Credit Enforcement and Firm Boundaries: Evidence from Brazil

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Abstract

I study how lenders develop alternative enforcement mechanisms to overcome weak creditor rights. Using data from a large agribusiness lender in Brazil, I examine the construction of grain silos that enable the lender to offer a credit contract that is repaid in grain. Consequently, the lender improves collateralization of its loans and significantly increases lending. The effects are stronger for municipalities with weaker courts, financially-constrained borrowers, areas exposed to more weather risk, and periods of high commodity price volatility. Thus, I uncover a new mechanism, accessed by expanding firm boundaries, to facilitate debt financing.

Keywords: Credit Enforcement, Debt Contracts, Firm Boundaries, Trade Credit

JEL Classification: D23, G32, G33, L22, L25

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1 Introduction

Credit markets play a critical role in fostering economic growth through allocation of capital in the economy. These markets, however, are characterized by imperfections such as information asymmetry between lenders and borrowers that create inefficiencies in the allocation process. Consequently, a large literature emphasizes the importance of financial contracts and legal institutions in mitigating these frictions (for example, La Porta et al. (1998)). In this paper, I document how lenders develop alternative enforcement mechanisms, accessed by expanding firm boundaries, to mitigate credit market frictions when formal creditor rights are weak.

Since the seminal work of Coase (1937), an extensive theoretical literature has analyzed the determinants of firm boundaries and the effects of these boundaries on economic outcomes (most notably, Williamson, 1975, 1985; Klein et al., 1978; Grossman and Hart, 1986; Holmström and Milgrom, 1991, 1994; Baker et al., 2002). Despite this large theoretical literature, empirical research has lagged behind. There are several obstacles that hinder research in this area. In particular, the effects of organizational form are difficult to identify empirically, as firms do not choose their form randomly. A profit-maximizing firm optimizes its organizational structure to achieve the highest profit. Thus, to assess the effect on economic variables, one requires a laboratory providing a plausibly exogenous variation in the boundaries of a firm. Furthermore, a researcher needs detailed contract-level data to analyze the effects of firm boundaries on financial contracts. This paper overcomes both of these challenges and documents how a lender facilitates debt financing through a contracting technology that is accessed by expanding firm boundaries.

In this paper, I use micro-level data from a large Brazilian agribusiness lender with sales of over 1 billion USD and a client base of 19,000 farmers in 2013. The agribusiness 1) sells farm production inputs such as fertilizer and pesticides, 2) provides trade credit to small farmers who have limited access to bank financing,[1] and 3) collects, stores and trades grain. Important to note, such agribusinesses are the main creditors for these farmers in Brazil.[2] Herein, I investigate how the construction of grain silos, a contracting technology, affects the supply of credit by this agribusiness lender.

[1]The agribusiness lender provides trade credit only in the form of production inputs such as fertilizer. It never gives out cash.

[2]See Agrarian Markets Development Institute (2011) for a detailed market overview.

The access to a silo enables the lender to offer a new credit contract, *barter credit*, that is repaid in grain rather than cash. In such a contract, the lender and a farmer fix the quantity of grain to be delivered to the lender's silo at the date of maturity. For credit that is settled in cash, however, a farmer chooses freely where to deliver and sell the grain (usually to a third party silo)[3] and repays the debt only after receiving a cash payment. As a result, the repayment takes place four to six weeks after the harvest and effectively leaves the creditor without the collateral during this period, since the farmer no longer owns the grain. Because the creditor can gain access to the unharvested grain during the harvest, a barter contract, which matures in this period, has a stronger enforcement due to a credible threat of liquidation. If a farmer does not deliver the grain, the agribusiness has the right, provisioned by the law, to liquidate the grain by harvesting it almost immediately. The same applies with cash credit contracts, however, by construction, cash contracts mature after the grain has been harvested. That makes it difficult to seize the collateral.[4] Furthermore, as the barter contract fixes the quantity of grain to be delivered, it provides a hedge against commodity price risk and reduces the need to monitor the borrower's open hedging positions.

The dataset is rich in detail and offers comprehensive information on all financial contracts between the lender and the borrowers. Most importantly, it provides both time-series and cross-sectional variation in the contracting technology. For identification, I exploit the staggered construction of grain silos by the lender and employ a difference-in-differences (DID) research design. It is important to note that the agribusiness lender has refused the use of third-party silo operators, based on the considerable risk in enforcing repayment from them.[5] Valid estimates,

[3] There is no written commitment to deliver the grain to the lender's silos under cash credit contracts even if a silo is accessible. For branches without silos, it is the norm to use cash credit contracts and deliver the grain to a third party silo.

[4] In comparison, the bankruptcy procedure for bank debt is very lengthy and and can last for several years.

[5] Upon recipient of the grain, a silo operator becomes an "effective" owner of the grain. If the silo operator defaults or decides to expropriate the grain, the bankruptcy procedure to repossess this grain is cumbersome and inefficient relative to recovering it from a farmer's premises (the CPR contracts are only available with farmers). This is the hold-up problem, as discussed by transaction-cost economics (Williamson, 1975, 1985; Klein et al., 1978). The lender also argued that writing a long-term lease contract with a silo operator is risky. It is difficult both to contract on all possible states of the world ex-ante and to renegotiate if the operator fails to respond to unforeseeable market developments. Thus, the lender may be burdened with silos that are inappropriate to serve farmers' future needs. For example, the offloading mechanisms may be significantly slower than those of a competitor. As delays in harvesting can be excessively costly, farmers will shy away from the lender in favor of competitors. Thus, it might be optimal for the lender to integrate the silos, as proposed by the property-rights theories of the firm (Grossman and Hart, 1986). For these two reasons, the lender expands the firm boundaries and constructs its own silos.

however, require identifying a branch that is, in effect, identical to the branch where the silo was constructed (henceforth, "the treated branch"). A random branch can differ from the treated branch in terms of local demand, land productivity and many other variables. I overcome this challenge by relying on alternative locations for silos that the lender considered "near equivalent" when the decision on where to locate the new silos was made. When the owners consider where to open a silo, they typically begin by examining several possible locations. Then they narrow the list to roughly four finalists. Thus, by knowing the finalists, I can identify the treated branch as well as the runner-up branches (i.e. the control branches).

The identification assumption is that from an existing borrower's perspective, the unit of analysis, the construction choice is exogenous.[6] This assumption is justified by the fact that the main purpose for constructing a silo is to enter the grain trading business rather than to issue more credit. A typical silo is used by roughly 800 farmers. Existing borrowers as a group deliver only 16 percent of the total grain volume, whereas individually these borrowers deliver a tiny 0.2 percent each. Thus, an existing borrower is an atomistic element and unlikely to drive the construction choice. Furthermore, 75 percent of the control branches are treated later on. This staggered construction arises from the substantial investment of 8 million USD that is necessary to build a silo.[7] Hence, the treated and control branches are "equal" except for the timing of the construction. To confirm that the alternative locations form a valid counterfactual for the treated branches, I formally tested for the differences between treated and runner-up branches in the period 18 to 0 months before the treatment. Treated branches are similar to runner-up branches on all variables such as the total credit and the number of borrowers. This convincingly shows that the runner-up branches do form a valid counterfactual for the treated sample.[8]

To alleviate concerns that the treatment and control groups differ on some unobservable dimensions, I perform several robustness tests. By including branch-month fixed effects, I show that the results remain strong even after controlling for the choice of where and when to build a silo, changes in aggregate branch level demand, investment opportunities, or any other observable and unobservable time-varying branch-specific component. I also exploit the staggered

[6] An existing borrower is a farmer who bought inputs on credit before the opening of a silo.

[7] The operating costs of a silo are roughly 1 million USD per year.

[8] I compare also treated branches to all non-treated branches and find significant differences. Treated branches issued less credit and lent to fewer customers during the period prior to building a silo. Thus a randomly selected non-treated branch would be a bad counterfactual already on observables.

nature of the treatment and run a DID specification, using the treated branches only. The identification assumption here is that all treated branches are "equal" and differ only on the time of construction. The results remain qualitatively the same. Additionally, a battery of cross-sectional tests uphold my identification strategy.

Besides its unique laboratory, the Brazilian farming industry has several practical features that make it favorable for analyzing the effect of a contracting technology on financial contracts. First, 70 percent of farming activities in Brazil are financed through credit (Agrarian Markets Development Institute, 2011). Second, and more importantly, 60 percent of this financing is raised through a special contract – called a Rural Product Note – that is largely provided by agribusiness lenders. The contract was created so that non-bank financial institutions, such as the lender studied here, could provide financing for farm production inputs, as bank financing was difficult to obtain. Both cash and barter contracts that are issued by the agribusiness lender fall under this contract type. Third, Brazil is a key player in the global agriculture commodity market.[9]

My main finding is that expanding firm boundaries and gaining access to the new contracting technology mitigates credit market imperfections. I find that the construction of grain silos enables the lender to offer a new credit contract that is settled in grain and has a better collateralization. This leads to an increase in lending to existing borrowers by 30 percent. At the same time, the issuance of credit that is repaid in cash remains unchanged. In terms of contract performance, I find that the default rates remain the same and the markup of credit sales declines by 9 percent.[10] Thus, the lender is able to provide more credit at a lower price. Importantly, none of these results are driven by pre-treatment trends.[11]

I also find real effects for the economy. Since my data does not provide direct measures of total production and profitability at the farmer level, I measure the effect of a new contracting

[9]For example, Brazil has been the second largest producer and the largest exporter of soybean since 2010 (United States Department of Agriculture, 2014). Furthermore, the agricultural sector accounts for 33 percent of Brazil's gross domestic product and employs more than 40 percent of the workforce (Agrarian Markets Development Institute, 2011). In addition, globally the agricultural sector employs more than 38 percent of the workforce (International Labour Organization, 2014), making the farming sector particularly important.

[10]The markup is calculated as the total farmer's payment for the inputs (fertilizer, seeds, etc.) that it sold on credit over the raw costs of those inputs. Thus, it also includes the interest rate.

[11]The results are similar for new borrowers (i.e., extensive margin) as well. The results are not reported here, since this analysis is done at the branch-level, which requires stronger assumptions on the exogeneity of the location of the branch.

technology at the municipality level. I find that both the total output and the GDP increase by 15 and 2.5 percent, respectively. Furthermore, the growth is stronger in municipalities with weak courts, measured by pending cases per judge. Thus, the access to a new contracting technology not only affects the supply of credit from the agribusiness's perspective but also increases the production output and GDP at the municipality level.

With regard to the mechanism, I provide several cross-sectional tests that identify a reduction in credit market frictions. Most importantly, the results are stronger in municipalities with lower court quality, thereby stressing the contract enforcement channel. Furthermore, the improved contracting technology provides more benefits to the constrained farmers and to farmers exposed to higher weather risk. Constrained farmers are those who rent the farmland and, thus, cannot use it as a collateral for bank financing. Finally, the embedded price hedge in a barter contract is particularly important to manage the price risk in periods of high commodity price volatility (as suggested by Smith and Stulz (1985); Froot et al. (1993)).[12]

My analysis contributes to several streams of the literature. First of all, I present evidence on how to mitigate credit market imperfections and improve access to finance. Law and finance literature argues that formal institutions such as courts are important for mitigating contracting frictions (La Porta et al., 1998; Levine, 1999; Benmelech et al., 2005; Djankov et al., 2007; Qian and Strahan, 2007; Benmelech and Bergman, 2008; Davydenko and Franks, 2008; Benmelech, 2009; Haselmann et al., 2010; Vig, 2013; Assunção et al., 2014). Alternatively, similar effects can be achieved through informal institutions such as relationships (Petersen and Rajan, 1994) or social capital (Karlan, 2005). I document that lenders controlling warehouses and distribution channels of their customers are more likely to extend credit. Thus, this paper describes a new mechanism, designed by a lender, to overcome weak creditor rights and improve access to finance, suggesting that markets invent alternative credit enforcement mechanisms where formal institutions fail to.

My research also adds to the literature on firm boundaries. Some previous empirical studies have shown that asset ownership creates incentives to preserve asset value (Baker and Hubbard,

[12]Besides the price risk management, bundling the forward contract with credit can solve incentive problems associated with both moral hazard and asymmetric information (Adams and Yellen, 1976; Laffont and Tirole, 1986; Holmström and Milgrom, 1991). For instance, the lender does not need to monitor the borrower's hedging position.

2004) and that vertical integration can lead to economies of scale (Hortaçsu and Syverson, 2007) and facilitate intra-firm transfer of intangible assets (Atalay et al., 2014). Others have analyzed the costs and benefits of consolidation in banking (Akhavein et al., 1997; Prager and Hannan, 1998; Berger et al., 1999; Sapienza, 2002) and the conglomerate structure (Rajan et al., 2000; Schoar, 2002; Seru, 2014). I provide a novel insight that lenders expand their boundaries to mitigate credit market frictions between lenders and borrowers by means of accessing a contracting technology. With that in mind, I do not claim that the integration of a grain warehouse is necessary. Whether it is possible to achieve similar results with a long-term lease contract is out of the scope of this paper.

