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Capital Accumulation and Structural Transformation*

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Abstract

Several scholars argue that high agricultural productivity can retard industrial development as it draws resources towards the comparative advantage sector, agriculture. However, agricultural productivity growth can increase savings and the supply of capital, generating an expansion of the capital-intensive sector, manufacturing. We highlight this mechanism in a simple model and test its predictions in the context of a large and exogenous increase in agricultural productivity due to the adoption of genetically engineered soy in Brazil. We find that agricultural productivity growth generated an increase in savings, but these were not reinvested locally. Instead, there were capital outflows from rural areas. Capital reallocated towards urban regions, where it was invested in the industrial and service sectors. The degree of financial integration affected the speed of structural transformation. Regions that were more financially integrated with soy-producing areas through bank branch networks experienced faster growth in non-agricultural lending. Within these regions, firms with pre-existing relationships with banks receiving funds from the soy area experienced faster growth in borrowing and employment.

Keywords: Agricultural Productivity, Bank Networks, Financial Integration
JEL Classification: O14, O16, O41, F11

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I Introduction

The process of economic development is characterized by a reallocation of production factors from the agricultural to the industrial and service sectors. Economic historians have argued that in the first industrialized countries technical improvements in agriculture favored this process by increasing demand for manufactures or generating savings to finance industrial projects (Crafts 1985 and Crouzet 1972). However, the experience of some low-income countries appears inconsistent with the idea that agricultural productivity growth leads to economic development.[1] The theoretical literature has proposed two sets of explanations. First, the positive effects of agricultural productivity on economic development might not take place in open economies where manufactures can be imported and savings can be exported (Matsuyama 1992). Second, market frictions might constrain factor reallocation (Banerjee and Newman 1993). The recent empirical literature has focused on understanding how these mechanisms shape the process of labor reallocation. However, there is scarce direct empirical evidence on the process of capital reallocation from the rural agricultural sector to the urban industrial sector.[2]

In this paper we study the effects of productivity growth in agriculture on the allocation of capital across sectors and regions. To guide the empirical analysis we refer to the Heckscher-Ohlin model, which illustrates the classic effect of agricultural technical change on structural transformation in an open economy: larger agricultural productivity increases the demand for capital in agriculture, thus capital reallocates towards this sector (Findlay and Grubert 1959). This is the negative effect of agricultural comparative advantage on industrialization highlighted in the development literature and we refer to it as the capital demand effect. In this paper, instead, we highlight that larger agricultural income generates savings, the supply of capital increases and thus the capital-intensive sector, manufacturing, expands. This positive effect of agricultural productivity on industrialization has been overlooked by the theoretical literature and will be the main focus of our empirical analysis. We refer to it as the capital supply effect.

Our empirical analysis attempts to trace the causal effects of agricultural productivity growth on the allocation of capital across sectors and regions. This has proven challenging for the literature due to the limited availability of data on capital flows within countries. We overcome this difficulty by using detailed information on deposits and loans for each

[1] For example, Foster and Rosenzweig (2004, 2007) show that, after the Green Revolution, regions in rural India with faster agricultural productivity growth experienced slower industrialization.

[2] For evidence on labor reallocation across sectors see McCaig and Pavcnik (2013) and Bustos, Caprettini, and Ponticelli (2016); see also Herrendorf, Rogerson, and Valentinyi (2014) for a review of the macro literature. For labor reallocation across regions see: Moretti (2011), Michaels, Rauch, and Redding (2012), Munshi and Rosenzweig (2016), Bryan and Morten (2019) and Fajgelbaum and Redding (2018). For capital reallocation see Banerjee and Munshi (2004) who document larger access to capital for entrepreneurs belonging to rich agricultural communities in the garment industry in Tirupur, India. See also the recent macroeconomic literature on financial frictions and development: Giné and Townsend (2004), Jeong and Townsend (2008), Buera, Kaboski, and Shin (2015), Moll (2014).

bank branch in Brazil. We match this data with confidential information on bank-firm credit relationships and social security records containing the employment histories for the universe of formal firms. Therefore, our final dataset permits to observe capital flows across both sectoral and spatial dimensions. We use this data to establish the causal effect of agricultural productivity growth on the direction of capital flows. For this purpose, we exploit a large and exogenous increase in agricultural productivity: namely the legalization of genetically engineered (GE) soy in Brazil. This new technology had heterogeneous effects on yields across areas with different soil and weather characteristics, which permits to estimate the local effects of agricultural productivity growth. In addition, a second step in our empirical strategy relies on differences in the degree of financial integration across regions to trace capital flows across rural and urban areas.

First, we study the local effects of agricultural productivity growth. We find that municipalities subject to faster exogenous technical change indeed experienced faster adoption of GE soy and growth in agricultural profits.[3] We think of these municipalities directly affected by agricultural technical change as *origin* municipalities. Consistent with the model, we find that these municipalities experienced a larger increase in savings deposits in local bank branches. However, there was no increase in local bank lending. As a result, agricultural technical change generated capital outflows from origin municipalities. This finding suggests that the increase in the local demand for capital is smaller than the increase in local supply. Thus, banks must have reallocated savings towards other regions. Therefore, we propose a methodology to track the destination of those savings generated by agricultural productivity growth.

In a second step of the analysis, we need to trace the reallocation of capital across space. For this purpose, we exploit differences in the geographical structure of bank branch networks for 115 Brazilian Banks. We think of these banks as intermediaries that reallocate savings from *origin* municipalities to *destination* municipalities where they have branches. First, we show that banks more exposed to the soy boom through their branch network indeed had a larger increase in aggregate deposits. Next, we track the destination of those deposits generated by agricultural technical change. For this purpose, we assume that, due to imperfections in the interbank market, banks are likely to fund part of their loans with their own deposits. This implies that we can construct exogenous credit supply shocks across destination municipalities using differences in the geographical structure of bank branch networks. We use this variation to assess whether destination municipalities more financially connected to origin municipalities experiencing agricultural productivity growth received larger capital inflows. We find that this is indeed the case. Interestingly, these funds went entirely to non-soy producing regions and were channeled to non-agricultural activities.

[3]We use agricultural profits per hectare as a proxy for land rents as 93 percent of agricultural land is farmed by its owners. See Agricultural Census of Brazil, IBGE (2006), Table 1.1.1, pag.176.

To interpret our findings, we present a simple two-period multi-region Heckscher-Ohlin model. We assume that there are rural and urban regions where both agricultural and manufacturing activities take place. Rural areas face agricultural productivity growth, which reinforces their comparative advantage in agriculture. However, new agricultural technologies generate a temporary increase in land rents, which result in larger savings. If rural areas are in financial autarky, this increase in local capital supply generates a reduction in the autarky interest rate and an expansion of the capital-intensive sector, manufacturing. Instead, if rural regions are financially integrated with other regions, agricultural productivity growth generates further specialization in agriculture and capital outflows. Urban regions financially integrated to areas experiencing agricultural technical change receive capital inflows, which generates an expansion of the manufacturing sector.[4]

The findings discussed above are consistent with the capital supply mechanism emphasized by the model for the case in which rural and urban regions are financially integrated. Our empirical analysis permits to quantify this effect by comparing the speed of capital reallocation across sectors in non-soy producing municipalities with different degrees of financial integration with the soy boom area. Between 1996 and 2010, the share of non-agricultural lending increased from 75 to 84 percent in the average non-soy producing municipality in Brazil. However, the speed of capital reallocation away from agriculture varied extensively across municipalities. Our estimates imply that one standard deviation in the degree of financial integration with soy-producing regions can explain 11 percent of a standard deviation in the increase of the non-agricultural lending share across non-soy producing municipalities.

