Capital surpluses in the farming sector and agricultural expansion in Brazil

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Abstract

In recent decades, soybean production has expanded rapidly across areas of South America. This expansion has been broadly credited to rising soybean returns, and the technical innovations and demand side growth that have raised farm prices or farmers’ profit margins. In this letter we argue that recent agricultural expansions in South America would be better framed as responses to periodic, short term shocks and incremental increases in the supply of investment capital available to the farm sector. More specifically, we suggest that soybean expansion in Brazil has been heavily driven not by the expectation of future profits, but by the need and desire to invest profits accrued during previous growing seasons. Similarly, we argue that future agricultural growth in Brazil, and likely in many other tropical areas, is primarily constrained by access to capital rather than the spatial extent of profit margins.

1. Introduction

Soybean farming has profoundly reshaped regional economies, improved social services (Garrett and Rausch 2015, Richards et al 2015, VanWey et al 2013, Weinhold et al 2013) and devastated natural landscapes across Brazil’s interior (Arima et al 2011, Barona et al 2010, Lapola et al 2010, Morton et al 2006). Academics, policy makers, and environmental interests have thus sought to better understand the drivers of soybean expansion. In turn, environmental or economic policy might be crafted to better encourage growth, or to minimize the environmental impacts.

To date, research on Brazil’s soybean sector has tied its recent growth to a confluence of favorable changes in both demand and supply-side factors. From the supply side, for example, a series of technical innovations and policy changes enabled farmers to profit from the country’s vast expanses of affordable land and its plentiful rainfall. (Hecht and Mann 2008, Riskin et al 2013, Warnken 2002). Meanwhile, other work has documented the influence of falling transportation costs between Brazil’s interior and its coastal port facilities, or the impact of rising global demand for vegetable oils and protein on the growth of agriculture in the country (Lathuilli`ere et al 2014, Oliveira and Schneider 2016, Walker et al 2009).

This article builds on this ample body of research. By framing agricultural expansion as not only a response to changes in expected profits, but as a response to the availability of liquid farm capital. Specifically, it argues that the Brazilian soybean sector was (and likely remains) both undercapitalized and capital constrained. It then argues that Brazil’s recent soybean expansion should be framed as not only a response to trends in commodity prices, or to incremental changes in production practices or seed technologies, but as a long term response to the supply of farm level investment capital. We support our argument with empirical estimates showing that the overall supply of soybean cropland in Brazil closely follows the sector’s ability to generate its own investment capital. Ultimately, we estimate that each 1$RS billion (or approximately 300$US million) change in capital generated by the soybean sector is associated with a cropland increase of between 41 000 and 76 000 ha.

Our results carry several implications for understanding and limiting agriculturally-driven land use
change. First, they suggest that farmland creation is closely tied to the extent to which operating farms are able to generate surplus investment capital. By extension, this implies that reducing (or increasing) the creation of new agricultural lands may mean reducing (or increasing) the ability of the agricultural sector to generate its own investment capital. Second, we argue that Brazil’s interior (and in fact many other developing regions) may be more constrained by access to investment capital than by potential profitability. Consequently, short-term periods of agricultural profits which temporarily create a flood of investment capital could have long term impacts on regional agricultural systems.

2. Background

To date, research on Brazil’s soybean sector has attributed much of its recent growth to a series of technical innovations, market shifts and policy changes put into place since the 1980s. For example, seed breeders adapted the photosensitive, mid-latitude soybean to the lower latitudes of the tropics. Advancements in soil correction helped farmers to better farm the highly weathered soils of central South America (Hecht and Mann 2008, Riskin et al. 2013, Roy et al. 2016, Warnken 2002). Roads were blazed, paved, widened or otherwise improved across the region, reducing the cost of moving harvests to the ports, and of bringing in material inputs.