The paper relates to the growing literature on the role of the trade credit in the real economy (for instance, Petersen and Rajan (1997)).[13] Some of the recent papers argue that trade credit is used to create barriers to entry (Barrot, 2015) and to provide liquidity (Garcia-Appendini and Montoriol-Garriga, 2013) and that limiting the contract space for trade credit terms can result in an integration of the customer (Breza and Liberman, 2015). Others have explored the propagation of bankruptcy through trade credit (Jacobson and von Schedvin, 2015) and the implicit cost when large firms borrow from smaller and more constrained ones (Murfin and Njoroge, 2015). I contribute by showing that financially constrained borrowers with limited access to high-quality pledgeable assets benefit more from the new contracting technology. Such borrowers are often characterized as "soft" information borrowers who are likely to be rationed by large and hierarchical banks (Petersen and Rajan, 1994; Liberti and Mian, 2009; Skrastins and Vig, 2014). Thus, the evidence supports the idea that trade creditors provide credit where banks do not.[14]

The rest of the paper is organized as follows. In the next section, I begin by providing an overview of the data and a description of the institutional details of the agribusiness lender and the farming industry in Brazil. In Section 3, I lay out my identification strategy. Section 4 describes the results on contract types, loan quantities, defaults, and prices; Section 5 analyzes potential mechanisms; and Section 6 rules out a range of alternative explanations. Section 7

[13]See Ng et al. (1999), Wilner (2000), Demirguc-kunt and Maksimovic (2002), Fisman and Love (2003), Cuñat (2007), Love et al. (2007), Giannetti et al. (2011), Klapper et al. (2012), Dass et al. (2015), and Antràs and Foley (2015) among many others.

[14]This result fits well with the theory of Frank and Maksimovic (2005) who argue that trade creditors value collateral higher than banks do.

concludes the study.

2 Institutional Background and Data

The data provider for this study is a large agribusiness lender in Brazil, with annual turnover above 1 billion USD and a customer base of over 19,000 farmers as of December 2013. The firm operates in three lines of business: 1) sales of farm production inputs such as fertilizer and pesticides to farmers, 2) sales of these production inputs on credit, and 3) trading of agriculture commodities – buying and storing grain from farmers and selling to large purchasers both domestically and internationally (see Figure (1)). The firm provides these services to small and medium size farmers (the average farm size is 150 hectares with a harvest-level revenue of 179,000 USD) who have limited access to bank finance. This study focuses on the lending side of the business, where the firm operates as a creditor to farmers.

The dataset is rich in detail. It contains detailed information on all loan contracts, hedging positions, purchases and sales of production inputs and grain products at the invoice level. At the loan contract level, it includes the loan balance outstanding, whether it is a barter or cash credit, the maturity, and the number of days late in payment, among other details. On the production inputs front, it includes raw costs, purchased quantity, and an inventory of all the products bought by the agribusiness lender from its suppliers. It also holds information on all sales invoices that the firm made to its clients – the quantity and the price by product. The sample spans seven years – from January 2006 to December 2012.

2.1 Institutional Setup: Credit

A farmer can purchase production inputs such as fertilizer or pesticides from the lender in two ways – either by paying cash or by borrowing on credit (see Figure (2)). When a client borrows to purchase the production inputs, there are two ways in which the debt can be settled. First, the borrower can repay the debt in cash at a predetermined date, making it a standard debt contract. Second, instead of repaying in cash, the borrower can agree to deliver grain at a price that is fixed at the issue of the contract. Essentially, such a loan agreement is a standard credit contract combined with a forward contract with physical delivery on an agriculture commodity.

For simplicity, I call this combined contract a *barter credit* because the lender and a farmer exchange production inputs for grain at two distinct points in time.

A few further details must be clarified. Both types of credit – cash and barter – are a special type of loan contract for farmers and are called Rural Product Notes (CPR or *Cedula de Produto Rural* in Portuguese). The CPR is a debt contract that allows farmers to finance their production with a credit agreement, before their crops are ready for sale. The CPR represents a promise of rural product delivery or cash payment. Both cash and barter contracts have the same collateral – future harvest – and are subject to the same enforcement and bankruptcy procedure. In Brazil, roughly 60 percent of external financing in farming is raised through these contracts, while the remaining 40 percent is raised through bank debt (Agrarian Markets Development Institute, 2011). In comparison to a bank debt, when a CPR is in default, the lender can liquidate the collateral immediately upon presenting the original CPR on which the farmer has defaulted. However, when a bank debt is in default, the bank has to go through a bankruptcy procedure to prove the borrower did not honor the contract. Only after approval by a judge the bank can liquidate the collateral. While the liquidation of the CPR can be executed within a few days, the average bankruptcy case in Brazil lasts for 4 years (The World Bank, 2014).

The two types of contracts have several important differences (see Figure (2)).[15] First of all, having access to a silo is essential for accepting grain as a repayment. Second, a barter credit fixes the commodity price by limiting a farmer's exposure to price fluctuation, which is a major risk in farming (Harwood et al., 1999; OECD, 2009). In addition, bundling together credit and a price hedge can overcome moral hazard and asymmetric information issues (Adams and Yellen, 1976; Laffont and Tirole, 1986; Holmström and Milgrom, 1991). For instance, there is no need to monitor the borrower's open hedging positions, as the lender knows that a farmer has hedged the total value of credit.

Finally and most importantly, barter contracts have a stronger enforcement. To better understand this, let's first look at how cash contracts work (see Figure (3)). Since under cash

[15] For detailed legal documentation, the reader can refer to laws 8,929/94, 10,200/01, and 11,076/04, which govern these contracts. A detailed description of the financial instrument is provided by National Association of Financial Market Institutions (2009).

contracts a farmer is free to choose where to deliver and sell the grain (usually to a third party silo), there are three players: a creditor, a farmer, and a silo operator. After obtaining credit, a farmer produces grain. To repay the credit, a farmer first must receive cash by harvesting and selling the grain. Since this takes four to six weeks, all cash contracts have to mature after the harvest. The challenge for the creditor is that during the period after the harvest it effectively loses access to the collateral, as it is stored in a third party silo. In case the silo operator defaults or decides to expropriate the grain, the bankruptcy procedure to repossess this grain is cumbersome and inefficient relative to recovering it from a farmer's premises. By contrast, barter contracts mature within the harvest. If a farmer does not deliver the grain, the agribusiness has the right, provisioned by the law, to liquidate the collateral – grain – by harvesting it almost immediately. The same applies with cash credit contracts, however, by construction, cash contracts mature after the grain has been harvested. Thus, a barter contract has a stronger enforcement due to a credible threat of liquidation.

2.2 Summary Statistics

I focus on farmers who bought production inputs on credit. Within the sample period, the firm issued roughly 300,000 such contracts. In Table (1), I present means, medians, standard deviations, and the 1st and the 99th percentile for the main variables of interest for both client-month and branch-month levels. The loan amounts are expressed in Brazilian reais.[16]

During the sample period 7,637 clients borrowed from the firm. Out of these, 2,951 clients or roughly 40 percent used barter credit. The average size of a farm in the sample is 158 hectares (roughly the size of 150 soccer fields), while the median is 50 hectares. To put this in perspective, farms less than 500 hectares in size constitute 98 percent of the number of farms and only 44 percent of the land area in Brazil (Berdegué and Fuentealba, 2011). The average total outstanding value of credit for a borrower is 34,200 reais a month, which is roughly 17,000 USD. Furthermore, the value-weighted default rate, defined as 1 if the loan is not repaid on time and is renegotiated or defaults, is 6.5 percent. The average maturity and markup, defined as the final payment over raw costs of the inputs,[17] are 192 days and 39 percent respectively. On an

[16] The average exchange rate during the sample period was 0.534 USD per Brazilian real.

[17] I observe the raw costs of the inputs sold on credit and the final value paid for those inputs. Hence, I can only calculate the markup. This markup also includes the interest rate.

average month 31 percent of borrowers' total outstanding debt is barter credit. However, that fraction increases to 83 percent after considering only those months when at least part of the total debt is raised through barter credit.

At the branch-month level, an average branch issues 451,000 reais (or 241,000 USD) worth of new debt each month. On average, a branch issues new credit to 43 borrowers per month. The value-weighted default rate, defined as 1 if the loan is not repaid on time and is renegotiated or defaults, is 6.5 percent. The average maturity and markup are 164 days and 36 percent respectively. The average fraction of barter credit is 31 percent.

Table (2) reports cross-sectional summary statistics based on whether a branch office has a silo or not. Both borrower-level and branch-level cross-sectional results (Panels A and B, respectively) suggest that a branch with a silo is associated with more lending and more barter contracts.[18] At the borrower level, both total credit and the barter credit are 50 percent higher in branches with a silo. At the branch-level, the difference in quantities is even greater. Total new credit and the number of borrowers taking out a loan are both at least twice as high in branches with a silo. In addition, the fraction of barter credit is 50 percent higher in branches with a silo. Moreover, the kernel densities in Figure (4) show that cross-sectionally the amount of credit is larger in branches that have a silo.

That said, it should be noted that all these cross-sectional patterns may be driven by heterogeneity in types of borrowers in different branches. For instance, borrowers in a branch with a silo may have a different appetite for risk or lower creditworthiness. Thus, to alleviate these concerns, I examine within-borrower variation in contracting technology (i.e. access to a silo), allowing me to control for such cross-sectional differences.

3 Identification Strategy

3.1 Construction of Silos

Historically, the firm started as a distributor of production inputs by selling both on the spot and on credit. The firm grew in two ways. First, whenever it expanded its geographic reach,

[18] The branch without a silo can still issue a barter contract, the delivery of grain would be to a lender's silo located next to another branch. This feature is exploited by farmers who are located roughly between two branches and find it economically feasible to deliver the grain to another silo. I exploit this feature in my robustness tests.

it did so by opening a branch that sold production inputs. Second, over time it also entered the grain business by constructing grain silos. At the end of 2013, the firm operated 77 branch offices, of which 36 had a silo.

The construction of a silo is a special case of vertical integration (see Figure (5)). The firm integrates a business unit that is vertically related in the farm supply chain. Thus, it is not the traditional vertical integration when a business absorbs either a customer or a supplier, but it integrates a downstream firm from a supply chain. Having a silo enables the firm to offer two new products. First, it can buy, sell and store grain that is produced by farmers. Second, it can offer a barter credit, since it has a facility where to store the delivered grain.

Noteworthy, the lender has strategically refused the use of third party silos for barter credit transactions, as it sees considerable risks in enforcing repayment by silo operators. Upon recipient of the grain, a silo operator becomes an "effective" owner of the grain. If the silo operator defaults or decides to expropriate the grain, the bankruptcy procedure to repossess this grain is cumbersome and inefficient relative to recovering it from a farmer's premises (the CPR contracts are only available with farmers). This is the hold-up problem, as discussed by transaction-cost economics (Williamson, 1975, 1985; Klein et al., 1978). The lender also argued that writing a long-term lease contract with a silo operator is risky. It is difficult both to contract on all possible states of the world ex-ante and to renegotiate if the operator fails to respond to unforeseeable market developments. Thus, the lender may be burdened with silos that are inappropriate to serve farmers' future needs. For example, silos with grain dryers and offloading mechanisms that are slower than those of a competitor. As delays in harvesting can be excessively costly, farmers will shy away from the lender in favor of competitors. Thus, it might be optimal for the lender to integrate the silos, as proposed by the property-rights theories of the firm (Grossman and Hart, 1986). For these two reasons, the lender expands the firm boundaries and constructs its own silos.

My identification strategy hinges on the construction of silos. Because the decision on where to locate the new silo is made to maximize profits, the branch selected for treatment is likely to differ substantially from a randomly chosen branch, both at the time of opening and in future periods. Valid estimates require the identification of a branch that is identical to the branch where the silo was constructed. That, however, is a difficult task. My solution is to rely on alternative locations for silos that the owners of the lender considered as "equivalent" at the time of construction (see Figure (6)). When the owners decide where to open a silo, they typically begin by considering several possible locations. Then they narrow the list to roughly four finalists. Thus, by knowing the finalists, I can identify the branch where a silo was constructed (i.e. the treated branch), as well as the runner-up branches (i.e. the control branches). The runner-up branches are the ones that survived a long selection process but narrowly lost out to the treated branch. They provide a counterfactual for what would have happened to the borrowers in a branch in the absence of the construction of a silo. These alternative locations are derived from the firm's archives and interviews with the owner-managers of the lender.

The identification assumption is that from an existing borrower's perspective, the unit of analysis, the construction choice is exogenous.[19] This assumption is justified by the fact that the main purpose for constructing a silo is to enter the grain trading business rather than to issue more credit. A typical silo is used by roughly 800 farmers. Existing borrowers as a group deliver only 16 percent of the total grain volume, whereas individually these borrowers deliver a tiny 0.2 percent each. Thus, an existing borrower is an atomistic element and unlikely to drive the construction choice. Furthermore, 75 percent of the control branches are subsequently treated. This staggered construction arises from the substantial investment of 8 million USD that is necessary to build a silo. This illustrates that the treated and control branches are "equal" except for the timing of the construction.

To confirm that the alternative locations form a valid counterfactual for the treated branches, I formally test for the differences among treated, runner-up and all non-treated branches in the period 18 to 0 months before the treatment. This exercise provides an opportunity to assess the validity of the research design, as measured by preexisting observable branch characteristics. To the extent that these observable characteristics are similar among treated and runner-up branches, this should lend credibility to the analysis. Furthermore, the comparison between the treated branches and all non-treated branches provides an opportunity to assess the validity of the type of analysis that would be undertaken in the absence of a quasi-experiment.

Table (3) reports the results. Compared to all non-treated branches (column 5), treated branches issue less credit, lend to fewer customers, and issue less barter credit in the period 18

[19] An existing borrower is a farmer who bought inputs on credit before the opening of a silo.

to 0 months before the treatment. But compared to runner-up branches (column 4), treated branches have similar trends in all variables. This finding is consistent with both the presumption that the average branch is not a credible counterfactual and the identifying assumption that the runner-up branches form a valid counterfactual for the treated branch. The next section outlines the full econometric model.