As mentioned above, our findings are consistent with the capital supply mechanism emphasized by the model. However, to the extent that destination municipalities which are more connected to origin municipalities through bank-branch networks are also more connected through the transportation or commercial networks, it is possible that our estimates are capturing the effects of agricultural technical change through other channels. For example, if technical change is labor-saving, former agricultural workers might migrate towards cities and increase labor supply, the marginal product of capital and capital demand. Similarly, cities could face larger product demand from richer farmers. As a result, our empirical strategy permits to assess the effect of agricultural productivity on the allocation of capital across sectors and regions but can not isolate whether this occurs through a labor supply, product demand or capital supply channel. To make progress on this front we need to implement a firm-level empirical strategy which permits to control for labor supply and product demand shocks in destination municipalities, as we describe below.

[4] We assume that regions within the country are financially integrated but in financial autarky with respect to the rest of the world. This assumption is an extreme way to capture larger financial frictions across than within countries.

In a third step of the analysis, we trace the reallocation of capital towards firms located in destination municipalities. For this purpose, we match administrative data on the credit and employment relationships for the universe of formal firms. We use this data to construct firm-level exogenous credit supply shocks using information on pre-existing firm-bank relationships. We use these shocks to assess whether firms whose pre-existing lenders are more connected to soy-producing regions through bank branch networks experienced larger increases in borrowing and employment growth. This empirical strategy permits to isolate the capital supply channel by comparing firms borrowing from different banks but operating in the same municipality and sector, thus subject to the same labor supply and product demand shocks. We find that firms having pre-existing relationships with banks receiving deposits from the soy boom borrow more from those banks, and not from other banks with whom they also had relationships. Consistent with the aggregate results described above, we find that most of the new capital was allocated to non-agricultural firms: out of each 1 R$ of new loans from the soy-driven deposit increase, 0.5 cents were allocated to firms in agriculture, 40 cents to firms in manufacturing, 48 cents to firms in services and 12 cents to other sectors. Finally, we study whether larger loans led to firm growth: we find that firms receiving credit from the soy boom also experience faster growth in employment and wage bill.

Taken together, our empirical findings imply that agricultural productivity growth can lead to structural transformation in open economies through its impact on capital accumulation. We interpret these findings in light of a neoclassical model where agricultural productivity growth induces land owners to save, which increases the supply of capital. In addition, the new technology reinforces agricultural comparative advantage in rural areas. As a result, it is optimal to reallocate manufacturing activities and capital towards other areas. Consistent with this model, we observe capital outflows from soy producing regions towards non-agricultural activities in non-soy producing regions.

Finally, the empirical results highlight the importance of financial frictions. The presence of these frictions suggests that the allocation of capital across destination regions and firms might not be optimal. In section VII we discuss how the introduction of credit constraints can modify the predictions of the model and the interpretation of the empirical results.

Related Literature

Our paper is related to a large literature characterizing the development process as one where agricultural workers migrate to cities to find employment in the industrial and service sectors. Understanding the forces behind this reallocation process is important, especially when labor productivity is lower in agriculture than in the rest of the economy (Gollin, Lagakos, and Waugh 2013). There is a rich recent empirical literature analyzing the determinants of the reallocation of labor both across sectors (McCaig and Pavcnik

2013, Foster and Rosenzweig 2004, 2007, Bustos et al. 2016), and across regions (Michaels et al. 2012, Fajgelbaum and Redding 2018, Moretti 2011, Bryan and Morten 2019, Munshi and Rosenzweig 2016). In contrast, our knowledge of the process of capital reallocation is extremely limited.[5]

The scarcity of empirical studies on the reallocation of capital is often due to the limited availability of data on the spatial dimension of capital movements.[6] In this paper, we are able to track internal capital flows across regions in Brazil using detailed data on deposit and lending activity at branch level for all commercial banks operating in the country. This data permits to obtain a measure of municipality-level capital flows by computing the difference between deposits and loans originated in the same location. To the best of our knowledge, this is the first dataset which permits to observe capital flows across regions within a country for the entire formal banking sector.

A second challenge we face is to sign the direction of capital flows: from the agricultural rural sector to the urban industrial sector. For this purpose we design a new empirical strategy which exploits differences in the geographical structure of bank branch networks to measure differences in the degree of financial integration across origin and destination municipalities. This strategy builds on the insights of the literature studying the effects of transportation networks on goods market integration, such as Donaldson (2018) and Donaldson and Hornbeck (2016).

A third challenge is to isolate the capital supply channel from other effects of agricultural technical change which could spill over to connected regions. We overcome this difficulty by bringing the analysis to the firm level. This allows us to construct firm-level credit supply shocks by exploiting differences in the geographical structure of the branch network of their lenders. Our paper is thus related to two strands of the literature studying the effect of exogenous credit supply shocks. First, the development literature studying the effects of exogenous credit shocks on firm growth (Banerjee and Duflo 2014, Cole 2009, McKenzie and Woodruff 2008, De Mel, McKenzie, and Woodruff 2008, Banerjee, Karlan, and Zinman 2015, Banerjee, Duflo, Glennerster, and Kinnan 2015). Second, the finance literature studying the effects of bank liquidity shocks. This literature has

[5]See Crafts (1985) and Crouzet (1972) for early studies on the role of agriculture as a source of capital for other sectors during the industrial revolution in England. See Gollin (2010) for references and a discussion of the role of agricultural productivity growth on industrialization in England. See also contemporaneous work by Marden (2016) studying the local effects of agricultural productivity growth in China, and Moll, Townsend, and Zhorin (2017), that propose a model on labor and capital flows between rural and urban regions, and calibrate it using data on Thailand. Another contemporaneous related paper is Dinkelman, Kumchulesi, and Mariotti (2019), which studies the effect of capital injections from migrants' remittances on local labor markets in Malawi. The authors find that regions receiving largest capital inflows from migrants experienced faster structural change. Dix-Carneiro and Kovak (2017) find that Brazilian regions more exposed to the 1990s trade liberalization experienced larger declines in employment and earnings, and argue that capital reallocation away from these regions could explain this result.

[6]For a detailed discussion of the literature which points out this limitation, see Foster and Rosenzweig (2007).

established that bank credit supply changes can have important effects on lending to firms and employment (Chodorow-Reich 2014, Khwaja and Mian 2008) as well as on loans to individuals such as mortgages (Gilje, Loutskina, and Strahan 2016). We contribute to this literature by proposing a methodology to trace the reallocation of capital from the rural agricultural sector to the urban industrial and service sectors.

Finally, let us note that this paper is part of a broader research agenda in which we study the effect of agricultural productivity on development, exploiting the recent introduction of genetically engineered soy in Brazil. We organize our work around three channels through which productivity growth in agriculture can foster structural transformation: increasing demand for industrial goods and services, releasing labor and generating savings. In Bustos et al. (2016) we study the second channel: we find that the new technology was labor-saving and induced a reallocation of labor away from agriculture into the local industrial sector. We also show that agricultural productivity growth had a limited impact on migration, indicating that the reallocation of labor primarily occurred within the local labor market. In this paper, we focus on the third channel: the effect of agricultural productivity growth on savings and the allocation of capital. Consistent with higher mobility of capital relative to labor, we find that capital reallocated both across sectors and across regions. In particular, capital reallocated from the rural regions where agricultural productivity increased into the urban regions financially connected to them. The fact that capital reallocated to regions not directly affected by soy technical change allows us to separately identify the savings channel from the labor channel discussed above.[7] We quantify their relative importance in section VIII.

The rest of the paper is organized as follows. We start by presenting a theoretical framework to illustrate the effects of agricultural technical change on structural transformation in open economies in section II. Section III describes the data and our empirical strategies. In sections IV, V and VI we present the main empirical results of the paper on the local effects of soy technical change, the reallocation of capital towards destination municipalities, and the reallocation of capital towards destination firms, respectively. Finally, we discuss the evidence in light of models in which credit constraints can affect the direction of capital flows in section VII of the paper.