From the demand side, changes in global diets and in Brazil’s economic policies also benefited soybean farmers. The introduction of the real in the mid-1990s and its subsequent floating at the end of 1998 inflated soybean profits in the early 2000s (Nepstad et al. 2014, Richards et al. 2012). Similarly, the elimination or reduction of subsidies for domestic food crops, and a public shift toward promoting (through tax exemptions for exports) the production of globally traded commodities, incentivized soybean production over domestic food crops such as wheat and rice (Garrett et al. 2013b, Goldsmith and Hirsch 2006, Helfand and Rezende 2004). Meanwhile, growth in global soybean demand, particularly from Asia, has helped to maintain relatively strong prices for soybeans (Fehlenberg et al. 2017, Garrett et al. 2013a, Oliveira and Schneider 2016).

Much of the recent literature on Brazil’s recent agricultural expansion has conceptualized the country’s recent growth in soybean production as a reflection of an ever-changing economic calculus, where rising profit or price levels incentivized farmland creation (Barr et al. 2011, Macedo et al. 2012, Richards et al. 2014). Per this framework, when profit margins increase, whether due to policy changes, infrastructure improvements, or technological adaptations, farmers are able to operate profitably in new areas (some of which were previously thought too marginal for agriculture). Much of this work has called, either directly or indirectly, on concepts drawn from rent theory and on the notion that land users will maximize the returns to their land (Arima et al. 2017, Walker et al. 2009).

Conceptually, this reasoning can be framed neatly by equation (1), where the probability of a land use change, or an agricultural expansion (written in equation (1) as $P_{Cit}$), is written as a function of three factors: the net present value of returns to agriculture ($R_{Ait}$), the net present value of returns to another, pre-existing land use ($R_{Kit}$) and the cost of converting an area from a pre-existing land use to agriculture ($C^6_{AKit}$). The superscript $\delta$, in this case, refers to the relative cost of capital (e.g. $\delta$ increases with scarcity or high interest rates, or decreases when farmers have significant savings, or low interest rates). The subscript $i$ and $t$ refer to location and time, respectively. Where and when the net present value of expected rents for agriculture exceeds that of the pre-existing land use and any potential conversion costs (e.g. $R_{Ait} - C^6_{AKit}$ exceeds $R_{Kit}$), the probability of that area being converted to agriculture increases.

$$P_{Cit} = f(R_{Ait} - C^6_{AKit} > R_{Kit}).$$  \hspace{1cm} (1)

Per equation (1), when supply and demand side conditions in Brazil shift in ways favorable to $R_{Ait}$ relative to $R_{Kit}$ (for example, a policy change favoring export products, or the creation of a new set of roadways which reduce transportation costs for soybeans), landowners became more likely to convert their areas to farmland, or sell to those who would.

In the 2000s, the rent framework from equation (1) neatly explained the growth of Brazil’s soybean sector. The surge in local soybean prices in the early 2000s, combined with falling transportation costs, were thought to have pushed out the margins of the so-called agricultural frontier. Per the rent framework, however, the lower returns to soybean farming (relative to cattle production or other land uses) that followed at the end of the decade should have also led to a retraction, or at the very least, stabilization in farming areas; yet the opposite appears to have occurred. Soybean areas continued to expand in the later 2000s and early 2010s, despite returns to soybean farming falling to pre-2003-04 levels.

We argue that the discrepancy between land expansion and profitability can be explained by an often overlooked factor in equation (1), namely the relative cost and availability of the capital needed to enable a new form of production. More specifically, we argue that expansion of the soybean sector was driven not only by expected returns to farming (which vary from year to year, and are lower now than they were in the early 2000s), but by farm level access to access to investment capital.

Soybean farming in Brazil’s interior, relative to other land uses, requires significant capital investments.
Preparing land and seeding fields requires specially designed tillers and planters. As the crop grows, farmers need sprayers and applicators engineered for row crop applications. At harvest, crops are collected by combines specifically built for grain harvests. Together (and sometimes, on their own), these machines can cost hundreds of thousands of dollars. In addition to machinery, soybean farming requires critical on-farm infrastructure, including access roads, employee housing, covered areas for inputs and machines, and silage facilities for post-harvest. In many cases, land itself must also be acquired and prepped for agriculture, a process that includes removing stumpage and soil correction.