3.2 Empirical Specification

My empirical strategy identifies the effect of a contracting technology on financial contracts, using a difference-in-differences (DID) research design. I compare borrowers in branches where a silo was constructed against a control group of borrowers in runner-up branches. I call each construction choice a "case" and compare treated borrowers against non-treated borrowers within each case. Thus, the empirical specification is given by:

$$y_{jmi} = \tau_{jm} + \tau_i + \delta \cdot \text{Treat}_{jmi} + \eta_{jmi}, \tag{1}$$

where the dependent variable (e.g., total credit) is measured at the case-borrower-month level; j references case, m month, and i borrower. $Treat_{jmi}$ is a dummy variable equal to one if the branch, of which borrower i is a client, has a grain storage unit in month m. Thus, once a silo is built, this variable turns from zero to one. The other two terms in equation (1) control for unobserved determinants that might otherwise confound the construction of silos. The borrower fixed effects (τ_i) control for fixed differences between borrowers. The case-month dummies (τ_{jm}) control for time trends within a case. These fixed effects ensure that the impact of silo construction is identified from comparisons within a "pair" of treated and runner-up branches. The coefficient δ is my DID estimate of the effect of a contracting technology. All reported standard errors are clustered at the branch level to account for the correlation in outcomes among borrowers in the same branch, both within periods and over time.

The identification approach can be understood via the following example. Suppose there are two branches, branch A and branch B, that the firm considers as "equal" among many when considering where to build a silo within Case 1. However, they can build only one silo and they build it next to branch A in 2010, leaving branch B as a runner-up branch. I wish to estimate what the effect of constructing a silo is on total credit. For a borrower in branch A, I would compare the total credit after 2010 with the total credit before 2010. However, in 2010 other things, such as the economic environment, may have affected the size of total credit. Borrowers in branch B, as a control group, would help to control for changing economic conditions. The difference between those two differences would then serve as my estimate of the effect of a contracting technology. Essentially, borrowers in branch B act as a control group for borrowers in branch A in all months within Case 1. Similar reasoning applies for all other "cases". Therefore, equation (1) implicitly takes as a control group all borrowers from branches that are not subject to the construction of a silo at month m in case j.

It should be noted that if branch B is also treated at some later point, this would imply a staggered nature of treatment. The staggered nature of silo construction implies that all treated branches belong to both treated and control groups at different points in time. Therefore, equation (1) implicitly takes as a control group all borrowers from branches that are not subject to silo construction at month m in case j, even if they will be treated later on, or will not be treated at all. Essentially, this makes my identification strategy even stronger as 75% of the control branches are treated later on, ensuring that these branches are "equal" except of the timing of construction.[20]

4 Results

In this section, I explore the effect of a contracting technology on existing borrowers (i.e. intensive margin). First, I evaluate the changes in the contract types that the firm offers. Then, I investigate how silo constriction affects loan quantities, credit repayment (risk), and the prices charged for the products sold on credit.

New Financial Contracts: Barter Credit

To begin, cross-sectional statistics at the borrower level show that barter credit constitutes approximately 30 percent of the total credit in branches with a silo, compared to only 20 percent

[20] Important to note, a staggered specification using only treated branches is a weaker identification, as it assumes that all branches are similar, whereas this approach assigns a specific branch that is similar and is treated later on in most of the cases, making it a within-case staggered treatment.

in branches without a silo (Panel A in Table (2)).[21] To alleviate the concern of endogenous choice of contracting technology and heterogeneity among different types of borrowers, I next discuss the difference-in-difference results.

Columns 1 and 2 of Table (4) report the effect of the construction of a silo on barter credit. The coefficient on *Silo*, a dummy variable equal to one if the branch has a silo in that month, is the DID estimate. I provide results on two measures. First, I report the effect on the probability of issuing a barter credit, defined as 1 if a borrower has a barter credit in a given month. Second, I evaluate the effect on the natural logarithm of the total value of barter credit. Before taking the logarithm, I add 1 to each observation so that zeros do not become missing values. The logarithm accounts for the skewness of the data.

I find that both the probability of issuing a barter credit and the value of that credit increase significantly. To be specific, the probability of issuing a barter credit increases by 8 percent and the value increases by more than 80 percent (columns 1 and 2, respectively).[22] In the same time, there is no effect on cash credit contracts (columns 3 and 4). This constitutes strong evidence that the the integration of a silo allows the firm to offer a new credit instrument.

Figure (8) plots the dynamics of the probability of issuing a barter credit around the construction of a silo after controlling for borrower specific characteristics and aggregate time trends. The graph reveals much about the treatment and addresses issues of reverse causality that might be driving the shift towards barter credit and hence the construction of a silo. One concern might be that, as the farmers are more concerned about price risk, the effect on issuing barter credit is a borrower-specific time trend rather than an effect stemming from the silo construction. To ensure that my results do not suffer from any pre-trends I evaluate the treatment effect within a 16 month event window.

Figure (8) reveals three important features. First, in the months before the silo opening, trends among borrowers are the same in treated and runner-up branches. Indeed, the dynamics of the effect is flat and indistinguishable from zero before the treatment. This finding furthermore supports the validity of the identifying assumption that runner-up branches provide a valid

[21] To settle barter contracts that are issued by branches without a silo, the farmer delivers the grain to another silo owned by the agribusiness. This is feasible for farmers who are in close proximity to such silos.

[22] The interpretation of the quantity result is difficult as it puts substantial weight on the existing borrowers who start using barter credit only after the treatment.

counterfactual for treated branches. Second, beginning in the month of the silo opening, there is a sharp increase in the difference between borrowers in treated and runner-up branches. Third, the significant difference between borrowers in treated and runner-up branches remains strong in the long run as well. Overall, the graph reveals much of my primary finding that the construction of a silo allows the firm to offer new financial contracts.

Analogous to the figure described above, columns 5 and 6 of Table (4) document similar findings in a tabular form. I replace the *Silo* from equation (1) with five variables to track the effect of an improved contracting technology before and after the construction of a silo: Before^{-2} is a dummy variable that equals 1 if a silo is due to be opened in one or two months; After^{0} is a dummy variable that equals 1 if a silo was opened this month or one month ago; After^{2} and After^{4} are dummy variables that equal 1 if a silo was opened two or three and four or five months ago, respectively; After^{6+} is a dummy variable that equals 1 if a silo was opened six months ago or more. The variable Before^{-2} allows me to assess whether any effects can be found prior to the opening of a silo. Finding a significant effect could suggest that my results are driven by factors other than the integration of a silo. In fact, the estimated coefficients on that variable are economically small and statistically insignificant. Furthermore, I find that the coefficient on After^{0} is smaller than those on After^{2}, After^{4} and After^{6+}. Thus, there are no signs of any pre-trends. In fact, the documented effect amplifies over time and persists in the long-run.

Loan Quantities

Cross-sectional evidence shows that the total borrower-level credit is larger in branches with a silo (see Table (2) and panel (a) in Figure (4)). Moreover, comparing the total credit before and after the construction of a silo, total credit is higher once a silo is open (Figure (7)). Thus, all cross-sectional evidence suggests more lending in branches with a silo.

Column 1 of Table (5) reports the effect of silo construction on total credit, controlling for aggregate time trends and borrower specific characteristics. I find that lending to existing borrowers increases by 32 percent (column 1) once a silo is constructed. Column 2 evaluates the dynamic effects of silo construction and finds no pre-trends. In fact, effects before the treatment are nonexistent and the effect becomes significant only 4 months after. A more extensive study of dynamics is plotted in Figure (9), which also shows no pre-trends. Overall, this evidence shows that access to a contracting technology significantly increases lending to existing borrowers.

Loan Repayment

So far I have shown that integrating a silo enables the firm to offer a new credit instrument with a price hedge and provide more credit. An important question is whether the quality of these loans is affected. While more leverage could push some borrowers closer to distress, better contract enforcement should improve borrowers' risk profiles.

I find that the quality of loans issued to existing borrowers remains unchanged. I measure default rates as whether or not a loan defaults or is renegotiated at some point. In fact, equally weighted default rates decline by 1.8 percentage points (column 1 of Table (6)), that is, by 27 percent when measured against the mean default rate. Meanwhile, the value-weighted default rates decline by 1.4 percentage points (column 2), that is, by 21 percent when measured against the mean. While the result is significant for the equally-weighted measure, it is marginally insignificant for the value-weighted defaults, as the p-value is 0.15. Overall, these results suggest that loan quality remains the same or even improves, which is consistent with better contracting technology.

Prices

Next, I examine the effect on the prices of products that are sold on credit. Theories of the boundaries of firm predict that integrating two businesses into one can lead to higher prices (for example, due to more market power (Salinger, 1988)) or, on the contrary, to lower prices (for instance, economies of scale (Spengler, 1950)). Furthermore, prices may also decrease if a silo significantly reduces credit market imperfections, for example, through contract enforcement. Thus, the ultimate effect is not certain. To assess the pricing of these contracts, I evaluate the markup that the firm charges to farmers on the products sold on credit. I compute the markup as the total sales value of a credit contract with the farmer over the total raw costs of the products sold. This markup includes the operating margin, the interest rate, and the profit margin.[23]

I find that for products sold on credit the markup goes down by 3.5 percentage points, which

[23]Unfortunately, the firm does not separate these values out in its dataset.

is roughly by 9 percent from the mean markup of 38.8 percent (column 1 of Table (7)). Moreover, the finding is robust to pre-trends, as documented in the column 2. This finding is important, as it shows that borrowers can benefit not only from higher borrowing and purchasing quantities but also from lower prices. Important to note, as the lending volume increases by 32 percent and prices decline by 9 percent, the total revenue per borrower increases by 20 percent. Thus, the gains are split between the lender and the borrower.

To sum up, I find that vertically integrating a silo provides access to a contracting technology that enables the lender to offer a new credit contract and to increase lending significantly.[24] Moreover, the risk level of the loan portfolio remains the same and the prices decline. Although all of these results are consistent with reduction in credit market frictions. The next section discusses several cross-sectional tests that yield direct evidence on the mechanism.

5 Mechanism

The broad array of results supports the view that the integration of a silo into lender's business increases farmers' pledgeable cash flows. As a result, the creditor can issue more debt against these cash flows. This section lays out evidence that the gains are attributable to mitigation of credit frictions and are to a large part explained by the new contractual innovation: barter credit.

At first, I show that benefits of a silo are larger in municipalities with weaker courts (5.1) and to constrained borrowers who have limited access to bank finance and, thus, suffer from more credit market imperfections (5.2). Then, I provide direct evidence on the barter credit contracts (5.3). After that, using cross-sectional interaction with price volatility (5.4), I point out the hedging channel that is embedded in the barter contract. Furthermore, using weather shocks (5.5), I provide further support for the enforcement channel.

[24] In addition, I do a similar analysis at the branch-level that also includes new borrowers (extensive margin). I find similar results. However, I do not report these results, as they require a much stronger identification assumption: the construction choice has to be exogenous at the branch-level. It is reasonable to assume this at the borrower-level, but much harder to justify at the branch-level.

5.1 Court Enforcement Quality

It is widely accepted that contract enforcement depends on the quality of legal institutions and creditor protection (Djankov et al., 2008; Davydenko and Franks, 2008; Ponticelli, 2015). If silos indeed mitigate credit market frictions associated with weak contract enforcement and court quality, then the effect of building a silo should be particularly strong in areas where formal institutions are weaker. Finding that constructing a silo is more important in areas of poor court quality would identify the enforcement channel and reinforce the notion that silos provide contract enforcement where legal institutions fail to.

To measure the court enforcement quality, I collect all the necessary data from *Justiça Aberta* of the National Justice Council that covers all courts and judges working in the Brazilian judiciary.[25] I focus my analysis on the civil courts of first instance, since these usually deal with bankruptcy cases. As in Ponticelli (2015), I measure the court enforcement quality as the speed in closing bankruptcy cases, calculated as the number of pending cases per judge in each judicial district in each month.[26] This measure proxies for the duration to solve a case: the larger the proxy, the longer it takes to solve a case. Then, I take the average of the monthly values for each judicial district and obtain a measure of court congestion. I classify court enforcement quality as weak if the court congestion of a judicial district is above the median congestion.

The effect on total credit and barter contracts is indeed stronger in judicial districts where court enforcement quality is weaker (Table (8)). The coefficient on the interaction term *Silo x Weak Court Enforcement* captures the additional effect of constructing a silo in areas where legal institutions are weak. The economic effects are large. The increase in total credit is twice as large and the increase in the probability of issuing a barter credit is three times larger in areas with weak legal institutions than in areas with strong institutions. We can see that grain silos improve contract enforcement and provide more benefit to regions with weak legal institutions.

[25] The data can be accessed here: http://www.cnj.jus.br/corregedoria/justica_aberta/.

[26] Brazil is divided in 2,738 judicial districts. A judicial district can map into a single municipality or it can enclose multiple municipalities. To obtain a measure of court enforcement quality for each branch, I match the municipality of a branch with the corresponding judicial district.