II Theoretical Framework

In this section we present a simple two-period and two-sector neoclassical model to illustrate the effects of agricultural technical change on structural transformation in open economies. The model builds on Jones (1965)'s version of the Heckscher-Ohlin model and

[7] This is because destination regions are only affected by agricultural technical change through its effects on capital inflows. Note that, in the case of origin regions, both the labor channel documented in Bustos et al. (2016) and the capital channel studied in this paper are at play, so that the net effect on capital allocation is ambiguous. We discuss this in section V.

the dynamic extensions studied by Stiglitz (1970), Findlay (1970) and Ventura (1997). The model also relates to the literature studying capital flows in the context of the Heckscher-Ohlin model (Mundell 1957, Markusen 1983 and Antras and Caballero 2009). We start by discussing the effects of technical change in a country which is open to goods trade but in financial autarky. Next, we split the country in two regions – Origin (o) and Destination (d) – which are open to international trade. We investigate the effects of agricultural technical change in one of the regions – the Origin – on the allocation of capital across regions and sectors under two scenarios: financial autarky and financial integration. In what follows we describe the setup and discuss the implications of the model. The formal setup of the model and all derivations are included in Appendix A.

II.A Setup

Consider a small open economy where individuals only live for two periods and display log preferences over consumption in periods one and two. There is one final good which can be used for consumption and investment. This final good is non traded but is produced using two traded intermediates: a manufacturing good and an agricultural good. In turn, production of the manufactured and the agricultural intermediate goods requires both capital (K) and land (T). The supply of land is fixed for both periods but the supply of capital can vary in the second period due to capital accumulation. We assume that capital can be turned into consumption at the end of each period, thus its price in terms of period 1 consumption, the numeraire, is equal to one. Instead, land can only be used for production, thus its price fluctuates to equilibrate asset markets. Factors of production are internationally immobile, but freely mobile across sectors. All markets are perfectly competitive and production functions in the final and intermediate goods sectors satisfy the neoclassical properties.

II.B Equilibrium

The intratemporal equilibrium in this model follows the mechanics of the 2x2 Heckscher-Ohlin Model. Provided that the small open economy produces both goods, free entry conditions in goods markets imply that factor prices are uniquely pinned down by international goods prices and technology, regardless of local factor endowments (Samuelson 1949).[8] In turn, the production structure is determined by relative factor supplies, which are pre-determined in the first period but are the result of capital accumulation in the second one. We obtain a solution for savings and the capital stock in the second period by considering the intertemporal equilibrium conditions in asset markets. Finally, we use

[8]See the Appendix A where we state the zero-profit conditions in the agricultural and manufacturing sectors, which can be used to solve for factor prices as a function of goods prices and agricultural technology. This result requires the additional assumption that there are no factor intensity reversals and is the Factor Price Insensitivity result by Samuelson (1949).

the factor market clearing conditions in each period to solve for the allocation of factors across sectors, manufacturing and agricultural outputs. See Appendix A.B for a formal statement of the equilibrium conditions.

II.C Comparative statics: the effects of agricultural technical change

In this section we discuss the effects of an increase in agricultural productivity brought by the adoption of a new technology. That is, we compare the equilibrium level of sectoral outputs in two scenarios. The first scenario is a benchmark economy which is in a steady state equilibrium with constant technology, international goods prices and consumption. The second scenario is an economy that adopts the new agricultural technology in period 1 but expects a reduction in the profitability of the new technology in period 2.[9]

II.C.1 Factor Prices

If agriculture is land-intensive, agricultural technical change increases the return to land and reduces the return to capital.[10] This is because agricultural productivity growth raises the profitability of agricultural production. As a result, land rents must increase to satisfy the zero profit condition in the agricultural sector. However, because manufacturing also uses some land, the increase in land rents reduces its profitability and the return to capital falls. Note that this reduction is expected to be small to the extent that the land cost share in manufacturing production is small. The mechanics of these effects are similar to the Stolper-Samuelson effect of changes in commodity prices on factor prices. Finally, note that the increase in land rents is larger in the first period because the profitability of the new technology falls in the second period.

II.C.2 The Supply of Capital

Agricultural technical change increases the supply of capital in the second period as long as the aggregate land income share is large relative to the land cost share in manufacturing. This is because the increase in land rents generates a temporary increase in income, which has a positive effect on savings. This positive effect is proportional to the land share of aggregate income, thus we expect it to be large in land-abundant rural areas. Second, the reduction in the rental price of capital has a negative effect on savings. As mentioned above, the reduction in the rental price of capital is small as it

[9]This can be the case, for example, if the economy is an early adopter of an agricultural technology and international prices are expected to fall when all countries adopt. Alternatively, technology adoption can generate a (partially) temporary increase in income when environmental regulation is expected to become stricter in the future.

[10]Agriculture is land-intensive if the land production cost share in agriculture is larger than in manufacturing. In Appendix Section A.C.2 we show that in this case, capital per unit of land is higher in manufacturing than in agriculture

is proportional to the the land cost share in manufacturing, thus this negative effect is expected to be small.

II.C.3 The allocation of capital across sectors

An increase in agricultural productivity has two opposite effects on capital allocation across sectors. A capital demand effect generates a reallocation of capital towards agriculture, the comparative advantage sector.[11] A capital supply effect, instead, generates a reallocation of capital towards manufacturing, the capital-intensive sector. Therefore, the net effect of agricultural technical change depends on the relative strength of the capital demand and capital supply effects.

The capital demand effect takes place because agricultural technical change increases the profitability of the agricultural sector and thus generates a reallocation of factors towards it, increasing the relative supply of agricultural goods. The effect of technical change on the the relative supply of agriculture depends positively on the supply elasticity of substitution between commodities. This is because an increase in agricultural productivity has a similar effect on the profitability of agriculture as an increase in the relative price of agricultural goods. In turn, this supply elasticity depends on the elasticity of substitution between land and capital in production. If this elasticity is low, when agricultural productivity increases and more capital is drawn into the agricultural sector, decreasing returns set in quickly. Thus, the increase in capital demand is small.

In turn, the capital supply effect takes place when agricultural technical change increases savings and the relative supply of capital, which leads to an increase in the relative supply of manufacturing, the capital-intensive sector. This is because, given factor prices, capital intensities are fixed within each sector. The only way to equilibrate factor markets is therefore to assign the new capital to the capital-intensive sector as in the Rybczynski theorem (Rybczynski 1955).[12] As a result, the growth in the relative supply of manufacturing due to the capital supply effect is proportional to the increase in capital supply. As mentioned above, the increase in capital supply is increasing in the land income share relative to the land cost share in manufacturing.

In sum, the capital supply effect tends to dominate when the agricultural productivity shock is temporary, the income share of agriculture is large, the land cost share is low in manufacturing and land and capital are not good substitutes in production (see condition (A16) in Appendix A.C.3). In what follows, we assume that this condition holds in the

[11] This effect has been emphasized by the theoretical literature linking larger agricultural productivity to de-industrialization (Corden and Neary 1982 and Matsuyama 1992).

[12] This prediction only applies when goods are traded. In a closed economy, the effect of an increase in the supply of capital on structural transformation depends on the demand elasticity of substitution between goods and services. When these are complements, an increase in the supply of capital would generate faster output growth in the capital intensive-sector, a reduction in its price and a reallocation of capital towards non-capital intensive sectors, as emphasized by Acemoglu and Guerrieri (2008).

benchmark equilibrium.

