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Assessing Brazil's *Cerrado* agricultural miracle ☆

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ABSTRACT

Brazil's emergence as a primary global agricultural producer is often credited to production expansion into soils of the Brazilian savannah or *Cerrado*. These soils are, however, deficient in important nutrients and prone to degradation, requiring input-intensive processes that suggest a low level of productive efficiency. Employing a sequence of agricultural censuses and a biome approach for characterizing agricultural zones, the present study evaluates the Cerrado's total factor productivity growth and productive potential. The analysis highlights the resource cost of Brazil's "Cerrado Miracle," the role of paved road infrastructure in expanding production opportunities, and the significant production gains that the Cerrado may yet achieve. Results suggest a substantial productivity gap between the Cerrado's most efficient and average producers, implying that Cerrado production might well be further boosted if average producers succeed in adopting the technologies and management practices of the more efficient operators. More generally, and to the extent the Cerrado model is generalizable elsewhere, agricultural development of the world's savannahs, such as Sub-Saharan Africa's Guinea regions, into breadbaskets will be expensive in terms of material inputs such as fertilizers and pesticides, depending for their success therefore on the real prices of these inputs.

Introduction

Shortly after the 2007–2008 food price crisis, the Food and Agricultural Organization (FAO) estimated global food production would, by mid-century, need to rise 70% to feed an additional 2.3 billion people (FAO, 2009). FAO expressed cautious optimism when saying that such a boost likely would require 120 million more hectares of arable land, pointing to Sub-Saharan Africa and Latin America as potential sources of farmland expansion. That optimism may in part be driven by Brazil's successful agricultural transformation of its broad savannah, the Cerrado. Some analysts now consider some of the world's other savannah regions, including Sub-Saharan Africa's vast Guinea Savannah, to have the potential to become new breadbaskets, in part because of the agro-climatic characteristics they share with the Brazilian Cerrado (Morris et al., 2012).

Brazil's agricultural ascendance into the global market is often credited to production expansion into the Brazilian Cerrado (Economist, 2010; New York Times, 2007). Yet these soils are made up primarily of oxisols (46%) and ultisols (15%), weathered soils deficient in important nutrients such as nitrogen, phosphorus, and potassium (Lopes, 1996). Indeed, these tropical soils are characterized by good physical structure but low fertility, high acidity, and a proneness to degradation (Thomas and Ayarza, 1999). Overcoming such obstacles, Brazilian farmers have employed improved management practices and Embrapa- and university-developed modified crops and grasses (for pasture) to improve the Cerrado biome's productive capacity. For example, Brazil was in 2006 the second-largest global producer of soybeans (FAO, 2011), 48.7% of that coming from the Cerrado.

Farms in this biome, often considered the frontier of Brazilian agriculture, rely on material inputs to ensure that farm technologies thrive in the biome's acidic soils. But as new policy assessments look to the Cerrado as a potential model for transforming other savannahs (Morris et al., 2012; World Bank, 2009), it is imperative that we understand the true resource cost of such transformations. The Guinea Savannah in particular stretches across 400 million hectares of arable land in Sub-Saharan Africa; yet less than 10% of it is cropped (World Bank, 2009). Successfully adapting Brazilian agricultural technologies may provide one key to expanding and improving its output, especially in Mozambique, Nigeria, and Zambia, where for each the Guinea Savannah accounts for a minimum of 63% of total land area (World Bank, 2009). Morris et al. (2012) and the World Bank (2009) have examined the success of the Cerrado transformation and the policy challenges facing the Guinea Savannah. The present study instead focuses on providing an economic evaluation of the Cerrado's agriculture, indicating

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how the productivity gap between the Cerrado's most-efficient and average producers provides an opportunity for expanding the Cerrado's agricultural potential.

Our hypothesis is that the Cerrado's soils require significant investments in the material inputs needed to, for example, improve nutrient composition enough to allow commercial exploitation. Taken on its own account, that fact is a drag on productive efficiency. The input-intensive nature of the biome's production processes, the substantial distances most material inputs must travel, and the sparseness of paved highways, are reasons to suspect the Cerrado of low productivity growth. If Cerrado producers have indeed operated at low productive efficiency, any significant output-price drop or input-price spike likely would reduce farm profitability and threaten Brazil's position as a globally competitive agricultural supplier. Employing Brazilian agricultural census data (1985, 1995/1996, 2006) and environmental rather than political boundaries, the present article explores the resource cost of agricultural production in a savannah of low nutrient quality, focusing on the role of infrastructure in expanding the technological frontier.

Results indicate that annual factor productivity growth among the Cerrado's most efficient producers has been slightly more rapid in the livestock than in the crop sub-sectors of the agricultural economy. Paved-road infrastructure investments have significantly affected crop and livestock productivity growth of the Cerrado's most efficient farms; a 1% improvement in paved-road density raises both livestock and crop production by more than 1%. However, the high resource cost of savannah production is clear. The average farm was, between 1985 and 2006, unable to keep pace with the most-efficient producers, achieving a total factor productivity (TFP) growth rate of only 0.4% per annum. Such high resource cost translates into a sizeable TFP gap between most-efficient and average farmer which, if closed, would substantially boost Brazil's international position as a globally competitive supplier of agricultural commodities.