5.2 Financially Constrained Borrowers

An extensive theoretical literature (for example, Harris and Raviv, 1991; Aghion and Bolton, 1992; Shleifer and Vishny, 1992; Bolton and Scharfstein, 1996) argues that optimal debt policy critically depends on the value of pledgeable assets. Thus, all else equal, a borrower possessing a high value collateral is more likely to obtain the necessary funding than a borrower owning a collateral with lower valuation. Put differently, constrained farmers should have more difficulties in accessing alternative sources of financing, in particular, bank debt, than farmers with more pledgeable assets. If the construction of a silo results in eliminating some credit market frictions, then the marginal benefit of these changes should be larger for borrowers whose total value of pledgeable assets is lower. Thus, the agribusiness lender should increase lending especially for the more constrained borrowers.

To show that the effects of the construction of a silo are particularly strong for constrained borrowers, I examine the cross-sectional variation between farmers who own their farmland and those who rent it. Since landowners have more pledgeable assets than renters, the effect on renters should be larger. Furthermore, this cross-sectional variation allows for strengthening my identification strategy. In particular, I can control for the aggregate time-varying branch-level demand and other branch-time specific characteristics by including the branch-month fixed effects.[27]

For the validity of this test, I have to show that the chosen locations of silos were not particularly tailored to meet the demand of renters of farmland. To begin, in the period before the construction, the treated branches were not located in areas with more renters as opposed to the control branches (Panel B, Table (9)). Furthermore, the treated branches did not switch their focus towards the farmers who rent their farmland after the silo was open (Panel A, Table (9)). These two results provide a compelling evidence that the construction choice was not determined by the renters, i.e. constrained borrowers.

As expected, farmers who rent their farmland benefit more (Table (10)). The results suggest that the total lending to those farmers increases twice as much (column 1) and that they are more likely to issue barter credit than the landowners (column 2). More importantly, the results

[27] Please note that this specification absorbs the *Silo* variable.

remain strong even after controlling for the time-series changes in branch-specific characteristics, such as the demand, investment opportunities, and the location of the silo (columns 3 and 4). These findings lend strong support for my identification strategy.

Furthermore, the test also relates to the issue of "hard" versus "soft" information borrowers and the role of trade credit in the real economy. High quality collateral is a typical example of "hard" information that is favored by banks (Petersen, 2004). Finding that "soft" information borrowers benefit more from the institutional change points towards the important role of non-bank financial institutions to serve these customers. It resonates to the notion that large and hierarchical banks are less fit to provide credit for "soft" information borrowers such as small and medium enterprises (Stein, 2002; Berger et al., 2005; Liberti and Mian, 2009; Skrastins and Vig, 2014). As a consequence, trade creditors take this as an opportunity to provide credit.

5.3 Barter Contracts

There are two important mechanisms within the barter credit: hedging and product bundling. First, the embedded forward contract protects the borrower from the downside risk when commodity price falls low (Smith and Stulz, 1985; Froot et al., 1993). Second, bundling the forward contract with credit can solve problems associated with both moral hazard and asymmetric information (Adams and Yellen, 1976; Laffont and Tirole, 1986; Holmström and Milgrom, 1991). For instance, the barter credit reduces the information asymmetry between the lender and the borrower about the borrower's open hedging positions. Alternatively, product bundling might reduce the adverse selection problem, as the bundled barter credit could be attractive to certain types of customers only.

To provide evidence on barter credit contracts, I begin by examining the cross-sectional differences among contract types. Barter credit contracts are thrice as large as the standard cash contracts (panel A of Table (11)). Similarly, Figure (10) plots the kernel density functions of the loan size by contract type. Both distributions are different with 1 percent statistical significance. Furthermore, a branch issues more barter credit than cash credit (panel B of Table (11)). Overall, these results suggest that loans are larger when using barter credit contracts. Nevertheless, these cross-sectional patterns might be driven by, for example, the heterogeneity among borrowers, which I address next.

To further show that the increase in lending is driven by the availability of the new financial contracts, I examine cross-sectional variation among borrowers who already had a barter contract against those who did not have one before the construction of a silo. The borrowers who had such a contract before the construction of a silo are located in close proximity to another of the lender's silos where they can deliver the grain. If barter credit contracts deliver a significant increase in lending, then the effects should be particularly strong for the borrowers who had no access to these contracts before the opening of a silo.

I find this to be true (Table (12)). First, the total credit for borrowers who had no access to barter credit ex-ante increases by 20 percent more than for those ones who had access (column 1). Second, the probability of issuing a barter contract increases by almost 17 percent for borrowers without previous access to barter credit (column 2). Both of these results suggest that access to barter credit contracts plays an important role in increasing the total outstanding credit.

In the next two subsections, I analyze the heterogeneity in commodity price volatility and weather volatility to further strengthen the evidence, especially in favor of barter credit contracts. If borrowers are concerned about the price risk and exploit barter credit to hedge against price fluctuations in order to borrow more, they should be inclined to use more of these contracts in times when price volatility is high. Furthermore, if the access to a silo mitigates frictions in credit markets, then these effects should be stronger in geographic regions that suffer from more credit imperfections, for instance, high weather uncertainty.

5.4 Commodity Price Volatility

Commodity price volatility is a major risk in farming, as it significantly affects the cash flow that a farmer can generate at the end of the harvest season (Harwood et al., 1999; OECD, 2009). Theoretical literature (Smith and Stulz, 1985; Froot et al., 1993; Leland, 1998; Holmström and Tirole, 2000) argues that in the presence of market frictions, the debt policy critically depends on whether a firm can protect itself against bankruptcy and costly liquidation. Clearly, a forward contract hedges the commodity price risk and gives more certainty about the cash flow that the farmer can expect at the end of the season. If farmers are greatly concerned about price volatility, one should observe that the availability of a price hedge is more important at times when commodity markets are volatile.

To provide additional evidence that the integration of a silo allows farmers to use hedges against the price risk, I evaluate how the treatment effect interacts with price volatility. To begin, I construct domestic, daily price indices. Using the lender's grain purchase data, I obtain daily prices for all commodities that are accepted as the in-kind payment for barter credit: soybean, wheat, and corn. Then, I compute daily returns for each commodity. Using these returns, I calculate both monthly and harvest commodity price volatilities as the standard deviation of those returns within each month and harvest, respectively. Second, I use the lender's data to establish which commodity each farmer specializes in. I do this by looking at both the seeds that they buy from the lender and the grain that they deliver or sell. Thus, I am able to obtain domestic price volatilities for all types of grain that the lender accepts as a payment in-kind for the barter credit and I know which commodity each farmer grows.

To control for differences among the three types of grain, I augment my main specification (equation 1) by replacing case-month fixed effects with case-grain-month fixed effects. In this way, I capture all time invariant characteristics that are associated with each type of grain. Thus, I can exploit the time-series variation of volatility within each commodity.

I find that the effect of the construction of a silo is stronger when the current and recent historic market volatility is higher (see Table (13)). I use five measures of price volatility: 1) lagged monthly volatility, 2) monthly volatility lagged by six months, 3) the current harvest's volatility, 4) the last harvest's volatility, and 5) the volatility two harvests ago. The first four measures show that after integrating a silo, a farmer is more likely to both issue a barter credit and borrow more at times when the commodity markets are more volatile or recently have been such (columns 1 through 4 and 6 through 9, respectively). By contrast, the volatility two harvests ago does not affect either the probability of issuing a barter credit or total outstanding credit (columns 5 and 10, respectively). This suggests that borrowers are concerned only about current or recent price volatility and not by distant price volatility. Clearly, this evidence is consistent with the view that farmers respond to price volatility and adjust their risk management policy to reduce their exposure to price risk when market volatility is high. All in all, this result strongly supports the notion of a hedging channel.

Overall, this result provides new evidence for why firms hedge. Similarly, Campello et al. (2011) show that hedging leads to lower credit spreads and higher investment levels. Pérez-

González and Yun (2013) show that hedging leads to higher valuation and investments, while Cornaggia (2013) finds a positive relation with productivity. This result isolates and examines the debt channel as a potential source of value creation.

5.5 Weather Shocks

Weather shocks are another major risk in farming, as they affect the yield of a harvest (The World Bank, 2005).[28] Geographic regions with high weather uncertainty suffers from more credit frictions than a region with highly predictable weather. Thus, finding evidence that effects of a silo are stronger in volatile weather areas would lend strong support for the enforcement channel.

The effect of volatile weather on the probability of issuing a barter credit is particularly important. Low levels of output resulting from adverse weather conditions would push regional prices up, thus a forward contract would harm these farmers. In other words, a forward contract would make this state of the world even worse as it limits all the potential upside from the price increase. For this reason, farmers located in geographic regions of high weather volatility should be less inclined to commit to deliver a fixed quantity of grain, as formally shown by Rolfo (1980). Thus, finding that the probability of issuing a barter credit is higher in more volatile weather areas identifies the enforcement channel in addition to the court quality result in section 5.1.

To analyze how the construction of a silo interacts with weather shocks, I exploit two spatial measures: monthly deviations in 1) temperature and 2) precipitation from the long-term monthly means of that month. First, I obtained a time-series of maps of both global monthly land surface temperatures and global monthly precipitation data from NOAA.[29] The same source also provides estimates of long-term monthly means of both measures for each month in the year. Monthly mean temperature is calculated as the mean daily temperature within a month, measured in Celsius. Monthly mean precipitation is calculated as the mean daily rainfall within a month, measured in millimeters. The spatial resolution of both datasets is 0.5 x 0.5 degrees.

[28] This includes both quality and quantity risk. If the quality of the crop is very low, the farmer would have to buy and deliver the high quality crop that was agreed to be delivered initially. Essentially, the prediction for quality risk is the same as for the quantity risk.

[29] The methodology for measuring land surface temperature was developed by Fan and Van den Dool (2008) and the methodology for measuring precipitation was developed by Chen et al. (2002). The temperature data can be downloaded from http://www.esrl.noaa.gov/psd/data/gridded/data.ghcncams.html and the precipitation data can be downloaded from http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.CPC/.PRECL/.v1p0/.deg0p5/.

For illustration, Figure (11) plots the mean temperature in December 2009 and the long-term mean temperature in December in Brazil.

To obtain the deviation from the long-term mean, each month I deduct the long-term mean (the expected weather) from the monthly mean (the realized weather) at the pixel level. For illustration, Figure (12) plots the monthly temperature deviation from the long-term mean for December 2009 in Brazil.[30] As a result, I obtain a monthly time-series of such maps ranging from January 2006 to December 2012 for both temperature and precipitation measures. Then, I extract the monthly deviation for each branch, depending on its location on the map. Eventually this provides a branch-level time-series of monthly deviation in both temperature and precipitation.

As a final step, I compute the standard deviation of both of these measures at the branch-level to capture the weather volatility. The larger the deviation, the more volatile is the location of a branch. Consequently, farmers in branches located in areas of high weather uncertainty suffer from more frictions. If the new contracting technology mitigates these frictions, the results should be stronger in these volatile regions.

Table (14) shows that the effects of a silo are stronger in regions with more volatile weather. I report the results on the probability of issuing barter credit (columns 1 and 2), the value of barter credit (columns 3 and 4), and the total outstanding credit (columns 5 and 6). Both temperature and precipitation measures show that the effects on all three variables are stronger for volatile weather areas. Most importantly, the effects are stronger for the probability of issuing a barter credit contract, showing that enforcement channel is important. All in all, these results further strengthen the argument that access to a contracting technology through expansion in the boundaries of the lender can mitigate frictions in credit markets and increase the pledgeable cash flows of borrowers.

Besides identifying some of the channels, this section makes another important conclusion. Specifically, the lender is able to increase lending to a market segment that is more challenged to raise external funds. Besides the borrowers with less "hard" information (see Section 5.2), the firm lends more in riskier time periods (price volatility) and in uncertain geographic regions (weather). Thus, vertically integrating a silo enables the lender to reach customers that could

[30] Figures (A1) and (A2) illustrate the precipitation data in similar vein.

have less access to credit.

6 Discussion and Real Effects

My main empirical finding in Section 4 is that integration of a silo leads to significant changes in financial contracts. Then, in the section above, I show that access to this contracting technology mitigates credit market frictions, particularly, weak contract enforcement. Nevertheless, the possibility remains that these results are driven by alternative channels. Consequently, this section provides some robustness tests and rules out several alternative explanations. Finally, I discuss real effects on the economy and the external validity of the results.

6.1 Staggered Specification

A concern might be that the alternative silo locations are a weak counterfactual for the treated branches. For robustness, I rerun my tests using the sample of treated branches only. This specification exploits the staggered nature of the construction of silos. Thus, it hinges on the time-series variation in the completion date. The identification assumption here is that all treated branches are "equal" and only differ on the time dimension of when a silo is constructed. As a result, I perform a staggered DID estimation and augment my main specification (1) by replacing case-month with month fixed effects. The results remain qualitatively the same (see Table (15)).

6.2 Storage Capacity

Lack of storage capacity might restrain farmers from borrowing more and increasing their production. Clearly, a new silo expands the total storage capacity in a municipality. Consequently, farmers might borrow more, as there is free storage space after the opening of another silo.

To examine how constructing a silo interacts with the available storage capacity, I obtain the total storage capacity (in tons) from the Brazilian census of agriculture, 2006 (Instituto Brasileiro de Geografia e Estatística, 2006). As municipalities differ in their size, I scale the total capacity by four proxies for potential total output: 1) the total area of a municipality, 2) the total farmland in a municipality, 3) the total planted area (all three in hectares), and 4) the total produced quantity of soybean, corn, and wheat in tons. The larger any of these proxies, the more storage space there is.