II.D Capital Flows Across Regions

We can use the model developed above to think about the consequences of financial integration across regions within a country. To simplify the exposition, suppose that the country has two regions, Origin (o) and Destination (d), which are open to international trade. The model developed above can be used to analyze the effects of agricultural technical change in the Origin on capital accumulation and structural transformation in both regions. We discuss first the results obtained when both regions are in financial autarky and later the results under financial integration.

II.D.1 Financial Autarky

If the origin region is open to international trade but in financial autarky, agricultural technical change generates a reallocation of capital towards the local manufacturing sector. Note that, in this case, the benchmark equilibrium and the effects of technical change are identical to those described in sections II.B and II.C above. In particular, when agricultural productivity grows, land rents increase and the rental price of capital falls to the financial autarky equilibrium level (r_K^a). In addition, the supply of capital increases more than capital demand in agriculture. As a result, the capital-intensive sector, manufacturing, expands. Finally, note that the destination region is not affected by technical change in the origin region. This is because the origin region is a small economy, thus agricultural technical change in this region does not affect world prices.

II.D.2 Financial Integration

In this section we consider the case in which the two regions are not only open to international trade but also open to capital flows. First, note that the small open economy assumption implies that if both regions were open to international capital flows, technical change in the origin would not have any effect on the destination region. Then, we assume that the two regions are financially integrated but in financial autarky with respect to the rest of the world. This assumption attempts to capture deeper financial integration within than across countries. In addition, we assume that in the benchmark steady state equilibrium all countries and regions share the same technology. Thus, trade in goods leads to factor price equalization at r_K^* and r_T^* if both regions produce both goods. In this case, capital owners are indifferent between investing in any of the two regions. Therefore, we assume that in the financial integration equilibrium there is a small cost ε for capital movements across regions so that the equalization of the rental rate of capital at r_K^* implies that capital flows are zero in the benchmark equilibrium. In this case, the benchmark equilibrium is the same under financial autarky and financial integration, which simplifies the analysis.

Origin Region Under financial integration, agricultural technical change in the origin region generates local deindustrialization and capital outflows. First, as in the autarky equilibrium, the increase agricultural productivity raises land rents. However, the rental rate of capital stays above the autarky equilibrium level due to capital mobility ($r_K^* > r_K^a$). This has two implications. First, the increase in land rents makes manufacturing production unprofitable and the sector closes. Thus, local aggregate capital demand falls even if agriculture demands more capital. Second, the temporary increase in land rents generates savings and an increase in capital supply. Thus, there are capital outflows. More generally, in Appendix A.D we show that capital outflows are increasing in agricultural productivity growth if the capital supply effect is larger than the capital demand effect (see condition (A21) in Appendix A.D.2)).

Destination Region Finally, we consider a destination region which does not experience technical change. In this region factor prices stay at the level r_K^* and r_T^* given by initial technology and international goods prices. As a result, capital leaving the origin region can flow into the destination region without affecting the rental rate of capital. Instead, the destination region absorbs this additional capital by expanding production of the capital-intensive sector, manufacturing. This is because the destination region faces a pure Rybczynski effect with no changes in technology. In sum, this region experiences structural transformation as capital reallocates towards the manufacturing sector.

III Empirics

Our empirical work aims at tracing the reallocation of capital from the rural agricultural sector to the urban manufacturing sector. This reallocation process takes place both across sectors and regions, thus our empirical strategy proceeds in two steps, which we summarize below.

First, we attempt to establish the direction of causality, from agriculture towards other sectors. For this purpose, we exploit a large and exogenous increase in agricultural productivity: the legalization of genetically engineered soy in Brazil. We use this variation to assess whether municipalities more affected by technical change in soy production experienced larger increases in land rents and savings, as predicted by the model. We think of these soy producing areas affected by technical change as *origin* municipalities, which can be described as small economies open to international trade in agricultural and manufacturing goods but closed to international capital flows, as required by the model. Under these assumptions, our empirical strategy captures the general equilibrium effect of agricultural technical change on land rents and savings in origin municipalities. This is because free trade pins down goods and factor prices. As a result, technical change in a given origin municipality does not affect outcomes such as land rents or savings in other municipalities. Then, our empirical strategy can quantify the local effects of agricultural productivity growth by comparing the growth rate of outcomes of interest across municipalities facing different growth rates of exogenous agricultural technical change. This reduced form empirical strategy mimics the comparative statics exercise performed in the model developed in Appendix A, which describes the general equilibrium response of each endogenous variable to exogenous agricultural technical change under autarky and financial integration.[13] Subsection III.A describes the context, data and empirical strategy we use to study the local effects of soy technical change on land rents and savings deposits.

Second, we trace the reallocation of capital across regions. For this purpose, we need to estimate the effects of agricultural technical change on the supply of capital in regions not affected by technical change but financially integrated to affected regions. The model predicts that a destination region financially integrated with an origin region facing larger agricultural technical change experiences larger capital inflows and faster reallocation of capital towards manufacturing. In contrast, a destination region that is not financially connected to the soy area is unaffected by technical change in other municipalities, because goods and factor prices are pinned down by international goods prices. In Appendix B we extend the model to derive a generalized version of this prediction for the case of many regions (municipalities) with different levels of financial integration. To measure the degree of financial integration across municipalities, we exploit differences in the geographical structure of the branch networks of Brazilian banks. We think of these banks as intermediaries that can potentially reallocate savings from soy producing (*origin*) municipalities to non-soy producing (*destination*) municipalities.[14,15] We link each destination

[13]For a closed form solution of the model showing the response of each endogenous variable to exogenous technical change see Appendix A section A.C for the financial autarky case and section A.D.2 for the case of financial integration across regions.

[14]We extend the model by introducing banks and many regions in Appendix B. As our main objective is to use banks to measure the degree of financial integration across regions, we do not explicitly provide micro-foundations of the role of banks. Instead, we extend our model in the simplest possible way by assuming that banks are providers of a technology that permits to reallocate capital across regions where the same bank has branches, in the same way as transportation technology permits to trade goods across regions connected by a road.

[15]The role of banks as intermediaries between investors and firms has been justified on the grounds of imperfect information leading to moral hazard or adverse selection problems. Diamond (1984) develops a theory of financial intermediation where banks minimize monitoring costs because they avoid the duplication of effort or a free-rider problem occurring when each lender monitors directly. Holmstrom and Tirole (1997) propose a model of financial intermediation in which firms as well as intermediaries are capital constrained due to moral hazard. Firms that take on too much debt in relation to equity do not have a sufficient stake in the financial outcome and will therefore not maximize investor surplus. In this case, bank monitoring acts as a partial substitute for collateral. However, banks also face a moral hazard problem and must invest some of their own capital in a project in order to be credible monitors. This makes the aggregate amount of intermediary capital one of the important constraints on aggregate investment. In this model, an increase in savings generates an expansion of bank credit and investment.

municipality to all origin municipalities within the same bank branch network to construct exogenous credit supply shocks at the destination-municipality-level. We use this variation to assess whether municipalities financially connected to soy-producing regions through bank branch networks experienced larger increases in aggregate bank lending and in the share of non-agricultural loans. Subsection III.B describes the data and the empirical strategy to study capital reallocation across regions.

One concern with our identification of aggregate capital flows across regions is that destination municipalities which are more financially connected to origin municipalities might also be more connected through migration or commercial networks. In that case, our estimates could be capturing the effects of agricultural technical change in origin municipalities on bank lending in destination municipalities through a labor supply or a product demand channel, rather than the capital supply mechanism emphasized by the model. Thus, we bring our analysis at a more micro-level and trace the reallocation of capital towards firms located in destination municipalities. For this purpose, we use administrative data on the credit and employment relationships for the universe of formal firms operating in Brazil. We use this data to construct firm-level exposure to capital inflows from origin municipalities using information on pre-existing firm-bank relationships. We use this variation to assess whether firms whose pre-existing lenders are more financially integrated to soy-producing regions through bank branch networks experienced larger increases in borrowing and employment than other firms operating in the same destination municipality.[16] Subsection III.C describes the data and the empirical strategy used to study capital reallocation towards firms in destination municipalities.