Much of the initial capital invested in new agricultural lands, infrastructure and machinery, we argue, has been generated through the soybean sector’s own profits. For while Brazil’s agribusiness and public financial mechanisms provide financing for variable production costs (e.g. the purchase of material inputs), the cost of acquiring or constructing fixed assets such as land and infrastructure must often be financed independently (Jepson 2006, Jepson et al 2010). Given high interest rates, many farmers rely either on their own capital returns, or on seller financing to support large acquisitions. The capital expenses implied in the creation of new farmlands and the acquisition of new machines, in many ways, thus represents or embodies the profits from previous harvest seasons.

For many farmers, agricultural land, machinery and infrastructure are not only productive investments; they also represent a relative safe haven for savings. It is reasonable to assume that many soybean farmers in Brazil’s frontier areas, having come of age during Brazil’s era of hyperinflation and economic instability, might harbor a level of skepticism towards relatively complex financial instruments, or towards holding significant capital reserves in cash. Whether for this reason, or any other, many farmers often invest their returns back into agriculture, via the purchase of land and machinery, or into the services and businesses which operate at the periphery of the agricultural sector (e.g. trucking, technical advice, material distribution, trading). These investments are not only made for their expected profitability (although this clearly factors into the equation), but for the perception that such investments are relatively safe.

More formally, we identify three key channels through which farm profits affect the cropland creation (see figure 1). The first two channels are derived from farmers’ profitability expectations, or the net present value of expected returns to farming (in figure 1, this is shown as a shift in $D^V$). For example, a profit shock would increase a farmer’s incentive to direct both (the first channel) their own capital and (the second) available agricultural credit toward the portion or creation of agricultural land, infrastructure or machinery. A third channel, however, derives from the effect of profits on the supply of liquid investment capital available at the farm level. Namely, the change in the supply of liquid investment capital potentially available to the soybean sector in any given year.

Figure 1. Supply and demand for investment capital pre and post a shock in soybean profits. Supply curves $S^l$ and $S^c$ represent the supply of liquid capital and credit (superscript l and c) for agriculture at location $i$ and time $t$. $D^V$ represents the demand for investment capital. The total quantity of investment capital supplied to agriculture is the sum of $Q^c$ and $Q^l$, $Q^V$. In (6), or after a shock in soybean profits, both the demand for capital and the supply of liquid capital shift to the right, resulting in an increase in both liquid capital ($Q^l'$) and credit ($Q^c'$) invested in the agricultural sector (e.g. $Q^V$ to $Q^V'$).
capital (the shift in $S^1$) decreases the relative cost of capital; this leads to a significant increase in the quantity of capital disbursed into the system (shown as the shift from $Q^t$ to $Q^t$).

Researchers have already documented the importance of liquid capital as a driver of agricultural change. Historical research on the modernizing American agriculture sector noted the clear relationship between investments and years of high profits (Johnson 1950). Farmers recognized that profits varied from year to year; however, rather than seek to smooth cost over unpredictable seasonal profits; they chose instead to use the profits from the best years as a principle source of investment capital. Access to liquid capital (as opposed to credit) has also been shown to have a greater impact on investments and agricultural productivity (Karlan et al 2014, Reardon et al 1994, Rosenzweig andBinswanger 1992), and has been associated with higher yields and reduced land degradation (Barbier 1997, Foster and Rosenzweig 2003, Rozelle et al 1999). In the case of Brazil’s recent soybean expansion, we argue that the soybean sector has converted significant amounts of its agricultural profits into agricultural land, and into the critical infrastructure and machinery needed to support the production process.

3. Sector-level profits and area responses

If changes in soybean area are directly tied to the ability of the sector to supply its own surplus capital for investment, then cropland areas should expand incrementally as this capital is generated. Similarly, if agricultural areas are expanding as capital constraints are relaxed, then the extent of soybean cropland in any given year should reflect the past ability of the sector to generate and accumulate farm profits. In this section we show that empirical evidence supports these statements.

