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Analysis

The economics of cropland conversion in Amazonia: The importance of agricultural rent

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ABSTRACT

We use spatially efficient logit models to explore the role of economic incentives on the expansion of cropland in the Mato Grosso region between 2001 and 2004. An empirical measure for agricultural economic rent is used to quantify the desirability of a particular plot of land, which previous research proxies with variables such as distance to roads or urban areas, and simple climatic and edaphic variables. Results indicate that the measure for economic rent provides additional information and explanatory power to one of the most commonly used proxies, distance to roads. As predicted by economic theory, it is not simply access or variation in transportation costs that drives the spatial determinants of agricultural expansion, but the expected total returns from the venture. This suggests that spatially explicit rent models can be used to simulate the location and quantity of land-use change in an economically consistent framework. Such a framework lays the foundation for an enhanced methodology that can evaluate the ability of fiscal policy levers to influence the location of agricultural conversion with the ultimate aim of balancing economic and environmental goals.

1. Introduction

To date, projections of land-cover or land-use change in the Amazon basin are based largely on variables that proxy the revenues and/or costs of production (Irwin and Geoghegan, 2001). We hypothesize that a more comprehensive evaluation of the systematic nature of revenue and cost streams can improve the accuracy of many policy assessments and provide new information on the financial and environmental implications of any policy.

From an economic perspective, one commonly used proxy variable, distance to roads, is only one component of transportation costs and may not be the most relevant. Transportation costs are in turn only one determinant of the economic returns obtained from a given land use. We use a Ricardian type rent, which is defined as the maximum return obtained from optimal land use, to represent both economic and biophysical determinants of a location's desirability for conversion to agricultural use. This rent is calculated as the expected annual return to soybean production for each pixel. To evaluate this notion, we test whether a direct measure of rent (expected returns) provides additional information that is not captured by nearness to roads (a single component of an input cost) or the agglomeration of other cost and revenue proxy variables.

Rent has not been used to model Amazonian deforestation because systematic spatial observations are difficult to obtain. Instead, rent has been proxied with variables that are roughly correlated with either revenues or costs. Revenues are determined in part by a parcel's productivity, and often are approximated using physical variables such as climate or soil characteristics (Aguiar et al., 2007; Jasinski et al., 2005; Laurance et al., 2002; Pfaff, 1999). In reality, revenues are determined by a complex series of interactions among climatic and edaphic variables, socio-economic conditions, land use decisions, and market forces (Kaufmann and Snell, 1997; Vera-Diaz et al., 2008). For instance it is clear that soil type and rainfall alone are poor predictors of soybean yield in the Amazon (see Vera-Diaz et al., 2008), which is the result of a complex interaction and timing of, among other things, nutrient levels, inputs, rooting depth, rain, and solar insulation. For more information on crop physiology models look to: Sinclair (1986), Sinclair and Seligman (2000), Acock and Trent (1991), or Penning de Vries et al. (1992). In the same vein, it is the interaction of these spatially heterogeneous potential yields, their expected market price, the socio-economic conditions and policies at that locale, and input or other costs that determine the desirability of a particular plot.

Costs, which are determined in part by a parcel's location relative to purchased inputs or product markets, often are approximated using

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linear variables such as nearness to roads or road density (Chomitz and Thomas, 2003; Pfaff, 1999; Reis et al., 1991). This treatment underestimates the complex nature of transportation networks and has only occasionally been addressed in recent literature. Considering the recent advances in geographic information systems, simplifying assumptions such as the use of straight-line distances and other second best measures are no longer desirable or likely necessary.

We assess the power of systematic observations of rent, which include measurements for both revenues and costs, to account for the spatial pattern of new cropland between 2001 and 2004 in an area that consists largely of the Brazilian state of Mato Grosso. This region accounts for 40% of Amazon deforestation during the study period 2001 to 2004 (Morton et al., 2006). Previous studies emphasize distance to roads as a key determinant of land-use change (Aguiar et al., 2007; Chomitz and Gray, 1996; Jasinski et al., 2005; Kirby et al., 2006; Laurance et al., 2002; Mertens and Lambin, 1997). Our results demonstrate that the location of new agricultural land is influenced by soybean rents and nearness to roads, but when evaluated simultaneously, the results indicate that rent expands on the explanatory power of nearness to roads such that the explanatory power of nearness to roads is largely subsumed by our measure for rent. This is consistent with economic theory. Moving output to the nearest road is only one component of transportation costs, which in turn is only one component of rent. Quantifying these effects in an empirical methodology lays the foundation for an enhanced methodology to evaluate the ability of market-based and fiscal policy levers to influence the location of agricultural conversion with the ultimate aim of balancing economic and environmental goals.

