Implications of Disrupting a Perennial Crop Replanting Cycle: The Brazilian Sugarcane Example

Daniel Tregeagle and David Zilberman

Brazilian sugarcane yields declined sharply in 2011, ending a decade-long expansion of the industry. In the aftermath of the 2008 financial crisis, credit-constrained farmers replanted fewer sugarcane fields, leading to an increase in the average age of canes and a decline in yield several years later. Had average age remained constant over this period, industry revenues would have been around 10% higher in 2011 and 2012. This example shows how interruptions to the regular replanting schedules of a perennial crop can have production effects years into the future.

Brazil was a world leader in biofuel production around the millennium and remained a leader until recently. However, while sugarcane production and yield per acre increased over the first decade, around 2010 yield per acre and overall production declined despite the profitability of biofuels. We investigate this phenomenon using yield data, and media and academic reports.

Our findings provide insight on the dynamic impact of aggregate shocks to the productivity and economics of perennial crops, particularly the role of financial and monetary policy shocks. This is especially relevant to California as much of its agriculture consists of fruit trees, vines, and other perennials, like alfalfa. The first part of our paper is a review of the economics of perennials and the impact of replanting on yields. Then we present the case of Brazilian sugarcane, and our findings and implications.

Replanting and Yield

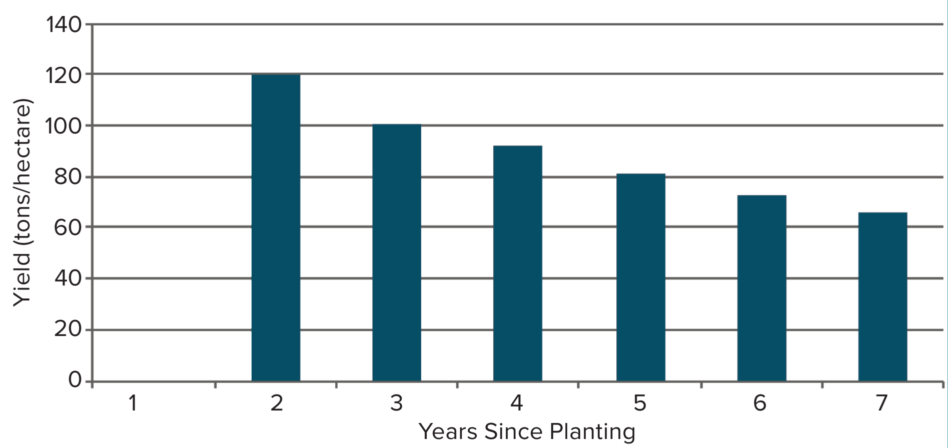
Perennial crops require an initial investment in planting. Then the plant grows and, after some time, starts producing valuable output. In the case of trees, outputs are mostly fruits and nuts. In the case of sugarcane, the stalks are harvested each year for conversion to sugar or ethanol.

The yield-per-acre profile of any perennial changes with the age of the plant. Figure 1 presents the yield profile of sugarcane, which has a non-bearing first year, a production peak at the first harvest, and then decreasing yield. One of the major economic challenges is to determine the optimal replanting age, which takes into account the cost of planting, discounting, yield, price, and operational costs over time.

The optimal replanting age, based on maximization of net present value of profit over time, occurs after the year of peak yield. It occurs at a time period where the economic loss due to delay of replanting (due to declining yields) is equal or greater than the discounted gain from delay of replanting (interest gain from delay of planting costs and delay of non-productive period). Because of differences in weather conditions, pricing, and other factors, optimal replanting age may change across locations. For example, introduction of high-yield varieties that accelerate maturity and yields in the early years can lead to shorter rotations. In some cases, such as California strawberries, we see annual replacement.

Producers aim to stabilize, as well as maximize, their income, so generally they don't replant all their fields at the same time, but rather have plants of varying age. In the case of sugarcane in Brazil, the optimal replanting age is around 5 years, and growers try to allocate their land equally along different vintages. However, if for some reason—perhaps lack of access to equipment—growers fail to rotate, then the age distribution of their plants changes. For example, if a grower wasn't able to replace 5-year-old sugarcane, then the next year he will have plants aged 2-6, but no 1-year-old plants. At the year of the delay, the average yield will go up

Figure 1. Yield of Sugarcane in the South-Central Region as a Function of Years Since Planting