Over the past two decades, soybean prices (and profits) have fluctuated significantly, rising in the early 2000s, falling in the mid-2000s, and then increasing later in the decade (CEPEA/ESALQ 2018. All data is included in table A1 in the appendix available at stacks.iop.org/ERL/13/075011/mmedia). Soybean area change followed this trend, rising and falling with profit levels during the early 2000s. The co-evolution of these trends appeared to affirm theories that agricultural areas in Brazil were highly sensitive to price levels (see figure 2, Barr et al 2011, Walker et al 2009). Trends during the last half of the decade, however, challenged this conceptual linkage. Agricultural areas continued to grow, despite profit levels (and long-term profit expectations) being lower than earlier in the decade. This suggested a decoupling of the relationship between soybean prices and soybean areas in Brazil. But it could also be explained by an agricultural sector limited not by the spatial extent of profitable farming (or the long-term expectations thereof), but by access to the investment capital needed to sustain its growth.

Brazil’s soybean sector generates, on average, approximately 30Srs billion in farm-level profits in a given growing season (in today’s values, estimated as farm level returns 6 harvested soybean area). Annually, since the late 1990s, sector-wide profits have ranged from roughly 1Srs billion in 2005/06 to 80Srs in 2002/035. In agreement with our conceptual argu-

\[ R_A = \left( Y_{t}^{\text{Brazil}} \cdot p_{t}^{\text{Srs}} \right) - X_{t-1}^{\text{Brazil}} \]

where $R_A$ is returns to soybean production at time $t$, $Y_t$ is average national yield, $p_{t}^{\text{Srs}}$ refers to the price of soybeans on the first day of each year, in Srs. $X_{t-1}$ refers to production costs. We estimated production costs as the average of per hectare production costs (labor, seeds, chemicals, etc.), post-harvest costs (transport, insurance, technical assistance), taxes, and maintenance expenses (includes depreciation of machines and infrastructure) in Primavera do Leste, Mato Grosso and Londrina, Paraná (CONAB 2018). The
ment, the magnitude of sector-level profits generated in a given year has been consistently correlated with changes in soybean area during the following growing season (see figures 3(a) and (b)). The highly profitable 2003 and 2004 harvests, for example, were followed by the creation of 5 mha of new soybean cropland in the ensuing growing seasons. The profitable 2014 and 2015 harvests, which generated an estimated 70$Rs were followed by an additional 5 mha of new farmland. Not coincidentally, we argue, the magnitude of agricultural expansion in any given year during the last fifteen years has been closely correlated with the profits generated by the soybean sector during the preceding harvest periods (figure 3(a)).

Since the late 1990s, the total capital generated by the soybean sector has grown in near parallel with production areas (figure 3(b)). We argue that these parallel growth tracks are a function, in part, of the conversion of the soybean sector’s own profits into new agricultural areas and production infrastructure. Put otherwise, we suggest that today’s soybean areas should be interpreted as the physical and material embodiment of yesterday’s soybean profits (figure 3(b)).

To estimate the effect of changes in sector level profits on soybean areas in Brazil we estimated a series of finite distributed lag models (see equation 3). The general estimation structure is shown in equation (3):

\[
\text{(Area}_t - \text{Area}_{t-1}) = \alpha + \rho(\text{Cap. Surplus}_{t-1} - \text{Cap. Surplus}_{t-2}) + \varphi(\text{Cap. Surplus}_{t-3} - \text{Cap. Surplus}_{t-4}) + \zeta(\text{Cap. Surplus}_{t-3} - \text{Cap. Surplus}_{t-4}) + u
\]

(3)

where we let Area\(_t\) represent the change in area planted as soybeans between \(t\) and \(t-1\); and the variable Cap. Surplus\(_{(t-1)} = \text{Cap. Surplus}_{(t-2)}\) refers to the change in capital generated by the soybean sector during previous growing seasons (in equation (3), seasons \(t-1\ldots t-4\)). The estimated coefficients \(\rho\), \(\varphi\) and \(\zeta\) capture the effect of a change in capital on area change.