The empirical results for each of the three steps in the empirical strategy discussed above are presented in sections IV, V and VI respectively. Let us note that, when interpreting our estimates, we do not take the model literally because some assumptions are quite extreme. First, the model considers the case in which regions are financially integrated within Brazil but in financial autarky with respect to the rest of the world. This assumption is an extreme way to capture larger financial frictions across countries than within countries. In practice, some savings likely leak abroad. Second, the model considers the case in which there is no interbank market. This assumption is also an extreme way to capture larger financial frictions across than within banks. In practice, some savings might leak through the interbank market to municipalities not directly served by

[16]Note that this empirical strategy requires that firms that have a pre-existing relationship with a bank are more likely to receive credit. In Appendix B section B.A.3 we extend the theoretical model by assuming that each bank can only lend to a subset of firms already connected to it. These long term firm-bank relationships can be the result of asymmetric information. For example, in the model developed by Sharpe (1990) a bank which actually lends to a firm learns more about that borrower's characteristics than other banks. In this model, adverse selection makes it difficult for one bank to draw off another bank's good customers without attracting the less desirable ones as well. Alternatively, long term bank-borrower relationships can reduce borrower moral hazard through the threat of future credit rationing as in Stiglitz and Weiss (1983).

banks operating in soy-producing regions. Note, however, that these deviations from the model's assumptions make us underestimate the effect of agricultural technical change on savings, capital flows and structural transformation in Brazil.

III.A Local Effects of Soy Technical Change: Data and Empirical Strategy

We start this section by providing background information on the technological change introduced by GE soy seeds in Brazilian agriculture. Next, we present the data and the empirical strategy used to study the effects of technical change in soy production on local land rents and savings.

The main innovation introduced by GE soy seeds is that they are genetically modified in order to resist a specific herbicide (glyphosate). This allows farmers to adopt a new set of techniques that lowers production costs, mostly due to lower labor requirements for weed control. The planting of traditional seeds is preceded by soil preparation in the form of tillage, the operation of removing the weeds in the seedbed that would otherwise crowd out the crop or compete with it for water and nutrients. In contrast, planting GE soy seeds requires no tillage, as the application of herbicide selectively eliminates all unwanted weeds without harming the crop. As a result, GE soy seeds allow farmers to save on production costs, increasing profitability.

Our empirical strategy to study the local effects of soy technical change builds on Bustos et al. (2016). In particular, we implement a difference-in-difference strategy that exploits the legalization of GE soy seeds in Brazil as a source of time variation, and differences in the increase of potential soy yields due to the new technology across regions as a source of cross-sectional variation. The first generation of GE soy seeds was commercially released in the U.S. in 1996, but these seeds were legalized by the Brazilian government only in 2003. Therefore, in our empirical analysis we use the year of GE soy legalization in Brazil (2003) as source of time variation.[17] In terms of cross-sectional variation, we exploit the fact that the adoption of GE soy seeds had a differential impact on potential yields in areas with different soil and weather characteristics. We obtain a measure of potential soy yields in different Brazilian regions from the FAO-GAEZ database. These yields are calculated by incorporating local soil and weather characteristics into an agronomic model that predicts the maximum attainable yield for each crop in a given area. As potential yields are a function of weather and soil characteristics, and not of actual yields in Brazil,

[17] The new technology experienced a fast pace of adoption. The Agricultural Census of 2006 reports that, only three years after their legalization, 46.4 percent of Brazilian farmers producing soy were using GE seeds with the "objective of reducing production costs" (IBGE 2006, p.144). The Foreign Agricultural Service of the USDA, reports that by the 2011-2012 harvesting season, GE soy seeds covered 85 percent of the area planted with soy in Brazil (USDA 2012). The legalization of GE seeds coincided with a fast expansion in the area planted with soy in Brazil. According to the Agricultural Census, the area planted with soy increased from 9.2 to 15.6 million hectares between 1996 and 2006. As shown in Figure I, soy area had been growing since the 1980s, but experienced a sharp acceleration in the early 2000s.

they can be used as a source of exogenous variation in agricultural productivity across geographical areas. Crucially for our analysis, the FAO-GAEZ database reports potential yields under different technologies or input combinations. Yields under "low" agricultural technology are described as those obtained using traditional seeds and no use of chemicals, while yields under "high" agricultural technology are obtained using improved seeds, optimum application of fertilizers and herbicides, and mechanization. Figure II shows maps of Brazil displaying the measures of potential yields for soy under each technology. Thus, the difference in yields between the high and low technology captures the effect of moving from traditional agriculture to a technology that uses improved seeds and optimum weed control, among other characteristics. We expect this increase in potential yields to be a good predictor of the profitability of adopting GE soy seeds.

In order to test the model predictions on the effect of agricultural technical change on land rents and local capital supply, we estimate the following specification:

$$y_{jt} = \alpha_j + \alpha_t + \beta \log(A^{soy}_{jt}) + \varepsilon_{jt} \tag{1}$$

where y_{jt} is an outcome that varies across municipalities (j) and time (t).[18] A^{soy}_{jt} is our measure of agricultural technical change in soy, defined as follows:

$$A^{soy}_{jt} = \begin{cases} A^{soy,LOW}_{j} & \text{for } t < 2003 \\ A^{soy,HIGH}_{j} & \text{for } t \geq 2003 \end{cases} \tag{2}$$

where $A^{soy,LOW}_{j}$ is equal to the potential soy yield under low inputs and $A^{soy,HIGH}_{j}$ is equal to the potential soy yield under high inputs as reported in the FAO-GAEZ dataset. The timing of the change in potential soy yield from low to high inputs corresponds to the legalization of GE soy seeds in Brazil. In Appendix B section B.B.1 we show how we derive this estimating equation from the model.

In our analysis of local effects of soy technical change, the main outcomes of interest are local land rents and savings. As a proxy of land rents we use agricultural profits per hectare as reported in the Agricultural Census of Brazil. Although the Agricultural Census includes farmers' expenses for the leasing of land into agricultural costs, 93 percent of agricultural land – and 76 percent of agricultural establishments – are farmed by the actual owners of the land.[19] Therefore, the vast majority of land rents are included in agricultural profits.[20] As a proxy for local savings we use deposits in local bank branches. The data on deposits is sourced from the Central Bank of Brazil ESTBAN dataset, which

[18]Since borders of municipalities changed over time, in this paper we use AMCs (minimum comparable areas) as our unit of observation. AMCs are defined by the Brazilian Statistical Institute as the smallest areas that are comparable over time. In what follows, we use the term municipalities to refer to AMCs.

[19]See Agricultural Census of Brazil, IBGE (2006), Table 1.1.1, pag.176.

[20]It is important to note that the measures of profits and investments as reported in the Census refer to all agricultural activities, and not only to soy.

reports balance sheet information at branch level for all commercial banks operating in the country. We use deposits and loans data at local level to construct a measure of capital outflow for each municipality, which is equal to (deposits-loans)/assets. Table I reports summary statistics of the main variables of interest used in the empirical analysis.

Our differences-in-differences empirical strategy attempts to isolate the contribution of technical change in soy production to the increase in land rents and savings during the period under study. One potential concern with this strategy is that, although the soil and weather characteristics that drive the variation in A_{jt}^{soy} across geographical areas are plausibly exogenous, they might be correlated with the initial levels of economic and financial development across Brazilian municipalities.[21] To address this concern, we add a set of baseline municipality-level controls interacted with year fixed effects to flexibly capture differential trends across municipalities with different initial characteristics during the period under study. In particular, we control for the initial share of rural population in all specifications. Additionally, we control for income per capita, population density and the literacy rate.