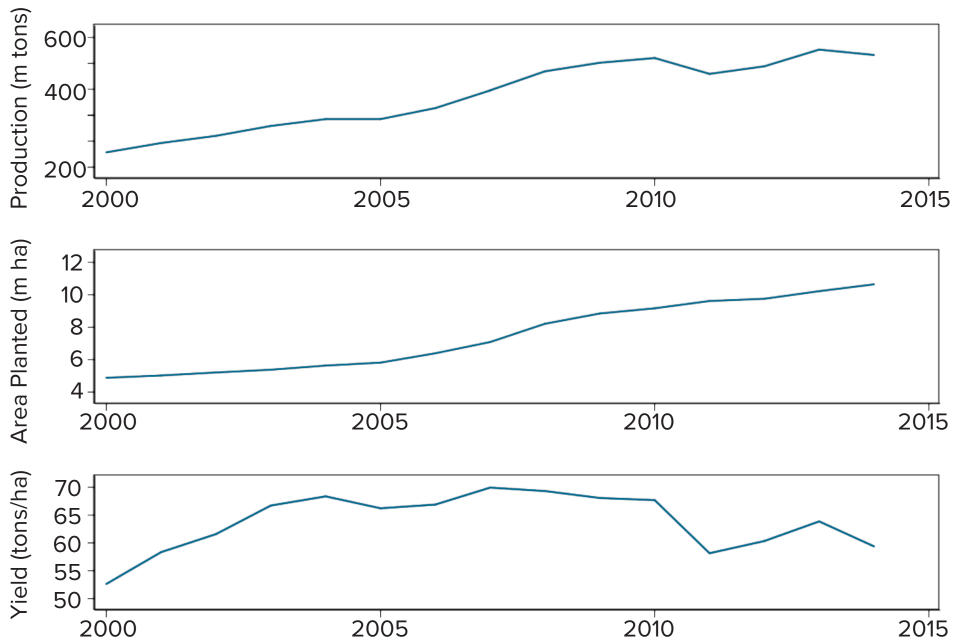


Source: Margarido and Santos (2012)

because the yield of the sixth year is greater than that of the first year. But in the following year, the grower may need to replace both the fifth and sixth year so that the subsequent year's average harvest goes down.

Based on our simple argument, we will see a period of increased yields followed by a strong yield reduction when, for whatever reason, harvesting was delayed. In 2011, Brazilian sugarcane exhibited a sudden decline in yields per acre (Figure 2). We investigated the role of replanting in explaining this decline.

Figure 2. Production, Planted Area, and Yield of Sugarcane in Brazil from 2000–2014



Source: Instituto Brasileiro de Geografia e Estatística

Growing Sugarcane in Brazil

Sugarcane is a perennial grass, usually grown on a replanting cycle of 4–8 years, which is harvested and sent to local mills for processing into sugar and/or ethanol. After it is cut, sugarcane is highly perishable and needs to be processed as fast as possible to avoid losing sugar content. Most cane is collected from fields close to the mill—the average distance is 22 kilometers in São Paulo—and is delivered less than 24 hours after harvesting.

In the 2014–15 harvest year, Brazil produced 532 million tons of sugarcane, which was processed into 35.5 million tons of sugar and 28.4 billion liters of ethanol. This harvest was grown on 10.9 million hectares of land, a small fraction of Brazil's 330 million hectares of arable land, but a more significant fraction of its 60 million hectares of cultivated agricultural land. Brazil is by far the world's largest producer of sugarcane, producing a greater mass of sugarcane in 2015 than the next six largest producing countries combined.

In 2014, the sugarcane sector produced over US$70 billion in revenue, accounting for around 3.5% of Brazil's GDP. The sector employs approximately 1% of Brazil's labor force. In Brazil, most sugarcane is grown in the South-Central region, accounting for 91% of production in 2015, and 98% of this production comes from six states: Goìas, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paranà, and São Paulo.