We test six models. The first three models test three combinations of distributed lags; three others, provided as robustness tests, estimate the effect of each lag in isolation. The coefficient \(\rho\) captures the instantaneous effect of a shock in capital. When estimated
together, the coefficients $\rho$, $\varphi$ and $\zeta$ estimate the joint or accumulated lag over a three year period.

The results are shown in full in table 1. The largest effects are associated with the coefficient $\varphi$, indicating that the impact of a wave of new capital is likely strongest in the second year after the capital is received. This follows intuitively, given a likely lag time between obtaining the new capital and putting new land into production.

The results also offer an indication of the reflexivity of the soybean sector to the change in capital generated by the soybean sector after a given harvest. We estimate that each $1$Rs billion change in capital available to soybean farmers is associated with an increase (or decrease) of approximately 760,000 ha in area used for soybean production of an ensuing three year period. The change in capital generated by the soybean sector during the 02/03 and 12/13 seasons (56 billion, respectively), for example, correlated with exceptional increases in cropland. Per our estimates, the 02/03 growing season should have led to the creation of an additional 4.256mha in cropland, distributed over the following three seasons. In practice, the 02/03 growing season was followed by an increase of nearly 2.9 and 1.9mha in 03/04 and 04/05 and a decrease of 0.5 mha in 05/06.

Our results are caveated with several limitations. First, we do not control for a shift in profit expectations that might follow a profit shock (as illustrated in figure 1). A rise in profits, for example, may lead to a higher profit expectation from farming, and thus an increase in the demand for cropland.

Second, our estimates do not account for a possible shift in the supply of credit available to the farm sector. Consequently, it is unclear to what extent agricultural capital is derived from agricultural profits or from other, external sources. Trends in interest rates in Brazil, and in the disbursement of capital to the agricultural sector, however, support our argument that liquid capital derived from agricultural profits has been a critical driver underlying agricultural growth.

Brazil’s Development Bank’s (BNDES) disburses loans across a range of agricultural projects, both directly and indirectly, through the national banking system. This funding supports the purchase of machinery or silage facilities, or for priorities in sustainable agriculture or family farming. Since the early 2000s, credit disbursements to agriculture fluctuated between 10 and 20$Rs billion per year (in 2017 values with earlier values inflated using Gross Domestic Product: Implicit Price Deflator (FRED2018)), or a fraction of the capital generated by the soybean sector (figure A1 in the appendix). Regressing BNDES disbursements on area expansion also suggests that these disbursements have little explanatory power for determining soybean expansions.

Soybean area creation also shows little correlation with interest rates in Brazil. Since the late 1990s, the Brazilian Central Bank’s Special Clearance and Escrow System Rate (SELC) has fallen from more than 30% in the late 1990s to 6.5% today. However, rises in the SELC rate, in late 2002 and 2003, in 2011, and in 2015–2016, correspond with years of soybean expansion, suggesting counterintuitively, a positive correlation between soybean profitability (and expansion) and the cost of capital in Brazil (figure A2 in the appendix). This relationship is artefactual to the relationship between the soybean sector and Brazil’s general macroeconomic health. When Brazil’s economy slows, as it did in the early 2000s, and again in the early to mid-2010s, the weaker economy drives down the value of the Brazilian real and raises the effective cost of capital. The weaker real raises returns to soybean farming and by extension, farm level access to investment capital, even as cost of credit in Brazil grows higher.

### 4. Discussion

Over the last two decades soybean farming has swept through vast areas of South America. The growing soybean sector has, in turn, reshaped and redrawn economies and landscapes across the continent. Soybean farms have been broadly tied to economic growth, particularly in Brazil, where they have been linked to better school quality, poverty alleviation, and urban population growth, as well as positive spillovers affecting employment outside of agriculture and non-agricultural GDP (Garrett and Rausch 2015, Richards et al 2015, VanWey et al 2013, Weinhold et al 2013).
Brazil’s soybean sector has also come at a tremendous cost to the environment. Nowhere has this cost been clearer than in central Brazil, where soybeans contributed to deforestation both directly, through the conversion of forests to cropland, and indirectly, through their impact on regional land prices (Arima et al. 2011, Barona et al. 2010, Lapola et al. 2010, Morton et al. 2006, Richards 2015, Richards et al. 2014). Beyond the Amazon, soybean farms have also been tied to forest loss in the Atlantic Forest region of eastern Paraguay (Richards 2011), the Bolivian lowlands (Kaimowitz and Smith 2001, Steininger et al. 2001) and, more recently, the Paraguayan Chaco (de Waroux et al. 2016).

