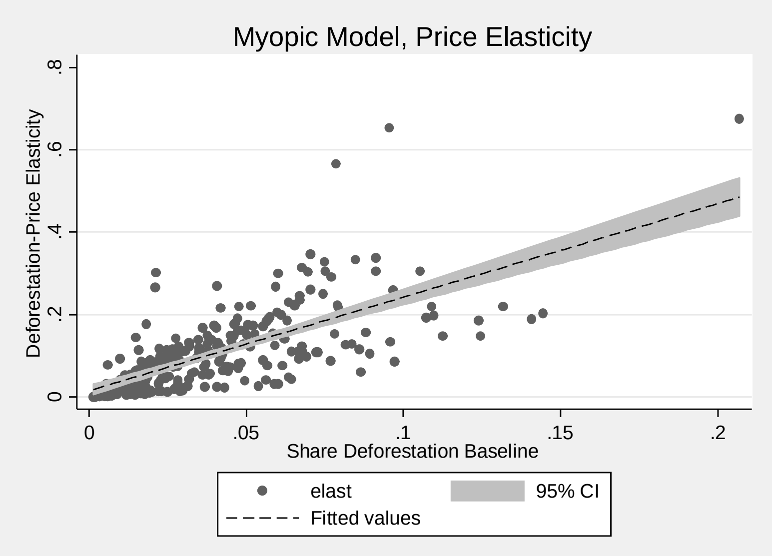
- Today: myopic model, short-run responses
- Baseline Deforestation:

  $Pr\,(deforest) = 0.038$
- Average Elasticity of the Probability of Deforest with respect to a 1% increase in Output Prices:
  - Point Estimate: 0.103
  - 95%-CI: $(0.081, 0.127)$

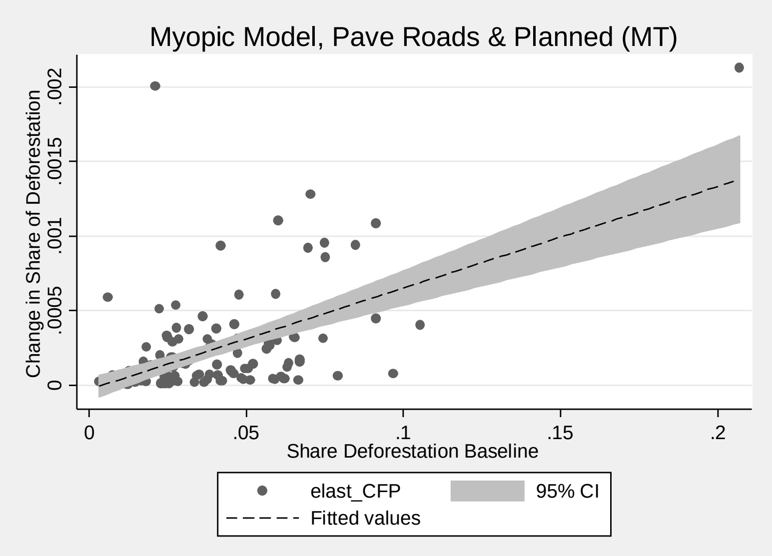
Preliminary Empirical Results



Preliminary Empirical Results



Preliminary Empirical Results – Paved/Planned Roads



Outline

Summary and Future Research

- We estimate deforestation elasticities
- We estimate impacts of roads on deforestation
- Future work:
  - multinomial choice model (forest/crops/pasture)
  - incorporate unobserved heterogeneity
  - impacts of policies on costs to deforest
  - impacts of carbon tax
  - Suggestions?