The 2011 Decline in Sugarcane Production

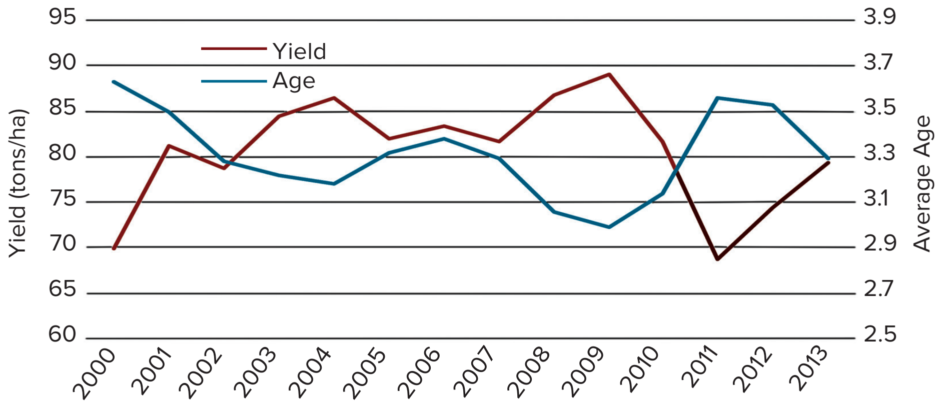
After a decade of steady growth, sugarcane production declined around 10% in 2011 relative to 2010 (Figure 2). There are a number of factors that may account for this decline, including poor weather, the loss of competitiveness of hydrous ethanol relative to gasoline, increased costs of production, and a reduction in the productivity of sugarcane fields. We focus on the reduction in productivity due to the increase of the average age of sugarcane fields because this provides an interesting case study of the lags between cause and effect in the production of perennial crops.

Despite prior predictions that it would remain sheltered, Brazil's economy was negatively affected by the 2008 global financial crisis, including a reduction in GDP, a sharp devaluation of the Brazilian currency, the Real, an increase in the average lending interest rate, and credit rationing. Brazilian sugarcane growers use credit to invest new capital, cover operating expenses, and renew their sugarcane. They receive credit from a mix of private and public lenders, including agricultural equipment manufacturers such as John Deere and Case New Holland, commercial banks, and government credit agencies, such as the National Bank for Economic and Social Development (BNDES).

Before the credit crisis in 2008, the sugarcane industry had taken on a high level of debt, partly to finance the mechanization of harvesting. The industry average debt/revenue ratio was approximately 0.5 in the 2006–07 harvest year, composed mostly of long-term debt. In the following year, however, debt levels rose rapidly to 125% of revenues with a short-term debt rising to around 40% of revenues.

High levels of debt, combined with the reluctance of lenders to provide new or refinance existing loans, led to a substantial reduction in the credit

Figure 3. Yield and Average Age of Sugarcane in the South-Central Region, 2000–2013



Source: União da Indústria de Cana-de-Açúcar

available to sugarcane growers. "Poor weather, and cash-strapped growers delaying their replanting after the 2008 credit crunch, have recently squeezed production." (*The Economist*, 2012) At the time, the vice president of the Brazilian National Agriculture Confederation, Carlos Sperotto, was quoted as saying "The amount of financing will determine the size of the crop… lower financing means smaller crops."

Unable to access credit, farmers responded by foregoing planned replanting operations, choosing instead to further harvest their aging canes. "Mills cut investment in renewing cane plants as they tried to get back on their feet financially, hitting output as yields from aging cane dipped." For reasons explained in the previous section, this did not have an immediate effect on sugarcane yields, rather the effect was delayed by several years. Figure 3 shows the average age and the average yields in the South-Central growing region. From 2008 to 2012, the average age of the sugarcane fields increased from 3.17 years to 3.7 years.

In addition to reduced yields and production, the difficult conditions led to the closure of sugarcane mills. In 2011 and 2012, 11 more mills closed than new mills opened each year, standing in contrast to the previous four years, which had an average of 18 net openings.

Increase in Age Explains Much of the Decline

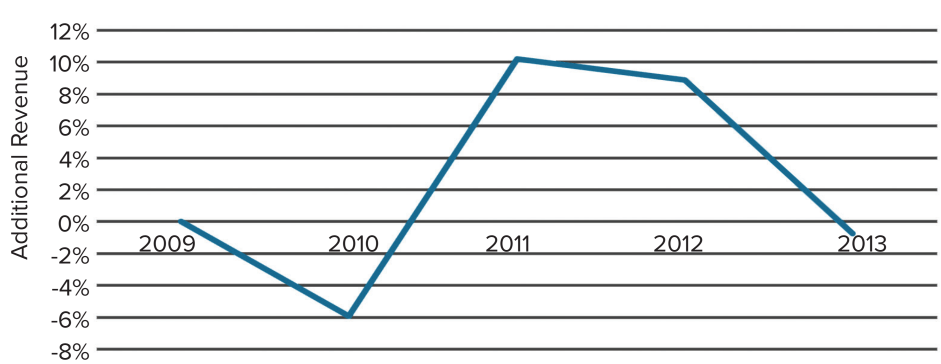
There is a strong, negative correlation between average age and yield, as shown in Figure 3. The average age can increase if sugarcane is not replanted regularly. A simple regression of yield as a function of average age using data from 2000 to 2013 shows that, on average, a one-year increase in the average age is associated with a 30-ton-per hectare reduction in yield.