Given the importance of tropical soybean production to the global food supply and economic growth, as well as the impact of soybean farming on the environment, researchers are now seeking to improve our understanding of the causes and consequences of soybean-driven land use change. A more sophisticated understanding of the drivers and impacts of South America’s recent agricultural growth will better equip policymakers to guide future agricultural growth and close yield gaps (Lobell et al. 2009, Mueller et al. 2012).

To date, much of the work towards understanding South America’s agricultural expansion has framed the process as a function of land rents, where farmers change their land use in response to changing institutions or commodity prices, or a change in knowledge or technology (e.g. Angelsen 2007, DeFries et al. 2010, Grau et al. 2005, Rudel et al. 2009). We follow this tradition, but also advance the framework by focusing on a relatively less understood driver of agricultural expansion, namely access to liquid investment capital, and the role of commodity price shocks as providing investment capital to farmers in frontier areas. In this research, specifically, we argued that the soybean expansion should not merely be framed as a function of changing profit expectations, but rather as a series of farm-level responses to shocks in the supply of available investment capital.

The implications of our argument are twofold. First, our findings carry important implications for understanding leakage and indirect land use change. They suggest that agricultural expansion is not limited by expected profit levels, per se, but in some cases, by access to the capital needed to finance new expansions. Put more broadly, they suggest that agricultural expansion is not necessarily a function of changing opportunities associated with land, but rather, a function of the ability of land users to take advantage of these opportunities. The opportunities may exist and may be well identified. The lack of capital, however, currently limits farmers’ abilities to take advantage of such opportunities. This suggests that highly profitable agricultural seasons which generate surplus investments capital are likely to lead to the creation of new cropland. The results also suggest which reduce forest loss in a specific location may only divert agricultural investment capital to new regions. Restrictions on land clearing in the Brazilian Amazon, for example, might redirect agricultural investment capital to the Paraguayan Chaco, the Matopiba region of the Brazil’s eastern Cerrado Biome, or the Pantanal. Similarly, the increase in the supply of farm capital is likely to raise the price of potential agricultural land. Ranchers in these areas may have a great incentive to relocate to where land is cheaper, such as Amazonia, where forest lands can be as much as ten times cheaper than pasture lands in agricultural regions (Arima et al. 2017).

Second, our results underscore the extent to which Brazil’s interior, and perhaps many other potential agricultural regions, are capital constrained. If farmers are able to leverage and convert their surplus capital to productive investments, even a short period of windfall profits (as observed in the soybean sector during the early 2000s) could have a long-term impact on the location and intensity of agricultural production. In the case of Brazil, the capital generated early in the millennium served as the foundation for future capital generation in the sector, and constituted a resource pool which has since continued to propel Brazil’s agricultural expansion. Conceptually, this realization could be critical to policy makers investing in the development of new agricultural frontiers in Sub-Saharan Africa (Gasparri et al. 2015) or elsewhere in Latin America (Graesser et al. 2015).

For much of the last decade, land use scientists have focused on profit expectations as a key driver underlying land use change. In this manuscript, we offered an additional perspective, and argue that capital scarcity, and particularly, the scarcity of liquid investment capital, has limited agriculturally-driven land use change. We also argued that windfall profits to the soybean sector have periodically relaxed these capital constraints, and contributed to rapid, agriculturally driven land use change. At a global level, our results imply that localized environmental protections are likely to divert investment capital to new locations. More broadly, they suggest that understanding or addressing so-called leakage will require not only addressing the leakage of people, but the diversion of investment capital.

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