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Land institutions and supply chain configurations as determinants of soybean planted area and yields in Brazil

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ABSTRACT

Soybean production has become a significant force for economic development in Brazil. It has also received considerable attention from environmental and social non-governmental organizations as a driver of deforestation and land consolidation. While many researchers have examined the impacts of soybean production on human and environmental landscapes, there has been little investigation into the economic and institutional context of Brazilian soybean production or the relationship between soy yields and planted area. This study examines the influence of land tenure, land use policy, cooperatives, and credit access on soy production in Brazil. Using county level data we provide statistical evidence that soy planted area and yields are higher in regions where cooperative membership and credit levels are high, and cheap credit sources are more accessible. This result suggests that soybean production and profitability will increase as supply chain infrastructure improves in the Cerrado and Amazon biomes in Brazil. The yields of competing land uses, wheat, coffee, and cattle production and a complementary use, corn production, also help to determine the location of soybean planted area in Brazil. We do not find a significant relationship between land tenure and planted area or land tenure and yields. Soy yields decline as transportation costs increase, but planted area as a proportion of arable land is highest in some of the areas with very high transportation costs. In particular, counties located within Mato Grosso and counties within the Amazon biome have a larger proportion of their arable, legally available land planted in soy than counties outside of the biome. Finally, we provide evidence that soy yields are positively associated with planted area, implying that policies intending to spare land through yield improvements could actually lead to land expansion in the absence of strong land use regulations. While this study focuses on Brazil, the results underscore the importance of understanding how supply chains influence land use associated with cash crops in other countries.

Introduction

In recent decades, agricultural expansion and the growth of domestic and international markets for food commodities have become the most important drivers of large-scale land cover change in Brazil (Rudel, 2007; Defries et al., 2010). Soybean production has comprised a majority of the crop-based agricultural expansion, with soybean planted area increasing from roughly 1 million hectares (Mha) in 1970 to more than 23 Mha in 2010, second only to the United States (IBGE, 2006, 2010). In the Center West and Amazon regions, crop area expansion has resulted in the conversion of native savannas and forests and planted pastures to intensive agriculture (Brandão et al., 2006; Müller, 2003; Morton et al., 2006; Jepson, 2005; Rudorff et al., 2011; Macedo et al., 2012), and in some states, particularly Rondônia and Pará, soy production has also increased through the conversion and consolidation of smallholder lots (Brown et al., 2005; Fearnside, 2001; Steward, 2007). Additionally, soy expansion is hypothesized to displace cattle pasture into areas of native vegetation, particularly within the Amazon biome (Barona et al., 2010; Arima et al., 2011).

The rapid increase in soy production in Brazil over the last four decades was supported by government interventions to promote increased supply and increases in the global and domestic demand for soy derivatives. On the supply side, the factors affecting soybean expansion include major technological improvements in seeds in the 1970s, the introduction of credit subsidies and price supports in the 1980s, market deregulation and tariff reduction in the 1990s, and high global prices for soy and a competitive Real/US

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Dollar exchange rate in the late 1990s and 2000s (Spehar, 1995; Chaddad, 2006; Luna and Klein, 2006; Damico and Nassar, 2007; Richards et al., 2012). Soybean production was neither economically, nor biophysically viable on a commercial scale in the Center West region of Brazil until Brazil's Agricultural Research Corporation (EMBRAPA) developed new high-yielding cultivars, capable of tolerating the region's shorter day length and high aluminum and low calcium soils (Spehar, 1995). To encourage soy expansion in this region during the 1970s the government provided credit at negative real interest rates for land purchases and storage infrastructure, as well as low interest credit for operational expenses and price supports for soy, which allowed producers to migrate from the South of Brazil and exploit the vast agricultural potential of the Cerrado (Sousa and Busch, 1998; Damico and Nassar, 2007; Jepson et al., 2008).

On the demand side, an extreme El Niño event in 1972 greatly reduced the anchovy harvest of the coast of Peru, which led to a major increase in the demand for soy meal as a substitute for fish meal in global markets, and increased global soy prices (Warnken, 1999). Secondly, the United States responded to a local drought and high prices the following year by imposing an embargo on soy exports which further increased prices (Warnken, 1999). As a result, importing nations looked for additional countries, namely Brazil, to supply soy to world markets in the event of future US shortfalls. Due the supply side interventions, Brazil was able to seize the opportunity and became the second largest soy producer in the world by 1975 after producing only 1 million tons in 1969. Throughout the next three decades, urbanization and income growth in Brazil, China, and other emerging economies, coupled with Brazilian policies to stimulate the domestic consumption of soy products and poultry, led to a substantial increase in the global demand for soy as cooking oil and livestock feed (Sousa and Busch, 1998).