2. Literature Review

In this section, we review statistical analyses of observational data sets to identify factors that drive land-use change in Amazonia (Table 1). Pfaff (1999) identify three core drivers of deforestation: land characteristics, factors that influence transportation costs, and government development policies. Pfaff et al. (2007) evaluate the role of spatial spillovers from road construction in deforestation. Using fixed effects regressions, they find that new roads increase the rate of deforestation within a radius of 100 km.

Jasinski et al. (2005) evaluates the development of mechanized agriculture in the state of Mato Grosso, Brazil. They find that 72% of land converted to cropland between 2001 and 2003 was used previously as pasture or cerrado. Using non-spatial logistic regressions, Jasinski et al. (2005) find that agricultural area depends on terrain slope and distance to paved roads, and that the rate of expansion depends on previous land-cover, slope, and distance from paved roads.

Chomitz and Thomas (2003) analyze highly disaggregated census data on land use and labor for the Brazilian Amazon. They create a conceptual model in which the propensity to clear land is a function of potential profit per acre. Profit depends on farm gate prices, costs and revenues of clearing, agro-climatic suitability, and proximity to previous clearing. Using proxy variables for these determinants of profitability, Chomitz and Thomas (2003) find that conversion to agriculture (predominately pasture) is positively correlated with previous land disturbance, being within 50 km of a main road, and straight-line distances to small cities. Conversion is negatively correlated with increased rainfall, protected areas, and nearness to large cities. They maintain that the importance of these effects are "qualitatively unchanged" by spatial autocorrelation, despite finding that six variables are no longer statistically significant, and other coefficients change by more than 50%, when spatial autocorrelation is accounted for.

Aguiar et al. (2007) use regressions that specify spatial lags to indentify drivers of deforestation that fall into three categories: (1) least-cost transportation to ports, urban areas, and markets, (2) settlement, and (3) soil characteristics. They emphasize the importance of spatial regression for efficient estimation, but suggest that the transportation cost variables "carry a large part of the spatial dependence" that is implied by the spatial lag.

Irwin and Geoghegan (2001) develop a methodology to model the economic incentives of land-use change that uses economic models and spatial regressions. Their methodology grounds land-use change in economic theory and moves away from the 'ad hoc' approach of sifting for significant correlations. They estimate spatially specific hedonic values for land parcels, and the value of competing land uses. These values, along with other characteristics that exogenously affect the costs of land-use conversion, are used in a spatial discrete choice model to estimate the probability of land-use conversion. Results are used to create a surface that shows the likelihood of future conversion.

The methodology described below extends previous efforts in several ways. Ours is the first methodology to use a spatially explicit estimate of agricultural rent, which allows us to replace proxy variables for transportation costs and land values. Second, these estimates for land value enable the methodology to assess the monetary costs and benefits of market-based policy options. This is important for policy makers who hope to use market-based mechanisms to guide the evolution of land-use change in the Amazon, as opposed to command and control mechanisms. Or alternatively, the model can be used to evaluate the impact of command and control mechanisms on captured agricultural

Table 1
Literature summary.

Author	Objectives	Methods	Important results
Pfaff (1999)	Identify determinants of deforestation	Non-spatial regression model using municipal survey data and remote sensing data	Primary drivers include land characteristics (soil quality and vegetation density), factors influencing transportation costs (distance to markets, own- and neighboring-county road density), and government development projects.
Pfaff et al. (2007)	Determine impact of road investments on deforestation	State and county fixed effects regressions	Previous road investment increases deforestation rates in neighboring census tracts (<100 km) w/o roads. Limitations to use of census data (estimation error w/ centroids, etc.)
Jasinski et al. (2005)	Identify drivers of conversion to mechanized agriculture	Non-spatial logistic regression and transition matrix for Mato Grosso,	72% of conversion from pasture/cerrado areas, conversion reduces with distance from paved roads, and changes with previous land uses
Aguiar et al. (2007)	Identifies drivers of conversion to pasture, temporary agriculture and permanent	Spatial regression	Conversion driven by least cost distance to urban centers and markets/ports, protected areas, soil characteristics, agrarian structures.
Irwin and Geoghegan (2001)	Develops method for spatially and economically consistent land use model	Spatial regression, maximum land use rents	For a more theoretically valid model, spatial discrete choice models and hedonic estimates of land uses should be used to identify the likelihood of conversion
Chomitz and Gray (1996)	Evaluate the effects of environmental and market characteristics, and land use policy on forest conversion and pasture productivity	Non-spatial tobit, compared with spatial error model	Probability of conversion to agriculture and the intensity of cattle stocking rates decline with rainfall. Conversion positively related with 50 km road buffer and distance to small cities.