I find that it does not matter whether a municipality has a deficit or unutilized storage space (Table (16)). I report the results on both total credit volume and probability of issuing barter credit. Neither of the four proxies are significant. In fact, many of the variables have an opposite sign to what storage deficit would predict. Thus, the results remain robust to insufficient storage capacity.

6.3 Real Effects

I have documented how a lender can improve the contract enforcement by accessing a contracting technology through expansion in the boundaries of a firm. Although it increased the supply of credit from the lender's point of view, I have not yet analyzed the real effects on farmers. While the dataset is comprehensive, it includes only the contracts between the farmers and the lender. Clearly, farmers could be contracting with other parties that are out of my sample. To overcome this and shed some light on the real effects, I analyze the significance of opening a silo at the municipality level. I obtain the annual agriculture output and GDP data at the municipality level from 2004 to 2012 from the statistics bureau of Brazil (IBGE).[31]

I find that the total production of soybean, corn and wheat in bushels and in Brazilian reais increases by 16.3 and 15.5 percent, respectively (columns 1 and 2 in Table (17)). Also, the harvested area and the GDP for each municipality increases by 7 and 2.5 percent, respectively (columns 3 and 4). Having said that, the last two results are statistically insignificant. Nonetheless, all four measures of real output increase significantly for municipalities with weak courts. In those municipalities, the total output both in bushels and reais increases by more than 20 percent (columns 5 and 6) and the total harvested area increases by 17 percent (column 7). Furthermore, the local GDP grows by 9.2 percent in municipalities where courts are weak (column 8). This cross-sectional finding highlights not only that the access to a contracting technology and expansion in the boundaries of the firm has real effects on the production output but also that these effects are achieved through the contract enforcement channel.[32]

[31] The data can be accessed here www.sidra.ibge.gov.br.

[32] These results agree with the previous finding by Butler and Cornaggia (2011) who show that higher access to finance leads to an increase in productivity, measured by crop yields.

6.4 Generalizability

Here, access to a contracting technology mitigates credit market frictions and boosts the real economy. Nevertheless, as with all empirical studies of this nature, one should be careful when trying to generalize these results to other industries or markets. Choice of a contracting technology is driven by various factors, of which financial contracts may or may not be one. Therefore, I briefly discuss the applicability of the findings more broadly.

From an agricultural perspective, such financing models, including barter credit contracts, are widely used not only in emerging but also in developed markets, including the US (for instance, by multibillion agribusiness firms such as Cargill, Bunge, ADM, and OLAM).[33] Bunge and OLAM reported 1.2 and 2.3 billion USD in prepaid expenses that are used for procurement of physical commodities in 2013.[34]

These contracts are used not only in farming but also in other commodity related industries, such as metal mining and oil. In 2013, Glencore, the world's largest producer and trader of metals, reported 4.1 billion USD in prepaid expenses. These prepayments were largely repaid by future production of the counterparty. To add, Troika Group and Noble Group, leading oil and metal traders, reported prepaid expenses over 2 and 6 billion USD, respectively, in the same period. The Economist (2015) highlights as well that besides the more traditional forms of bank financing, such as the structured commodity trade finance, firms engage in direct lending that requires large funds from these firms.[35] Thus, the mechanism documented in this paper for the farming industry could be generalized to the cross-section of commodity sectors.

Furthermore, the global agricultural sector employed approximately 38% of the available worldwide workforce in 2011.[36] This fraction is over 80% for regions such as Africa and other

[33] Both Cargill and ADM sell production inputs such as fertilizer on credit and trade grain worldwide. Similarly as the agribusiness here, they allow the credit to be repaid both in grain and in cash. For more details on credit applications in the US please see here: http://www.cargillag.com/Marketing/ProductServices/crop-inputs/crop-inputs-financing (Cargill) and https://www.e-adm.com/corpcredit/creditapplform.asp (ADM).

[34] It is difficult if not impossible to extract exact numbers about these credit contracts from the public statements, since they could be classified both as accounts receivables and as prepaid expenses. Additionally, firms seldom discuss in detail credit contracts that they provide. Thus, any measure is likely to significantly under-report the true situation. Furthermore, as farming is cyclical, the numbers that are reported at the end of the fiscal year might fall between harvesting and plowing seasons when most of debt is settled. One would require to know the total flow of funds during the year to determine an accurate number of the volume of credit contracts.

[35] The Economist (2015) stresses that it is very common for traders to lend money to their commodity suppliers.

[36] The data was obtained from The World Factbook, Central Intelligence Agency: https://www.cia.gov/library/publications/the-world-factbook/fields/2048.html.

developing regions that severely suffer from credit market frictions. Since access to a warehouse is likely more important for markets with a weak institutional environment, the findings could be helpful for mitigating enforcement problems and improving welfare in those regions.

These findings shed light on the large popularity of trade credit. Fisman and Love (2003) argue that trade credit is prevalent in poorly developed financial markets. I have documented that the improvements in contracting technology are particularly important for borrowers with limited access to tangible assets. These "soft information" borrowers are commonly thought of as constrained from bank debt. Thus, trade creditors may use these enforcement problems as an opportunity to provide credit to a market segment that is starved for bank debt.

Last but not least, a barter credit is a very old contract with a history long before the invention of the modern banking. For example, in Babylonian times silver was borrowed against a repayment in grain (Goetzmann and Rouwenhorst, 2005). This is in line with the point above that such forms of financing are important when financial markets are underdeveloped.

7 Conclusion

I document how lenders develop alternative enforcement mechanisms to mitigate credit market fictions in an economy with weak legal infrastructure. In particular, a lender expands its firm boundaries to access a contracting technology that improves the collateralization of its loans. To show this, I consider the staggered construction of grain silos by a large agribusiness lender in Brazil. I find that access to a silo enables the lender to provide a credit contract that is repaid in grain. This contract provides a significantly better enforcement than the traditional cash contract due to a credible threat of liquidation of the collateral, i.e. grain. Consistent with this view, access to the contracting technology is more important for both municipalities with weak courts and financially constrained borrowers. Furthermore, this contract also offers a hedge against price fluctuations, which proves to be particularly useful in volatile periods. Overall, I document that gaining access to a warehouse by expanding firm boundaries can significantly mitigate credit market frictions. Thus, I uncover a new mechanism, designed by a trade creditor, to overcome weak creditor rights, suggesting that markets invent alternative credit enforcement mechanisms where formal institutions are weak.

While there has been much theoretical work on the Coasian topic of organizations and their boundaries, there has been far less empirical work. My analysis contributes to the debate by documenting that the lender expands its boundaries to access a contracting technology. However, an important question remains: is ownership of a silo necessary or can the same results be achieved through a long-term lease contract? In a rational world, if replicating a transaction outside a firm is no different from performing it inside, a firm should be indifferent between the two options. Since the agribusiness lender never utilizes a third-party silo, I implicitly assume that performing this outside the firm is sufficiently costly, making it economically unattractive.[37] This is a conjecture that would greatly benefit from further empirical investigation.

From the policy perspective, it is important to understand whether banks could benefit from access to such a contracting technology and whether they should own warehouses.[38] Since funding costs of banks are generally lower than those of trade creditors, they could provide cheaper credit. However, trade creditors are likely to have more expertise and information about its borrowers, making the screening costs very low. Understanding the comparison between the two types of lenders I leave for future research.

[37] In section 3, I discuss the specific frictions, indicated by the lender, that prevent it from outsourcing silos.

[38] For instance, both Goldman Sachs and JP Morgan Chase have been reported to own aluminum warehouses around the world: http://www.bloomberg.com/news/articles/2015-03-04/goldman-sachs-jpmorgan-dropped-from-aluminum-antitrust-lawsuit.

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Figure 1: Agribusiness Description

The figure below illustrates the three lines of business that the agribusiness lender operates in: 1) sales of production inputs, 2) sales of these inputs on credit, and 3) trading in agriculture commodities (soybean, corn, and wheat).

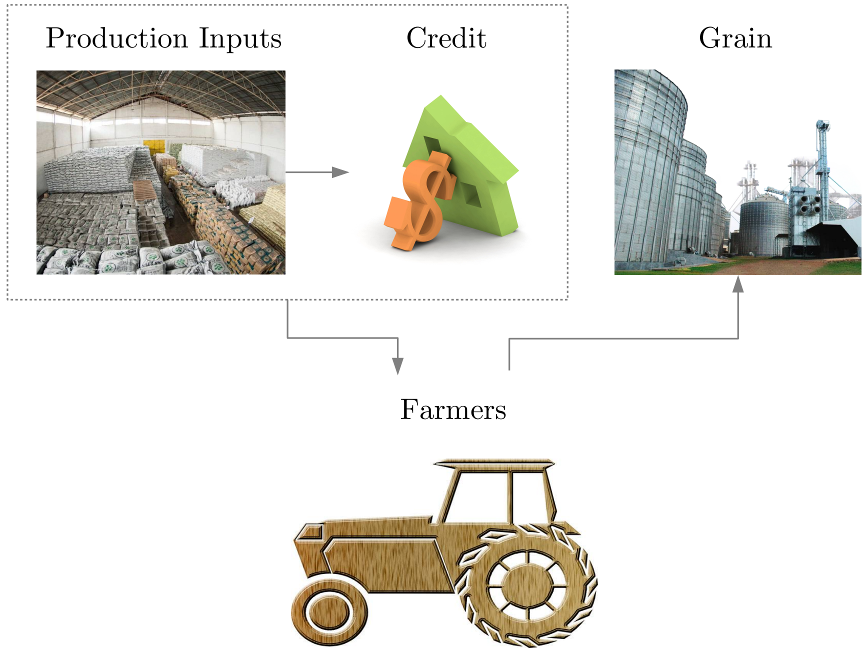

Figure 2: Sales of Production Inputs, Credit and Grain Silos

This figure illustrates the flowchart of how production inputs are sold to farmers. They can be sold either in cash or on credit. Then, credit can be repaid in cash or in grain (measured in bags) at a pre-specified date. The credit that is repaid in grain differs from the cash credit on three dimensions: 1) it requires a silo where the grain can be delivered and stored, 2) it fixes the commodity price, and 3) it provides a better contract enforcement.

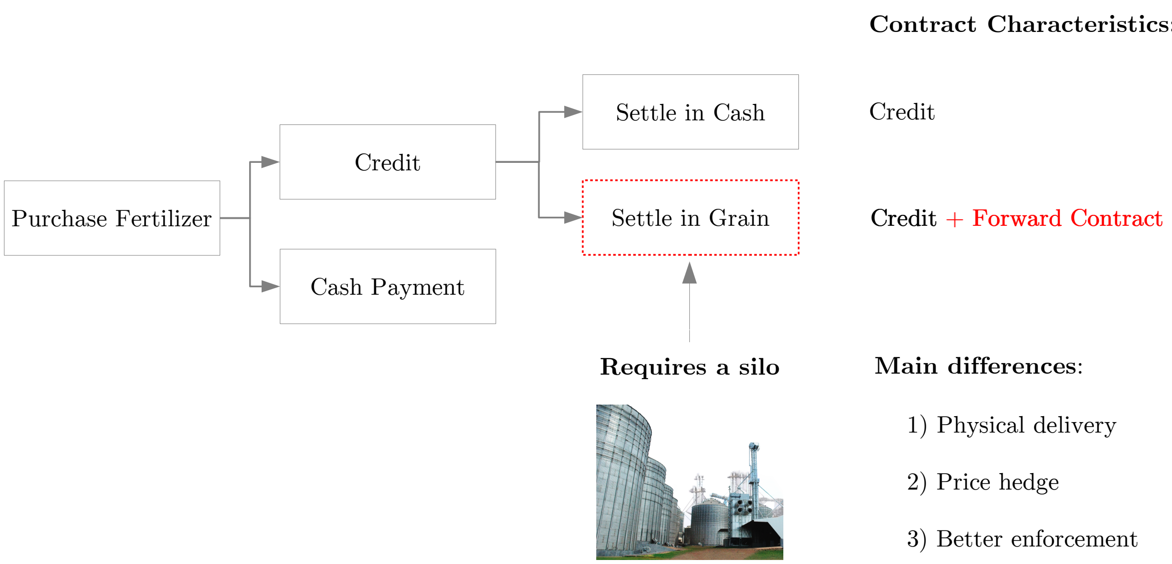

Figure 3: Cash vs Barter Credit

This figure illustrates the difference in repayment and enforcement between cash and barter credit contracts. Under cash contracts (left) a farmer is free to choose where to deliver and sell the grain. To repay the credit, a farmer first must receive cash by harvesting and selling the grain. Since this takes four to six weeks, all cash contracts have to mature after the harvest. The challenge for the creditor is that during the period after the harvest it effectively loses access to the collateral, as it is stored in a third party silo. By contrast, barter contracts mature within the harvest. If a farmer does not deliver the grain, the agribusiness has the right to liquidate the collateral – grain – by harvesting it almost immediately. The same applies with cash credit contracts, however, by construction, cash contracts mature after the grain has been harvested. Thus, a barter contract has a stronger enforcement due to a credible threat of liquidation.