As a result of these programs, the Center West, which had virtually no soy production prior to 1980, now plants more soy than any other region in Brazil. Despite extensive study of the impacts of Brazilian soybean production as a driver of land cover change,[1] there has been little research on the economics of soybean production, in particular, the effect of supply chain configurations on local profits, the role of land institutions on land use, or the relationship between soybean yields and planted area. While past research largely focused on smallholders and cattle ranchers, soy production is very different from subsistence farming and ranching, requiring expensive machinery, skilled labor, and high levels of liquidity to finance yearly investments in soil correctives, defensives, and seeds (Brown et al., 2004, 2007). In order to predict how soybean production will develop in the dynamic agricultural regions of the Cerrado and Amazon ecosystems, it is necessary to understand better the determinants of spatial variations in soybean planted area and yields across all of Brazil.

The objective of this study is to assess the importance of biophysical, economic, and institutional conditions as determinant of regional variations in soybean planted area and yields, with a particular emphasis on the relationship between supply chain conditions and soy profits. To analyze the relative importance of each of these variables, we use von Thünen's spatial market model adjusted to include additional local variations in supply chain conditions. To examine the determinants of yields we use a bioeconomic yield model similar to that of Kaufmann and Snell (1997). We then use a two stage least squares model to analyze the influence of soy yields on planted area. This study adds to both the theoretical understanding of how supply chain configurations and land institutions influence land use and input usage, and the empirical understanding of soybean production patterns across all of Brazil. We find that supply chain configurations have a very strong relationship with soybean planted area and yields, but land institutions fail to predict land use patterns or yields. We also provide evidence that soybean yields and planted area in Brazil have had a positive relationship, as do yields and farm size, so land sparing is not likely to occur as a result of increasing soy yields if the global demand for soy is increasing or continues to be elastic.

Background

Planted area

To understand land use patterns we draw on agricultural location theory and the work of Johann Heinrich von Thünen, who hypothesized that in an area of spatially uniform fertility, the rent for a given parcel of land would be determined by its distance to the closest market (Jones et al., 1978). Over time, the basic transportation cost model developed by von Thünen has been adapted to include non-uniform biophysical conditions and variable input usage and used in numerous deforestation and agricultural expansion models (see Kellerman, 1989 for a detailed overview of the use of von Thünen models or Chomitz and Thomas, 2001; Mertens et al., 2002; Sills and Caviglia-Harris, 2009, or Walker et al., 2009 for applications in Brazil).

The von Thünen rent model we use differentiates between fixed and variable costs, acknowledges spatial differences in fertility, and allows rents to vary with input use and transportation costs to be non-linear.

$$R(U_{i,j}) = p_{i,j}y_{i,j}(x) - a_{i,j}x - t_{i,j}(m) - a^*_{i,j} \quad (1)$$

where $R(U_{i,j}(x))$ is the rent of a farm in location i in use j, $y(x)$ is the output of j at location i when x units of input are used, $p_{i,j}(y)$ is the market price of crop j in location i when y units of crop j are produced, a is the price per unit of input, $t_{i,j}(m)$ is the cost of transporting j m miles, and $a^*_{i,j}$ is the fixed cost of production for crop j in location i.

The resulting land use in a given location i is then modeled by the following discrete choice problem: if the present value of use j in a given area is greater than that of use k for an anticipated future time horizon h, then the profit maximizing land owner will convert their land to j. The present value (PV) of $U_{i,j}$ is given by:

$$PV(U_{i,j}) = \sum_h E\left[\frac{R(U_{i,j})}{\prod_p (1+r)^p}\right] - C_{i,j} \quad (2)$$

where E is the expectation, r is the interest rate, p is the number of years of ownership, and $C_{i,j}$ is the cost of conversion from the existing land cover to use j in location i. As present value is based on the expectation of rents, it incorporates the land user's understanding of the probability of multiple yield and price scenarios.

In the context of soybean production, which can be double cropped with corn, wheat, and other crops, the present value of converting the land to soybean production should also take into account the expected profits obtained from the production of a second crop within a given year. The present value of soy and its complements should then be compared to the expected profits of potential land use substitutes. From one year to the next, substitution options are limited to other annual crops for which the producer has technical expertise and suitable machinery. However, over multiple years, land cover can be changed, soil can be corrected, and ownership and/or operation can be transferred, increasing land use substitution possibilities. In Brazil, the main competitive land uses are cattle ranching and sugar production, whereas corn and wheat can be complements or substitutes

[1] See for example: Fearnside (2001), Brandão et al. (2006), Müller (2003), Brown et al. (2005), Morton et al. (2006), Jepson (2006a), Steward (2007), Arima et al. (2011), and Macedo et al. (2012).