What if Brazilian sugarcane growers had been able to keep the average age of their canes relatively constant? We perform a simple calculation to estimate the approximate loss of revenue to the Brazilian sugarcane sector from the reduction in average age. After 2009, average age is assumed to be constant at the 2000–2009 average, and the yield in those years is calculated using the results from the regression of yield on age.

We then multiplied this counterfactual yield series by the planted area to obtain production. We calculated the counterfactual revenue by multiplying this production series by the sugarcane price received by producers each year. Subtracting the counterfactual revenue from the revenue calculated using the fitted yields from the observed age series gives us an estimate of the revenue lost from the reduction in age. We compare counterfactual yields to fitted yields rather than observed yields to keep the error in the model constant. Comparing counterfactual yields to observed yields would confound the result, with part of the difference in revenue due to holding age constant, and another part due to the error in the regression of yield on age.

Figure 4 shows the increase in revenues from holding the average age constant in 2010–2013, expressed as a percentage of the fitted revenues. Holding age constant over the 2010–2013 period resulted in a 6% revenue reduction in 2010, increases of 10% and 9% in 2011 and 2012, and a small reduction of around 1% in 2013. These results represent an upper bound on

Figure 4. Additional Revenue to Sugarcane Sector from Holding Average Age Constant at Pre-2010 Levels



Source: Authors' calculations

the revenue changes because we are holding the sugarcane price constant. The actual sugarcane price would likely have been lower in 2011 and 2012 in response to the extra sugarcane production, and higher in 2010 and 2013 due to lower production. Nevertheless, these results represent an estimate of the order of magnitude of the effect of holding the average age constant.

This simulation suggests that the Brazilian sugarcane industry could have had around 5 billion additional Reals (2.5 billion USD) in revenue in each of 2011 and 2012 if the average age of the sugarcane crop had been kept constant over this period by replanting aging canes in the preceding years. During this period, growers did not have access to private credit due to their pre-existing indebtedness and the reluctance of private banks and firms to lend during the credit crisis. In 2012, the Brazilian government, through the BNDES, made a R$4 billion line of subsidized credit available to growers specifically for plantation renewal. However, had such loans been available throughout and after the credit crisis, yields could have remained stable, mills might have avoided closing, and the sector might have avoided the shock in 2011 and 2012.

Conclusions

Perennial crops are, in essence, durable assets, and growers rely on credit when investing in them. A dysfunctional system, which breaks down and cannot provide credit at certain times, has a short-term and long-term impact on perennial agriculture. This needs to be addressed by some mechanism to allow farmers access to credit during these times. Inability to obtain credit may alter the replacement of crops, resulting in a period of surplus followed by shortage. Both growers and—especially—consumers, may lose from such cycles.

The example of the Brazilian sugarcane sector illustrated this instability by showing how the productivity and success of an industry that relies on perennial crop production can depend on the crop's average age. The average age depends on the recent history of planting and replanting decisions. A shock to these investments has persistent effects years after the shock itself has passed.

Credit availability is only an example of a shock to input availability causing persistent effects to average age. Other inputs to perennial production can also have long-lasting impacts. California has relatively robust credit markets, but irrigation water is a key scarce input to agricultural production. During droughts, water stress can reduce tree yields and even lead to tree death. Even after the drought, stressed trees may not return to full yields. Furthermore, growers may delay planting new trees since seedlings are particularly vulnerable to unreliable water supply (although in the recent drought, perennial plantings actually increased due to factors unrelated to water scarcity).

Illustrating the value of reliable input supply, growers are willing to pay high prices for key inputs to preserve the productivity of perennials. In California, intra-district water transfers are increasingly common, shifting water to perennials from lower-value crops such as rice, and the water is traded at a high price. In a similar, international example, water prices in the Murray-Darling Basin in Australia rose tenfold during the depths of the Millennium Drought in 2007 as citrus growers tried to preserve the productivity of their investments.

Ensuring steady access to key inputs like credit or water during times of stress and crisis can aid the future stability and profitability of a perennial crop industry. Policymakers can assist by identifying key inputs and implementing mechanisms to preserve access during times of crisis, such as emergency loans or water-trading schemes.

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