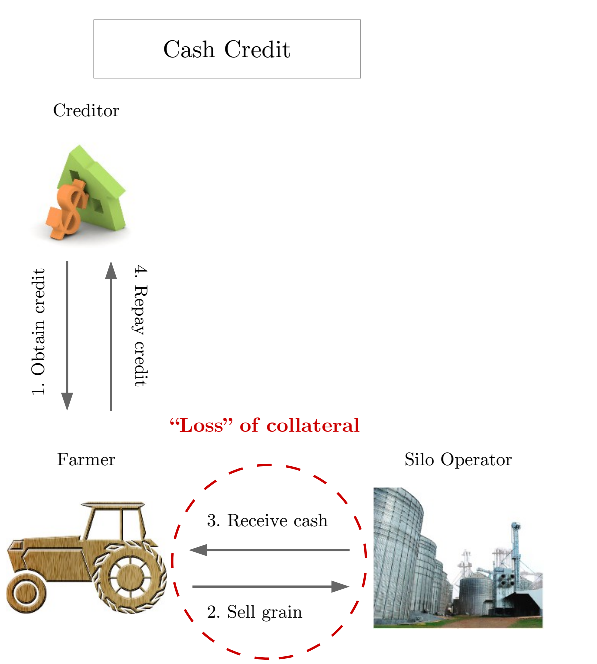

Figure 4: Cross-Sectional Variation: A Branch with and without a Silo

This figures illustrates the differences in cross-sectional loan size depending on whether the branch office has a silo. I report the results at both borrower- and branch-level in panels (a) and (b), respectively. Both figures plot smoothed kernel density functions. The vertical axis measures the smoothed estimate of the density function, while the horizontal axis measures the natural logarithm of the loan size. The dashed line represents a branch without a silo, the solid line a branch with a silo.

(a) Borrower-Level **(b)** Branch-Level

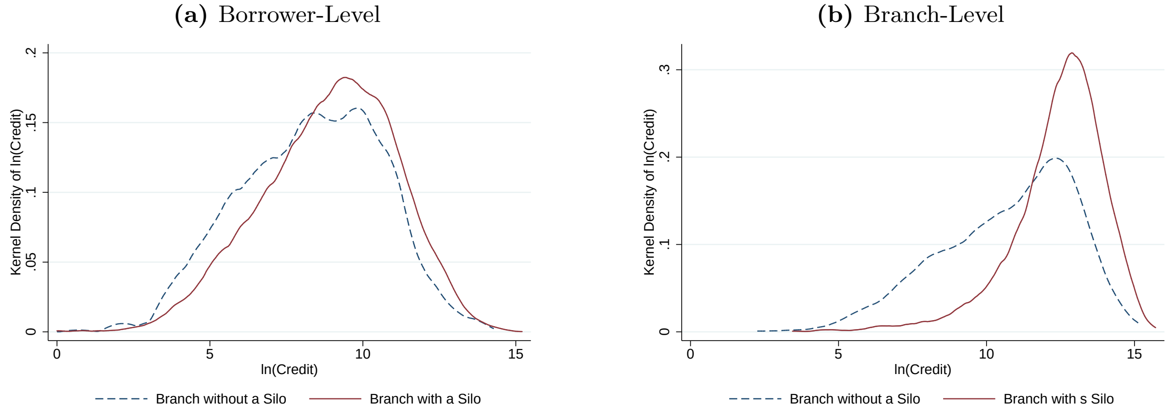

Figure 5: Vertical Integration and the Supply Chain

This figure illustrates the supply chain in farming. At first, the firm provides inputs and credit to farmers. Then, by using these inputs farmers produce grain that is then later bought by the traders and sold further. In this case, the business integration is between two vertically related entities: the branch office providing credit and inputs (top) and the grain business (bottom).

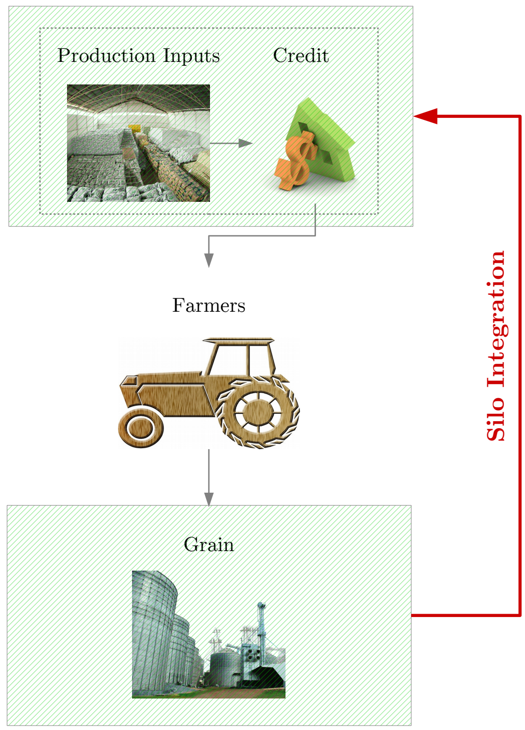

Figure 6: Identification Strategy – Control and Treatment Groups

The figure below illustrates my identification strategy. Each time the lender considers building a new silo, it considers several alternative locations. As a counterfactual to the treated branches, I consider the branches that the lender considered as "equal" when deciding where to locate the silos (i.e. the runner-up branches).

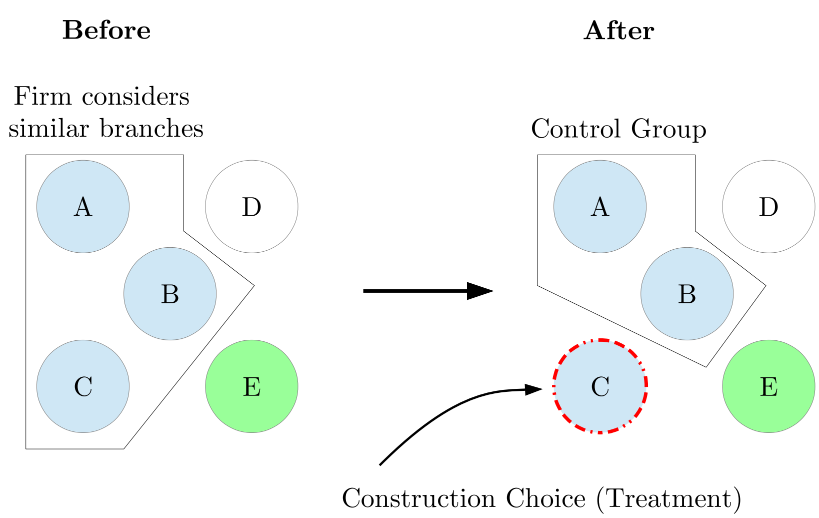

Figure 7: Total Credit Pre- and Post-treatment: Borrower-level

The figure below illustrates the effect on total outstanding borrower-level loan value before and after integrating a silo. The figure plots smoothed kernel density functions. The vertical axis measures the smoothed estimate of the density function of the natural logarithm of the total credit outstanding in a month, while the horizontal axis measures the natural logarithm of the total credit outstanding in a month. The dashed line represents the period before the construction of a silo, the solid line the period after the construction.

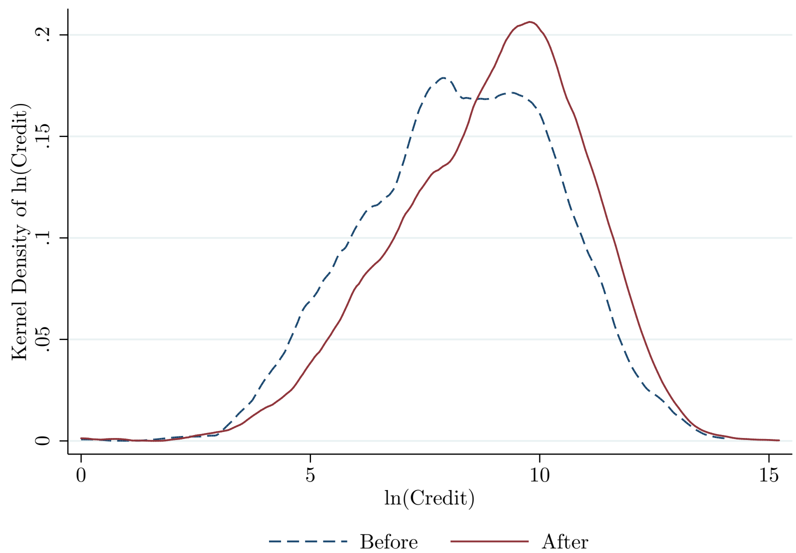

Figure 8: Dynamics Plot: Barter Credit

The graph below plots the evolution of the treatment effect (construction of a silo) on the probability of issuing a barter credit contract at the borrower-level. The horizontal axis measures time, in months, since the construction of a silo (0 represents the opening of a silo). The vertical axis measures the probability of issuing a barter contract at the borrower-month-case level. The coefficients are estimated using equation (1) and represents the effect on existing borrowers, i.e. intensive margin. The dashed lines indicate a 95% confidence interval.

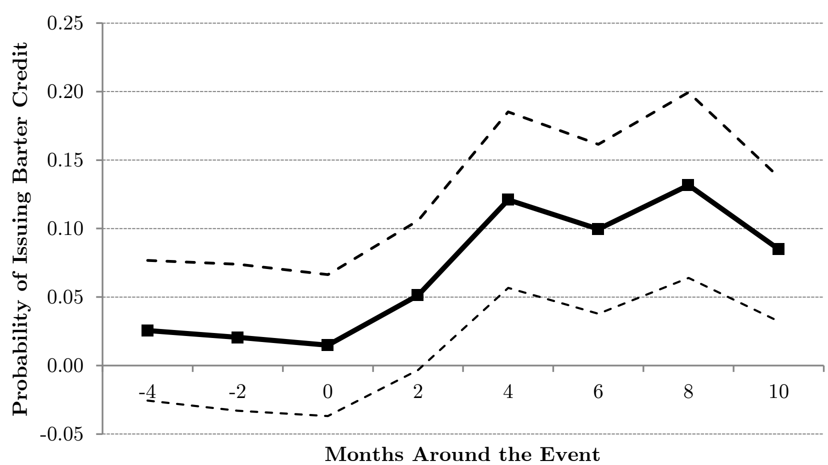

Figure 9: Dynamics Plot: Total Credit

The graph below plots the evolution of the treatment effect (construction of a silo) on the total credit outstanding at the borrower-level. The horizontal axis measures time, in months, since the construction of a silo (0 represents the opening of a silo). The vertical axis measures the log total value of credit at the borrower-month-case level. The coefficients are estimated using equation (1) and represents the effect on existing borrowers, i.e. intensive margin. The dashed lines indicate a 95% confidence interval.

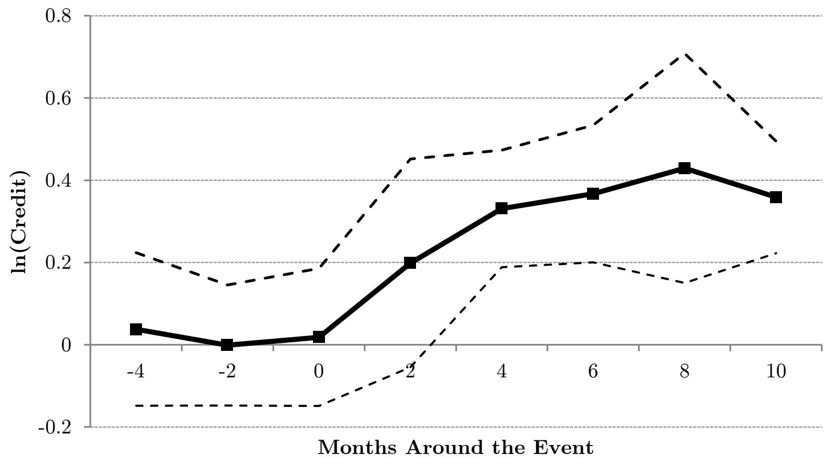

Figure 10: Cross-Sectional Variation: Cash Credit vs Barter Credit

The figure below illustrates the differences in cross-sectional loan size between cash and barter credits. The figure plots smoothed kernel density functions. The vertical axis measures the smoothed estimate of the density function of the natural logarithm of credit, while the horizontal axis measures the natural logarithm of the loan size. The solid line represents cash credit, the dashed line – barter credit.

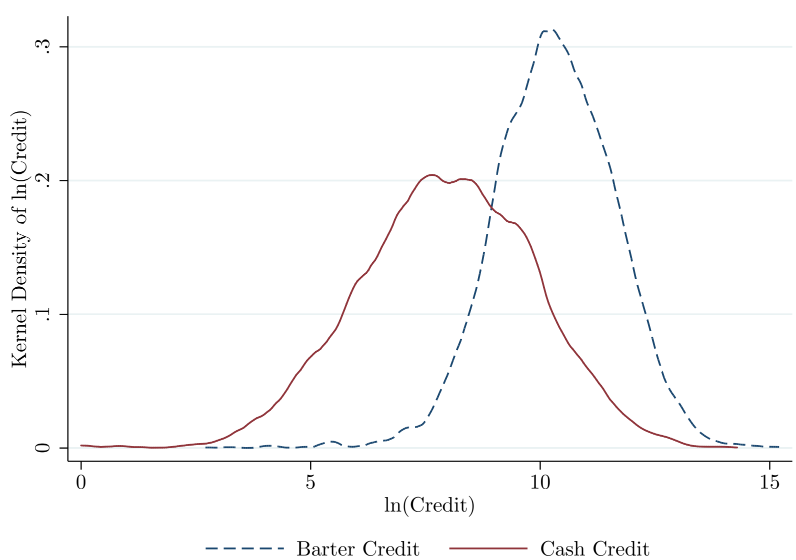

Figure 11: Mean Monthly Temperature in Brazil

The figures below plot the heat maps of the long-term mean temperature of December (left map) and the monthly mean temperature in December 2009 (right map) in Brazil. The spatial resolution of the heat map is 0.5 x 0.5 degrees.