III.B Capital Reallocation towards destination municipalities: Data and Empirical Strategy

In the second step of our identification strategy, we trace the reallocation of capital across regions. In this section, we explain how we use the structure of the bank branch network to trace the flow of funds from *origin* municipalities – soy producing regions experiencing an increase savings and capital outflows – to *destination* municipalities – regions not affected by soy technical change but financially integrated with origin municipalities.

In the model presented in section II we consider the case of two regions: one *origin* and one *destination*. In the data, on the other hand, there are many regions (municipalities) and we can only observe capital flows that are intermediated through banks. To test the model's predictions, therefore, we adapt them to our empirical context. Appendix B extends the two-region model presented in Appendix A to the case of many regions financially integrated through banks. The objective of this exercise is to derive an empirical measure of destination municipality exposure to the GE soy-driven increase in deposits. This measure exploits differences in the geographical structure of bank branch networks to capture differences in financial integration across origin and destination municipalities. Destination municipality exposure is higher for municipalities served by banks which have branches in origin municipalities facing larger growth in potential soy yields.

Before describing how we construct the measure of municipality exposure in more detail, let us illustrate the intuition behind it with one example. In Figure III we show the geographical location of the branches of two Brazilian banks with different levels of

[21] See Table 5 in Bustos et al. (2016) for a comparison of baseline characteristics across municipalities with different potential increases in soy yields.

exposure to the soy boom. The Figure reports, for each bank, both the location of bank branches across municipalities (red dots) and the increase in area farmed with soy in each municipality during the period under study (where darker green indicates a larger increase). As shown, the branch network of bank A extends into areas that experienced a large increase in soy farming following the legalization of GE soy seeds. On the contrary, the branch network of bank B mostly encompasses regions with no soy production.[22] Therefore, non-soy producing municipalities served by bank A are more exposed to a potential GE-soy driven increase in deposits than those served by bank B.

The first step in the construction of the measure of municipality exposure is to estimate the increase in national deposits of each bank due to technical change in soy production. For each bank b, national deposits can be obtained by aggregating deposits collected in all municipalities where the bank has branches:

$$Deposits_{bt} = \sum_{o \in O_{bt}} deposits_{bot} \tag{3}$$

where $Deposits_{bt}$ are national deposits of bank b, $deposits_{bot}$ are local deposits of bank b in origin municipality o, and O_{bt} is the set of all origin municipalities where bank b has branches at time t. Note that this equation implies that the growth rate of national deposits for a bank is a weighted average of the growth rate of deposits in each of the municipalities where the bank has branches. In turn, in Appendix B.A we show that the growth rate of deposits in each origin municipality is a function of local agricultural productivity growth. This implies that the growth rate of national deposits for each bank is a weighted average of the growth rate of agricultural productivity in each of the origin municipalities where the bank has branches (see equation A28). In Appendix B.B we use this insight to obtain the following empirical specification linking aggregate deposits for each bank b to the vector of potential soy yields in all municipalities:

$$\log Deposits_{bt} = \gamma_b + \gamma_t + \beta \underbrace{\left[\sum_{o \in O_b} \omega_{bo} \lambda_{TAo} \left(\log A_{ot}^{soy} \right) \right]}_{BankExposure_{bt}} + \eta_{bt}, \tag{4}$$

where γ_b and γ_t are bank and time fixed effects and η_{bt} is an error term capturing classical measurement error and other bank-level shocks to deposit growth not explicitly included in the model. We define the summation in brackets as our measure of bank exposure. The elements inside the summation are the empirical mapping of the model equation describing the growth in savings in the origin municipality as a function of local agricultural productivity growth (see equation (A26) in Appendix B). Note that this equation im-

[22] A potential concern with this strategy is that the initial location of bank branches might have been instrumental to finance the adoption of GE soy. Thus, to construct bank exposure, we do not use the actual increase in soy area but our exogenous measure of potential increase in soy profitability, which only depends on soil and weather characteristics.

plies that deposit growth is faster in municipalities facing larger agricultural productivity growth, specially if the land income share is large. We measure agricultural productivity growth using the FAO-GAEZ potential yields of soy A_{ot}^{soy}. In turn, our proxy for the land income share is λ_{TAo}, the share of land employed by the agricultural sector in the initial year of our sample, which we source from the 1996 Agricultural Census. The weights ω_{bo} are the share of national deposits of bank b coming from origin municipality o in the initial period.[23]

Finally, we construct a measure of predicted capital flows to destination municipalities. In principle, banks could lend the funds raised through deposits in the national or in the international interbank market, in which case it would be hard for us to trace where the money goes. However, to the extent that there are frictions in the interbank market, banks are more likely to finance their loans with their own deposits. Thus, we can trace intra-national capital flows by exploiting differences in the geographical structure of bank branch networks. Recall that, in the model, capital inflows do not generate changes in the return to capital in destination municipalities because free trade in goods implies that factor prices are pinned down by international goods prices. Thus, in our extension of the model to many municipalities, banks are indifferent between allocating capital across any destination municipality as these will absorb capital by expanding manufacturing output at a constant interest rate. Then, we can make the simple assumption that each bank responds to the growth in deposits by increasing the supply of funds proportionally in all destination municipalities where it has branches. Using this assumption, in Appendix B.A we show that the growth of credit in each destination municipality can be written as a weighted average of the growth rate of national deposits in each bank present in that destination municipality, which in turn is a weighted average of agricultural productivity growth in each origin municipality where the bank has branches.[24] The empirical counterpart of this measure of destination municipality exposure can be written as follows:

$$MunicipalityExposure_{dt} = \sum_{b \in B_d} w_{bd} BankExposure_{bt} \tag{5}$$

where weights w_{bd} capture the lending market share of bank b in destination municipality d and are constructed as the value of loans issued by branches of bank b in municipality d divided by the total value of loans issued by branches of all banks operating in municipality d (whose set we indicate with B_d) in the baseline year 1996. The weighting should capture the total exposure of destination municipality d to funds coming from origin

[23]Focusing on the initial period ensures that we do not capture the opening of new branches in areas with faster deposit growth due to the new technology. These new openings are more likely to occur by banks which face larger demand for funds. Thus, focusing on the pre-existing network ensures that we only capture an exogenous increase in the supply of funds.

[24]See equation (A30) in Appendix B.A.

municipalities through bank networks. Note that, in order to link origin and destination municipalities, we assume that banks' internal capital markets are perfectly integrated. This implies that deposits captured in a given municipality are first centralized at the bank level and later distributed across municipalities where a bank has branches. Figure IV shows the geographical distribution of our measure of municipality exposure. We present this measure separately for soy-producing regions, non-soy producing regions and for all municipalities in Brazil.

The definition of municipality exposure in equation (5) captures the capital flow from origin municipalities exposed to soy technical change to a given destination municipality. The model predicts that destination municipalities more financially integrated with origin municipalities facing larger agricultural technical change experience a larger increase in capital supply and faster reallocation of capital towards manufacturing. We test these predictions by estimating the following equation:

$$\log(loans_{dt}) = \alpha_d + \alpha_t + \mu MunicipalityExposure_{dt} + \varepsilon_{dt} \tag{6}$$

where $loans_{dt}$ are total loans originated by bank branches located in destination municipality d at time t, as observed in ESTBAN. Appendix B.B shows how to derive the equation above as the empirical counterpart of equation (A30) in the model, which links changes in capital supply in the destination region to capital outflows from the origin region. In turn, capital outflows are a function of soy technical change and the land income share in origin regions.