A biome assessment of Brazil's productive efficiency

Evaluations of Brazil's agricultural performance have focused predominately on measuring total factor productivity (TFP) growth and on comparing growth rates across such political boundaries as states or regions (Rada and Buccola, 2012; Gasques et al., 2010; Pereira et al., 2002; and Avila and Evenson, 1995). Of these studies, only Avila and Evenson (1995) have reported TFP growth rates beyond political boundaries, namely by agro-ecological zone. The latter provides an opportunity to evaluate production's performance on the basis of climate, soil, and terrain characterizations. Brazil has 92 agro-ecological zones, too many for concise result reporting. Indeed, Avila and Evenson (1995) reported TFP growth estimates for only 22 of them.

The Brazilian savannah extends across every Brazilian region and 11 of the 27 states (Fig. 1). Hence, any analysis focusing on political boundaries obscures the agricultural performance and productive potential of the Cerrado itself. In evaluating the Cerrado, the present article evaluates, for the first time, agricultural TFP by Brazilian biome, providing an improved understanding of the productive efficiency of Brazil's most important macro-ecosystem. A biome approach is not uncommon in the environmental literature (Klink and Machado, 2005; Ratter et al., 1997) but apparently has not yet been used for productivity estimation in the economics literature. Castro de Rezende (2003) and Barros et al. (2007) provide the only other known economic analyses focusing strictly on the Cerrado. The former is a land market analysis, the latter an assessment of the Cerrado's competitive agricultural potential. Both define the Cerrado by political boundaries. Moreover, Barros et al. (2007) define the Cerrado differently in the same report, alternating between using the Center-West states and the states of Goiás, Minas Gerais, and Mato Grosso. Unfortunately also, all these states contain biomes other than the Cerrado's, and the Cerrado biome itself extends into seven other Brazilian states.

Brazilian biomes

Brazil may be divided into six biomes: Amazônia, Cerrado, Pantanal, Caatinga, Mata Atlântica, and Pampa (Fig. 1) (IBGE, 2006). Biome classifications are unique in that they express the environmental conditions which enable flora and fauna to inhabit the given area. The primary objective of the present analysis is to isolate and evaluate farm productivity in the Cerrado biome. For comparison, the Pantanal and Amazônia biomes are grouped together to form a Western biome, and the Pampa, Caatinga, and Mata Atlântica biomes to form an Eastern biome.

The Amazônia biome is the largest in Brazil, accounting for 49.3% of the nation's total area (Portal Brasil, 2011). Covering five states, it may be generally classified as a tropical rainforest with a hot and humid climate, heavy rainfall, and highly acidic soils of low fertility and drainage. The Pantanal biome borders the Amazônia on one side, spans two states, and is characterized as temperate grasslands with long-term flooding. These two biomes together cover 51.1% of Brazil's land area yet, over the 1985–2006 period, generated only 6% of its mean total production value.

The Cerrado biome is Brazil's second largest, accounting for 23.9% of the nation's area (Portal Brasil, 2011). Crossing 11 states, it contains the source of three major river basins, has a hot sub-humid tropical climate, distinct wet and dry seasons, and consists of tropical grasslands and savannah whose acidic soils are relatively infertile. As farm expansion into this biome accelerated, so did its share of total farm revenue, rising from 19.2% in 1985, to 28.7% in 1995/1996, and peaking at 33.2% in the 2006 census period. As shown in Fig. 2, 1985–2006 mean production shares in the Cerrado are greatest for cotton (48.8%), oranges (41.7%), soybeans (39.6%), cattle (37.0%), and sugar (32.0%).

The Eastern biome – Caatinga, Mata Atlântica, and Pampa – is slightly larger than the Cerrado, accounting for 25% of Brazil's land (Fig. 1). The Caatinga extends over 10 states and is a tropical scrub forest of deciduous vegetation and two distinct dry seasons prone to drought. The Mata Atlântica, or Atlantic Forest, biome stretches over 15 states comprised of hot, humid, tropical deciduous forest. The Pampa biome, present only in the state of Rio Grande do Sul, is classified as a steppe and extends into Uruguay and Argentina. It has rainy weather and no dry season; grasses and shrubs are the primary vegetation. Although the Eastern biome covers only one-quarter of Brazil, it accounts for a mean 65.45% of total crop revenue and 34.55% of total livestock revenue over the sample time period. As shown in Fig. 2, the Eastern biome has produced, on average, a minimum 48% of all commodities reported over the three census periods (see Fig. 3).

Transportation infrastructure investments

Concern about Brazil's transportation infrastructure and its impact on farm production and profitability, especially in the Cerrado, have been widespread (Vera-Diaz et al., 2009; Costa and Rosson, 2007; Matthey et al., 2004; Schnepf et al., 2001). The most vital form of Brazilian farm transportation is the road system. Matthey et al. (2004) found farm transportation costs in the state of Mato Grosso highest if commodities traveled by truck; yet 62% of farm products are shipped in this manner. Caixeta-Filho and Gameiro (2001) note that greater than 95% of the Cerrado biome's export-destined cotton production is transported by truck to Brazil's