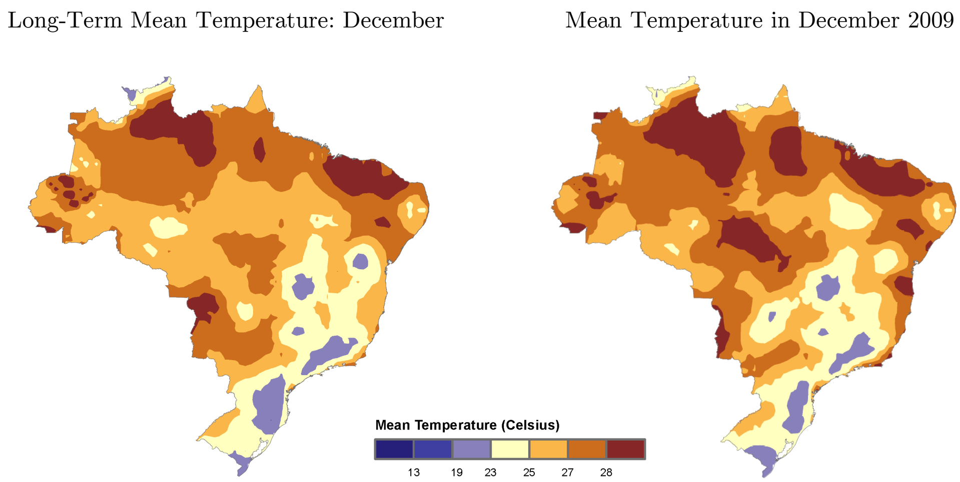

Figure 12: Deviation from the Long-Term Mean Temperature (December, 2009)

The figure below plots the heat map as the deviation of the monthly mean temperature in December 2009 from that of the long-term mean temperature in December in Brazil. The difference between the two monthly measures is calculated at a pixel level with resolution of 0.5 x 0.5 degrees (both original maps are plotted in Figure (11)). In terms of scale, deviation of 0.5 Celsius represents roughly one standard deviation of the deviation from the long-term mean.

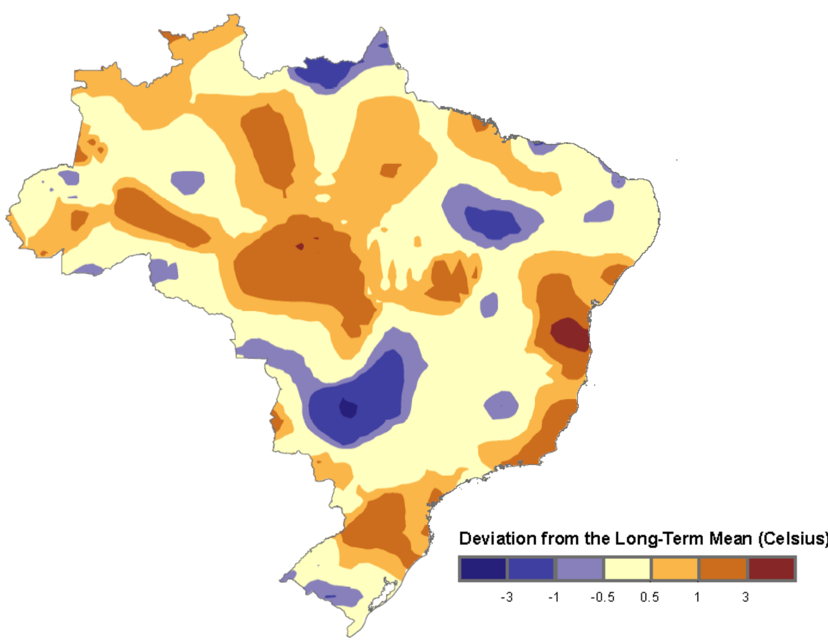

Table 1: Summary Statistics

The table below reports client-month (Panel A) and branch-month (Panel B) summary statistics. I report the mean, standard deviation, the 1st percentile, median, and the 99th percentile for all the variables.

	Mean	Std. Dev.	p1	p50	p99
Panel A: Client-Month statistics					
Total credit (1,000 reais)	34.2	114.6	0.04	8.21	508.40
Fraction of debt in default	0.065	0.224	0.000	0.000	1.000
Markup	0.388	0.337	-0.194	0.356	1.235
Maturity (days)	192.73	107.24	34.00	181.22	576.42
Fraction of credit with hedge	0.308	0.417	0.000	0.000	1.000
Fraction of credit with hedge if hedge>0	0.826	0.216	0.066	0.913	1.000
Panel B: Branch-Month statistics (New Credit)					
Total new credit (1,000 reais)	451.48	641.78	0.26	235.66	2,859.97
Number of clients borrowing	42.58	39.29	1.00	34.00	174.00
Fraction of debt in default	0.065	0.154	0.000	0.006	0.976
Markup	0.356	0.190	-0.035	0.332	0.935
Maturity (days)	164.40	53.12	47.55	161.48	314.00
Fraction of credit with hedge	0.311	0.334	0.000	0.181	1.000

Table 2: Summary Statistics: Cross-Section – Branch Type

The table below reports client-month (Panel A) and branch-month (Panel B) summary statistics across branch types: 1) all branch types, 2) a branch without a silo, and 3) a branch with a silo. I report the mean and the standard deviation for all the variables.

	All Branch Types		No Silo		Combined (incl. silo)	
	Mean	Sd	Mean	Sd	Mean	Sd
Panel A: Client-Month statistics						
Credit (1,000 reais)	34.2	114.6	23.4	83.3	36.9	121.0
Defaults	0.065	0.224	0.064	0.228	0.065	0.223
Fraction of credit with a hedge	0.308	0.417	0.208	0.369	0.318	0.415
Panel B: Branch-Month statistics (New Credit)						
Total New Credit (1,000 reais)	451.5	642.7	213.2	361.0	555.4	703.1
Number of Borrowers	42.58	39.28	24.34	29.87	52.04	38.83
Fraction of credit with a hedge	0.311	0.334	0.253	0.345	0.344	0.327

Table 3: Branch Characteristics by Treatment Status

The table below reports branch characteristics by the treatment status 18 to 0 months prior to the opening of a silo. Columns 1 to 3 compute mean values for all variables within each group: Treated, Runner-up, and All branches. Columns 4 and 5 calculate the average difference between groups within a case (i.e. it uses case fixed effects to account for differences between cases). *Treated branches* are those next to which a silo was constructed, *Runner-up branches* are those that were considered as alternative locations for the silos, and *All branches* includes all non-treated branches. All variables are aggregated at the branch-month level. Standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	Treated branches (1)	Runner-up branches (2)	All non-treated branches (3)	Difference (Col. 1- Col. 2) (4)	Difference (Col. 1- Col. 3) (5)
ln(New Credit)	10.03	10.55	11.67	-0.299	-1.498***
				(0.379)	(0.447)
ln(# borrowers)	1.34	2.07	3.01	-0.532	-1.578***
				(0.331)	(0.315)
ln(Barter Credit+1)	4.54	5.84	6.91	-0.698	-2.094**
				(0.710)	(0.894)
ln(Mean Credit)	8.70	8.48	8.66	0.232	0.080
				(0.166)	(0.189)
Maturity	152.76	158.70	153.19	-4.890	-2.082
				(5.790)	(6.271)

Table 4: Financial Contracts – Barter Credit

The table below reports the effect of the construction of a silo on the probability of issuing barter credit (columns 1 and 5), the value of barter credit (columns 2 and 6), the probability of issuing cash credit contract (column 3), and the value of cash credit (column 4) for existing borrowers. The probability of issuing a barter credit is equal to 1 if the borrower has an outstanding barter credit in that month. The value of barter credit is measured as the total sum of barter credit that is outstanding in that month (analogous for cash credit measures). The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. Before^{-2} is a dummy variable that equals 1 if a silo is due to be opened next to the branch in one or two months. Before^{0} is a dummy variable that equals 1 if a silo was opened next to the branch this month or one month ago. After^{2} and After^{4} are dummy variables that equal one if a silo was opened next to the branch two or three and four or five months ago respectively. After^{6+} is a dummy variable that equals 1 if a silo was opened next to the branch six months ago or more. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	P[BartC]	ln(BartC+1)	P[CashC]	ln(CashC+1)	P[BartC]	ln(BartC+1)
	(1)	(2)	(3)	(4)	(5)	(6)
Silo (Treat)	0.077***	0.852***	-0.012	0.083		
	(0.020)	(0.214)	(0.016)	(0.170)		
Before^{-2}					0.016	0.174
					(0.025)	(0.249)
After^{0}					0.011	0.133
					(0.028)	(0.272)
After^{2}					0.048*	0.481*
					(0.028)	(0.278)
After^{4}					0.117***	1.211***
					(0.031)	(0.344)
After^{6+}					0.085***	0.960***
					(0.026)	(0.288)
Obs	259,450	259,450	259,450	259,450	259,450	259,450
Adj-R2	0.620	0.628	0.422	0.550	0.620	0.628
Month-Case-FE	Y	Y	Y	Y	Y	Y
Borrower-FE	Y	Y	Y	Y	Y	Y

Table 5: Total Credit

The table below reports the effect of the construction of a silo on total outstanding credit for existing borrowers. The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. Before^{-2} is a dummy variable that equals 1 if a silo is due to be opened next to the branch in one or two months. Before^{0} is a dummy variable that equals 1 if a silo was opened next to the branch this month or one month ago. After^{2} and After^{4} are dummy variables that equal one if a silo was opened next to the branch two or three and four or five months ago respectively. After^{6+} is a dummy variable that equals 1 if a silo was opened next to the branch six months ago or more. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	ln(Credit)	ln(Credit)
	(1)	(5)
Silo (Treat)	0.321***	
	(0.046)	
Before^{-2}		-0.007
		(0.069)
After^{0}		0.013
		(0.086)
After^{2}		0.193
		(0.133)
After^{4}		0.326***
		(0.073)
After^{6+}		0.359***
		(0.068)
Obs	259,450	259,450
Adj-R2	0.732	0.732
Month-Case-FE	Y	Y
Borrower-FE	Y	Y

Table 6: Default Rates

The table below reports the effect of the construction of a silo on equally- and value-weighted default rates in columns 1 and 2, respectively. The loan is classified as defaulted if it defaults or is renegotiated at some point. The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	Defaults	
Weights:	Equal	Value
	(1)	(2)
Silo (Treat)	-0.018*	-0.014
	(0.009)	(0.010)
Obs	259,450	259,450
Adj-R2	0.57	0.57
Month-Case-FE	Y	Y
Borrower-FE	Y	Y

Table 7: Prices

The table below reports the effect of the construction of a silo on the markup for existing borrowers. Markup is defined as the total sales value of a credit contract with the farmer over the total raw costs of the products sold. The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. Before^{-2} is a dummy variable that equals 1 if a silo is due to be opened next to the branch in one or two months. Before^{0} is a dummy variable that equals 1 if a silo was opened next to the branch this month or one month ago. After^{2} and After^{4} are dummy variables that equal one if a silo was opened next to the branch two or three and four or five months ago respectively. After^{6+} is a dummy variable that equals 1 if a silo was opened next to the branch six months ago or more. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	Markup	
	(1)	(2)
Silo (Treat)	-0.035**	
	(0.017)	
Before^{-2}		-0.028
		(0.020)
After^{0}		-0.056**
		(0.024)
After^{2}		-0.035***
		(0.012)
After^{4}		-0.033**
		(0.016)
After^{6+}		-0.039**
		(0.020)
Obs	259,450	259,450
Adj-R2	0.550	0.550
Month-Case-FE	Y	Y
Borrower-FE	Y	Y

Table 8: Court Quality

This table reports the effect of the construction of a silo depending on court quality. To measure court enforcement quality, I collect the necessary data from *Justiça Aberta* of the National Justice Council. The court enforcement quality is measured as the speed in closing bankruptcy cases, calculated as the number of pending cases per judge in each judicial district in each month. Then, I take the average of these values for each judicial district and obtain a measure of court congestion. I classify court enforcement quality of a judicial district as weak if its court congestion is above the median congestion rate. Thus, the dummy variable, *Weak Court Enforcement*, is equal to one when court congestion is above the median and zero otherwise. I report the estimated effect on total outstanding credit (column 1) and the probability of issuing a barter credit (column 2). The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	ln(Credit)	P[BarterCred]
	(1)	(2)
Silo (Treat)	0.255***	0.047***
	(0.043)	(0.019)
Silo x *Weak Court Enforcement*	0.223***	0.099***
	(0.075)	(0.038)
Obs	259,450	259,450
Adj-R2	0.74	0.63
Month-Case-FE	Y	Y
Borrower-FE	Y	Y

Table 9: Distribution of Financially Constrained Borrowers

The table below reports the treatment effect on the fraction of borrowers that rent their farmland (Panel A) and the distribution of borrowers by treatment status 18 to 0 months prior to the opening of a silo (Panel B). In Panel A, Columns 1 and 2 report the treatment effect on the equally- and value-weighted fraction of clients that rent their farmland, respectively. In Panel B, Columns 3 and 4 compute mean values for all variables within each group: Treated and Runner-up branches. Column 5 calculates the average difference between groups within a case (i.e. it uses case fixed effects to account for differences between cases). *Treated branches* are those next to which a silo was constructed and *Runner-up branches* are those that were considered as alternative locations for the silos. All variables are aggregated at the branch-month level. Standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	% Rent EW	% Rent VW
	(1)	(2)
Panel A: Treatment effect		
Silo (Treat)	-0.038	-0.059
	(0.060)	(0.094)
Obs	3,826	3,826
Adj-R2	0.728	0.657
Month-Case-FE	Y	Y
Branch-FE	Y	Y

	Treated	Runner-up	Difference
	(3)	(4)	(5)
Panel B: Pre-treatment comparison			
% Rent (EW)	0.469	0.541	-0.059
			(0.058)
% Rent (VW)	0.587	0.668	-0.078
			(0.057)

Table 10: Financially Constrained vs Unconstrained Borrowers

The table reports the effect of the construction of a silo depending on whether the farmer owns (unconstrained) or rents (constrained) the farmland. I report the estimated effect on total outstanding credit (columns 1 and 3) and the probability of issuing barter credit (columns 2 and 4). *Renter* is a dummy variable equal to one if a farmer rents the farmland. The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. Columns 1 and 2 control for time trends within a case (month-case fixed effects), whereas columns 3 and 4 control for all time-variation for each branch, therefore absorbing the *Silo* variable and controlling for all aggregate changes in the demand (month-case-branch fixed effects). The standard errors are reported in the parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	ln(Credit)	P[BarterCred]	ln(Credit)	P[BarterCred]
	(1)	(2)	(3)	(4)
Silo (Treat)	0.199**	0.045*		
	(0.089)	(0.025)		
Silo x Renter	0.254**	0.057*	0.341***	0.100**
	(0.113)	(0.030)	(0.119)	(0.047)
Obs	259,450	259,450	259,450	259,450
Adj-R2	0.733	0.622	0.735	0.622
Month-Case-FE	Y	Y	N	N
Month-Branch-FE	N	N	Y	Y
Borrower-FE	Y	Y	Y	Y

Table 11: Summary Statistics: Cross-Section – Contract Type

The table below reports client-month (Panel A) and branch-month (Panel B) summary statistics across loan types: 1) combined, 2) cash credit, and 3) barter credit.