Finally, let us note that during the second half of the 2000s, Brazil experienced a fast increase in non-agricultural bank lending, documented in Figure C8. Our empirical strategy attempts to isolate the contribution of technical change in soy production to the reallocation of capital towards non-agricultural activities during this period. One potential concern with this strategy is that destination municipality exposure is correlated with other contemporaneous shocks that might have contributed to the increase in the share of non-agricultural lending during this period. For example, other forces that might have contributed to the aggregate increase in the share of non-agricultural lending during the 2000s are the introduction of institutional reforms increasing creditors' protection (Ponticelli and Alencar 2016, Assunçao, Benmelech, and Silva 2013), favorable international commodity prices, or the increase in trade with China (Costa, Garred, and Pessoa 2016). To address this concern, in the next section we present an empirical strategy that exploits variation in exposure to capital accumulation from soy technical change across firms operating within the same destination municipality. This specification fully absorbs any macroeconomic forces that differentially affected Brazilian destination municipalities during the period under study.

III.C Capital reallocation towards destination firms: Data and Empirical Strategy

A potential concern with the identification strategy described in subsection III.B is that destination municipalities that are more financially connected to origin municipalities might also be more connected through migration or commercial networks. In that case, our estimates could be capturing the effects of agricultural technical change in origin municipalities on bank lending in destination municipalities through a labor supply or a demand channel, rather than the capital supply mechanism described in the model. To make progress on this front, we bring our analysis at a more micro-level and trace the reallocation of capital towards firms located in destination municipalities.

In particular, we construct a measure of firm-level exposure to capital inflows from origin municipalities using information on pre-existing firm-bank relationships. To construct this measure we match administrative data on the credit and employment relationships for the universe of formal firms operating in Brazil. Data on credit relationships between firms and financial institutions is sourced from the Credit Information System of the Central Bank of Brazil for the years 1997 to 2010.[25] The confidential version of the Credit Information System uniquely identifies both the lender (bank) and the borrower (firm) in each credit relationship. This allows us to match data on bank-firm credit relationships with data on firm characteristics from the Annual Social Information System (RAIS). RAIS is an employer-employee dataset that provides individual information on all formal workers in Brazil.[26] Using worker level data, we constructed the following set of variables at firm-level: employment, wage bill, sector of operation and geographical location.[27] One advantage of our dataset is that we observe both the universe of credit relationships and the universe of formal firms.[28] That is, we observe both firms with access to credit and

[25]The Credit Information System and ESTBAN are confidential datasets of the Central Bank of Brazil. The collection and manipulation of individual loan-level data and bank-branch data were conducted exclusively by the staff of the Central Bank of Brazil. The dataset reports a set of loan and borrower characteristics, including loan amount, type of loan and repayment performance. We focus on total outstanding loan amount, which refers to the actual use of credit lines. In this sense, our definition of access to bank finance refers to the actual use and not to the potential available credit lines of firms. Unfortunately, data on interest rate are only available from 2004, after GE soy legalization.

[26]Employers are required by law to provide detailed worker information to the Ministry of Labor. See Decree n. 76.900, December 23^{rd} 1975. Failure to report can result in fines. RAIS is used by the Brazilian Ministry of Labor to identify workers entitled to unemployment benefits (*Seguro Desemprego*) and federal wage supplement program (*Abono Salarial*). For firms with ten or more employees, RAIS covers, on average, 76.2 percent of firms with a juridical person fiscal code that are present in the Brazilian Business Registry (CEMPRE) during the period under study. It is important to note that our data on bank-firm relationships exclusively covers the formal sector, as firms need to have a tax identifier (CNPJ) to apply for a loan and need to make contributions to the social security system in order to be registered in the employer-employee datasets (RAIS).

[27]When a firm has multiple plants, we aggregate information on employment and wage bill across plants and assign to the firm the location of its headquarters. Whenever workers in the same firm declare to operate in different sectors, we assign the firm to the sector in which the highest share of its workers declare to operate.

[28]See also Bottero, Lenzu, and Mezzanotti (2019) for a study that uses similar datasets for Italy.

firms that do not have access to credit. This allows, for example, to study the evolution of credit market participation in Brazil. Appendix C.A presents a set of stylized facts on credit market participation between 1997 and 2010 that can be uncovered using our database. In particular, we show the different evolution in credit market participation among Brazilian firms of different sizes and operating in different sectors during the period under study.

We use our matched dataset to construct firm-level exposure to credit supply shocks using information on pre-existing firm-bank relationships. This allows us to assess whether firms whose pre-existing lenders are more financially integrated to origin municipalities through bank branch networks experienced larger increases in borrowing and employment growth. This empirical strategy permits to compare firms operating in the same destination municipality and sector but initially borrowing from different banks. Thus, it allows to control for labor supply and product demand shocks in destination municipalities and isolate the capital supply channel. More formally, we estimate the following equation:

$$\log(loans_{ibdst}) = \nu_i + \nu_b + \nu_{dt} + \nu_{st} + \mu BankExposure_{bt} + \varepsilon_{ibdst} \tag{7}$$

This equation relates borrowing of firm i from bank b to the measure of bank exposure presented in equation (4). The subscript d indexes the destination municipality where the firm is located, and s the industry in which the firm operates.[29] Appendix B.B shows how to derive the equation above as the empirical counterpart of equation (A31) in the model, which links changes in loans from a given bank b to firm i in the destination region to capital outflows from origin regions in which the bank has branches. In turn, capital outflows are a function of soy technical change and the land income share in origin municipalities.

Firms credit demand could grow because local firms face larger demand from richer soy farmers or larger labor supply from former agricultural workers. A second and related concern is that different industries might be on differential growth trends because of other changes in the world economy such as increased trade with China, or could be indirectly affected by GE soy legalization because they supply or buy inputs from the soy sector. To address these concerns, we include in equation (7) destination municipality fixed effects interacted with time fixed effects (ν_{dt}), and industry fixed effects interacted with time fixed effects (ν_{st}). Thus, this specification allows us to mitigate the concerns that our estimates could be capturing the effects of agricultural technical change in origin municipalities on bank lending in destination municipalities through a labor supply or a demand channel, rather than the capital supply mechanism described in the model.[30]

[29] Sector fixed effects are 2-digits sectors according to the Brazilian CNAE 1.0 classification. Firms in our sample are present in 56 2-digit CNAE 1.0 sectors.

[30] All our results are robust to restricting our sample to firms operating in non-soy producing municipalities (that is, municipalities that do not produce soy at any point during the period under study) and firms not operating in sectors directly linked to soy production through input-output linkages. These

In addition to studying the effect of capital reallocation on firm borrowing, we are also interested in assessing its real effects. In particular, we want to understand the extent to which firms use additional credit to finance growth enhancing investments. These investments can take the form of expanding the use of capital, labor or other inputs. Because in the RAIS dataset we observe labor and the wage bill, we focus our analysis on these two inputs. However, to the extent that there is some complementarity between production inputs, we expect that any investment leading to expansion of the firm is likely to be reflected in larger employment and wage bill. Thus, we analyze real effects through the following firm-level specification:

$$\log(L_{idst}) = \nu_i + \nu_{dt} + \nu_{st} + \lambda FirmExposure_{it} + \varepsilon_{idst} \tag{8}$$

where:

$$FirmExposure_{it} = \sum_{b \in B} \pi_{ib,t=0}\ BankExposure_{bt}$$

The variable L_{idst} denotes employment in firm i, located in destination municipality d, operating in industry s at time t. Our measure of firm exposure is defined as a weighted average of bank exposure of all lenders with which firm i had a credit relationship in the pre GE-soy legalization period, which corresponds to the years 2001 and 2002 in the Credit Registry Data. The weights $\pi_{ib,t=0}$ correspond to the share of borrowing of firm i from bank b in 2001 and 2002 as a share of total borrowing of firm i in the same years. We use pre-existing bank relationships to minimize the concern that endogenous formation of firm-bank relationships — which could result from a bank exposure to the soy boom — might affect our results.[31]

IV Local Effects of Soy Technical Change

We start by estimating the effect of local agricultural technical change on local land rents. In both the autarky and financial integration equilibrium, the model predicts that municipalities experiencing faster technical change should experience faster growth in land rents. As a proxy for land rents we use agricultural profits sourced from the Agricultural Census. Since the Agricultural Census is released at intervals of 10 years, we focus on the last two waves (1996 and 2006) and estimate the following first-difference version of equation (1):

results are available from the authors upon request.