	Combined		Cash Credit		Barter Credit	
	Mean	Sd	Mean	Sd	Mean	Sd
Panel A: Client-Month statistics						
Credit (1,000 reais)	34.2	114.6	19.7	71.8	60.0	120.6
Defaults	0.065	0.224	0.043	0.192	0.067	0.220
Panel B: Branch-Month statistics (New Credit)						
Total New Credit (1,000 reais)	451.5	642.7	248.9	349.0	306.4	518.7
Number of Borrowers	42.58	39.28	40.34	37.87	8.59	11.23

Table 12: Barter Credit Contracts

The table reports the effect of the construction of a silo depending on whether the borrower already used a barter contract before a silo was built next to the treated branch. I report the estimated effect on total outstanding credit (column 1) and the probability of issuing barter credit (column 2). The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. The variable *No Barter Before* is a dummy variable equal to 1 if a borrower did not have a barter contract with the agribusiness lender before the treatment. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	ln(Credit)	P[BarterCred]
	(1)	(2)
Silo (Treat)	0.190**	-0.092
	(0.094)	(0.055)
Silo x No Barter Before	0.202**	0.259***
	(0.097)	(0.080)
Obs	259,450	259,450
Adj-R2	0.732	0.621
Month-Case-FE	Y	Y
Borrower-FE	Y	Y

Table 13: Commodity Price Volatility

The table below reports the heterogeneous effect of the construction of a silo depending on domestic commodity price volatility. I report the effect on the probability of issuing barter credit (columns 1 to 5) and total outstanding credit (columns 6 to 10). In each column, I use one of five measures of volatility: 1) lagged monthly volatility, 2) monthly volatility lagged by six months, 3) the current harvest's volatility, 4) the last harvest's volatility, and 5) the price volatility two harvests ago, respectively. Commodity price volatility is measured as the standard deviation of daily returns at the month- or the harvest-level. The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. The specification controls for case-month-grain fixed effects to account for differences across commodities that the farmers grow. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	P[BarterCred]					ln(Credit)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Silo (Treat)	0.062***	0.053***	0.050***	0.040**	0.070***	0.274***	0.279***	0.220***	0.271***	0.346***
	(0.021)	(0.019)	(0.019)	(0.017)	(0.022)	(0.057)	(0.053)	(0.060)	(0.052)	(0.076)
Silo x Vol_{t-1}	0.230**					1.014*				
	(0.090)					(0.577)				
Silo x Vol_{t-6}		0.551***					0.940**			
		(0.144)					(0.374)			
Silo x $\text{Vol}_{harvest}$			0.582**					2.603**		
			(0.237)					(1.029)		
Silo x $\text{Vol}_{harvest-1}$				0.979***					1.225	
				(0.309)					(0.833)	
Silo x $\text{Vol}_{harvest-2}$					0.038					-1.160
					(0.211)					(1.302)
Obs	238,471	238,471	238,471	238,471	238,471	238,471	238,471	238,471	238,471	238,471
Adj-R2	0.603	0.603	0.603	0.603	0.603	0.696	0.696	0.696	0.696	0.696
Month-Case-Grain-FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Borrower-FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Table 14: Weather Shocks: Temperature and Precipitation

This table reports the effect of the construction of a silo depending on the weather uncertainty. I report the estimated effect on the probability of issuing barter credit (columns 1 and 2), volume of barter credit (columns 3 and 4), and total credit (columns 5 and 6). The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. High Temperature Deviation is a dummy variable equal to 1 if the branch is located in an area where the variation in monthly mean temperature relative to the long-term monthly mean is above the median of this variation among all branches. High Precipitation Deviation is a dummy variable equal to 1 if the branch is located in an area where the variation in monthly mean precipitation relative to the long-term monthly mean is above the median of this variation among all branches. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	P[BarterCred]		ln(BarterCred+1)		ln(Credit)	
	(1)	(2)	(3)	(4)	(5)	(6)
Silo (Treat)	0.027***	0.028***	0.315***	0.307***	0.252***	0.281***
	(0.005)	(0.007)	(0.056)	(0.038)	(0.039)	(0.023)
Silo x High *Temperature* Deviation	0.091***		1.080***		0.154**	
	(0.018)		(0.251)		(0.077)	
Silo x High *Precipitation* Deviation		0.079***		0.974***		0.090
		(0.021)		(0.260)		(0.074)
Obs	259,450	259,450	259,450	259,450	259,450	259,450
Adj-R2	0.620	0.620	0.64	0.64	0.733	0.733
Month-Case-FE	Y	Y	Y	Y	Y	Y
Borrower-FE	Y	Y	Y	Y	Y	Y

Table 15: Staggered Specification

This table reports the effect of the construction of a silo, using only the sample of treated branches. The specification exploits the staggered nature of the construction and augments specification (1) by replacing case-month with month fixed effects. I report the estimated effect on the total outstanding credit (column 1), value of barter credit (column 2), the probability of issuing a cash credit (column 3), and the markup (column 3). The unit of analysis is borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	ln(Credit)	ln(barter+1)	P[Barter]	Markup
	(1)	(2)	(4)	(5)
Silo (Treat)	0.359***	0.815***	0.073***	-0.036**
	(0.066)	(0.192)	(0.021)	(0.018)
Obs	56,095	56,095	56,095	56,095
Adj-R2	0.732	0.620	0.324	0.550
Month FE	Y	Y	Y	Y
Borrower FE	Y	Y	Y	Y

Table 16: Storage Capacity

This table reports the effect of the construction of a silo depending on the available grain storage capacity in a municipality. I obtain the total grain storage capacity (in tons) at each municipality from the Brazilian census of agriculture, 2006 (Instituto Brasileiro de Geografia e Estatística, 2006). To obtain a measure of storage deficit/utilization I scale this variable by four proxies for total production, also obtained from the same source: 1) the total area of a municipality in hectares (*Municipality Area*), 2) the total farmland in a municipality in hectares (*Total Farmland*), 3) the total planted area (*Planted Area*), and 4) the total quantity produced of soybean, corn, and wheat in tons (*Produced Quantity*). I report the estimated effect on total outstanding credit (columns 1, 3, 5, and 7) and the probability of issuing a barter credit (columns 2, 4, 6, 8). The unit of analysis is case-borrower-month. The variable *Silo* is equal to 1 if a branch has a silo in that month. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	ln(Credit)	P[BarterCred]	ln(Credit)	P[BarterCred]	ln(Credit)	P[BarterCred]	ln(Credit)	P[BarterCred]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Silo (Treat)	0.352***	0.075***	0.354***	0.077***	0.353***	0.070***	0.338***	0.063***
	(0.053)	(0.025)	(0.053)	(0.025)	(0.055)	(0.024)	(0.053)	(0.024)
Silo x Capacity/Minicipality Area	-0.159	-0.008						
	(0.132)	(0.072)						
Silo x Capacity/Total Farmland			-0.139	-0.015				
			(0.093)	(0.052)				
Silo x Capacity/Planted Area					-0.137	0.027		
					(0.154)	(0.072)		
Silo x Capacity/Produced Quantity							-0.080	0.159
							(0.479)	(0.194)
Obs	243,403	243,403	243,403	243,403	243,403	243,403	243,403	243,403
Adj-R2	0.737	0.623	0.737	0.623	0.737	0.623	0.737	0.623
Month-Case-FE	Y	Y	Y	Y	Y	Y	Y	Y
Borrower-FE	Y	Y	Y	Y	Y	Y	Y	Y

Table 17: Real Effects

This table reports the effect of the construction of a silo on the total production output measured in bushels (columns 1 and 5) and Brazilian reais (columns 2 and 6), harvested area in hectares (columns 3 and 7), and GDP (columns 4 and 8) at the municipality level. The annual output data are obtained from statistics bureau of Brazil (IBGE). To measure court enforcement quality, I collect the necessary data from *Justiça Aberta* of the National Justice Council. The court enforcement quality is measured as the speed in closing bankruptcy cases, calculated as the number of pending cases per judge in each judicial district in each month. Then, I take the average of these values for each judicial district and obtain a measure of court congestion. I classify court enforcement quality of a judicial district as weak if its court congestion is above the median congestion rate. Thus, the dummy variable, *Weak Court Enforcement*, is equal to one when court congestion is above the median and zero otherwise. The unit of analysis is case-municipality-year. The variable *Silo* is equal to 1 if a branch has a silo in that month. The standard errors are reported in parentheses and clustered at the branch level. * significant at 10%; ** significant at 5%; *** significant at 1%

	ln(Volume)	ln(Output)	ln(Area)	ln(GDP)	ln(Volume)	ln(Output)	ln(Area)	ln(GDP)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Silo (Treat)	0.163**	0.155*	0.069	0.025	0.061	0.060	-0.024	-0.033
	(0.071)	(0.082)	(0.067)	(0.036)	(0.078)	(0.078)	(0.053)	(0.037)
Silo x *Weak Court Enforcement*					0.218**	0.204**	0.199**	0.125**
					(0.096)	(0.092)	(0.072)	(0.046)
Obs	480	480	480	480	480	480	480	480
Adj-R2	0.93	0.93	0.954	0.99	0.94	0.93	0.95	0.99
Year-Case-FE	Y	Y	Y	Y	Y	Y	Y	Y
Branch-FE	Y	Y	Y	Y	Y	Y	Y	Y

A Appendix

Figure A1: Mean Daily Precipitation in Brazil

The figures below plot the heat maps of the long-term mean daily precipitation in December (left map) and the monthly mean daily precipitation in December 2009 (right map) in Brazil. The spatial resolution of the heat map is 0.5 x 0.5 degrees.

Long-Term Mean Daily Precipitation: December Mean Daily Precipitation in December 2009

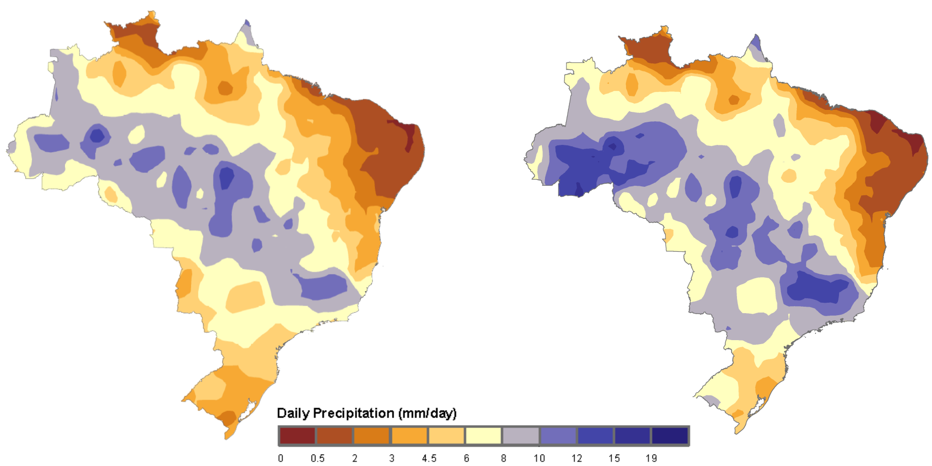

Figure A2: Deviation from the Long-Term Mean Precipitation (December, 2009)

The figure below plots the heat map as the deviation of the monthly mean daily precipitation in December 2009 from that of the long-term mean daily precipitation in December in Brazil. The difference between the two monthly measures is calculated at a pixel level with resolution of 0.5 x 0.5 degrees (both original maps are plotted in Figure (A1)). In terms of scale, deviation of 1 mm/day represents roughly one standard deviation of the deviation from the long-term mean.