[31]Note that this implies that we use the exposure of the pre-2003 lenders for all years in which a firm is present in our sample, no matter whether the firm is borrowing or not from those lenders in the years after GE soy legalization. Since the set of lenders used to construct this measure is defined in the initial period and it is constant for each firm, the bank fixed effects ν_b are effectively absorbed by firm fixed effects ν_i in this specification.

$$\Delta y_j = \Delta\alpha + \beta\Delta\log(A_j^{soy}) + \Delta\varepsilon_j \tag{9}$$

Where Δy_j is the decadal change in outcome variables between 1996 and 2006 and $\Delta\log(A_j^{soy}) = \log(A_j^{soy,HIGH}) - \log(A_j^{soy,LOW})$.

Columns 1 and 2 of Table II show the results of estimating equation (9) when the outcome is agricultural profits per hectare.[32] The point estimate on $\Delta\log(A_{jt}^{soy})$ indicates that municipalities with a one standard deviation larger increase in soy technical change experienced a 10.7 percent larger increase in agricultural profits per hectare between 1996 and 2006. In principle, extra agricultural profits could have been reinvested in agriculture, channeled into consumption, or into savings. We start by studying the effect of soy technical change on agricultural investment in columns 3 and 4 of Table II. The estimated coefficient on $\Delta\log(A_{jt}^{soy})$ is positive and significant, indicating the municipalities more exposed to soy technical change experienced larger increase in investment in agriculture. The magnitude of the estimated coefficient in column 4 is similar to the effect on agricultural profits per hectare. However, agricultural profits per hectare are three times larger than investment per hectare in the 1996 Agricultural Census baseline. Thus, taken together, these coefficients imply that for every R$10 increase in profits per hectare due to soy technical change, only around R$3.45 are reinvested in agricultural activities. Then, we observe that agricultural productivity growth generates an increase in capital demand in agriculture as predicted by the model. However, growth in agricultural profits is larger than investment so that there is an excedent that could be used to increase consumption or savings to finance investment in other sectors or regions.

Next, we estimate the effect of local agricultural technical change on local savings. In both the autarky and financial integration equilibrium, the model predicts that municipalities experiencing faster technical change should experience faster growth in capital supply. To test this prediction, we estimate equation (1) where the outcome variable is the log of the total value of bank deposits in bank branches located in municipality j.[33] We define bank deposits as the sum of deposits in checking accounts, savings accounts and term deposits as reported by the ESTBAN dataset of the Central Bank of Brazil. Results are reported in columns 1 and 2 of Table III. The estimates indicate that municipalities with higher increase in soy technical change experienced a larger increase in local bank deposits during the period under study. The magnitude of the estimated coefficient in

[32] Using a similar identification strategy, Bustos et al. (2016) show that municipalities more exposed to soy technical change experienced higher adoption of GE soy seeds and higher agricultural productivity growth in the period between 1996 and 2006. We replicate these results for the sample of municipalities studied in this paper in Table C1 of the Appendix.

[33] Note that when estimating equation (1) we focus on the average effects of soy technical change on deposits. That is, we do not take into account the heterogeneous effects predicted by the model depending on the land income share in each municipality. This is to keep these results directly comparable with those on agricultural outcomes presented in Table II. We will take into account differences in land income shares across municipalities when computing our measure of bank exposure in the next step.

column 2 indicates that a municipality with a one standard deviation higher increase in soy technical change experienced a 3.3 percent larger increase in bank deposits in local branches.[34]

We also investigate the timing of the effect of soy technical change on bank deposits, and in particular whether it is consistent with the legalization of GE soy seeds in 2003. To this end, we estimate a version of equation (1) in which we allow the effect of $\Delta \log(A_j^{soy})$ to vary over time. Figure V plots the time varying estimated coefficients on $\Delta \log(A_j^{soy})$ and ninety-percent confidence intervals when the outcome variable is the log of deposits in local bank branches. As shown, the timing of the effect is consistent with the timing of the legalization of GE soy seeds. There are no pre-existing trends in the years 1996 to 2001 – the magnitude of the point estimates is close to zero and not statistically significant – and positive effects of soy technical change on local deposits afterwards.[35] We find, however, that the effect starts in 2002, one year before the official legalization of GE soy seeds. This is consistent with the timing of the expansion in the area planted with soy documented in Figure I. This figure documents a break in the trend of the expansion of the area planted with soy starting in 2002, which might respond to the contraband of soy seeds from Argentina (USDA 2003).

Next, we estimate equation (1) when the outcome variable is the total value of loans originated by bank branches located in municipality j.[36] The results are reported in columns 3 and 4 of Table III and show that municipalities with higher increase in soy technical change experienced a decrease in bank loans originated by local branches. Taken together, the results reported in columns 2 and 4 suggest that municipalities with a larger increase in soy technical change experienced an increase in deposits and a decrease in loans, thus becoming net exporters of capital. Indeed, the model predicts that municipalities

[34]In additional results reported in Table C2 of Appendix C, we decompose the effect of soy technical change on deposits into three different types: checking, savings and term deposits accounts. One potential concern is that areas more affected by the soy boom experienced an increase in the use of formal banking due to the higher amount of transactions linked to growing soy production rather than an increase in actual savings. As shown in Table C2, the growth in deposits triggered by soy technical change was concentrated in savings deposits.

[35]These results also imply that our estimates do not capture a delayed response to the trade liberalization that occurred at the beginning of the previous decade in areas with different initial agricultural intensity, as studied by Dix-Carneiro and Kovak (2017). In particular, Dix-Carneiro and Kovak (2017) find long-run negative effects of tariff cuts on formal employment and earnings and show that tariff cuts were smaller in the agricultural sector relative to other sectors. By showing that soy technical change has no effect on bank deposits until the early 2000s, Figure V addresses the concern that the long-lived dynamics of the trade liberalization of the early 1990s has a confounding effect on our results.

[36]Note that the total value of loans includes loans to both individuals and firms, which we cannot separate in ESTBAN. We observe three major categories of bank loans: rural loans, which includes loans to the agricultural sector; general purpose loans to firms and individuals, which includes: current account overdrafts, personal loans, accounts receivable financing and special financing for micro-enterprises among others; and specific purpose loans, which includes loans with a specific objective, such as export financing, or acquisition of vehicles.The ESTBAN data do not allow us to distinguish between loans to individuals and loans to firms. Also, we can not distinguish loans to different sectors with the exception of rural loans, which are loans directed to individuals or firms operating in the agricultural sector.

with faster agricultural productivity growth experience capital outflows if the capital supply effect is larger than the capital demand effect and they are financially integrated with other regions. To test the model prediction more formally, in columns 5 and 6 of Table III we estimate equation (1) when the outcome variable is capital outflow, defined as total value of deposits minus total value of loans originated by bank branches located in municipality j, divided by total assets of the same branches. As shown, we find a positive and precisely estimated coefficient on $\log(A_j^{soy})$, which indicates that municipalities with a higher increase in soy technical change experienced a larger net increase in capital outflows through the formal banking sector during the period under study.[37]

V Capital reallocation towards destination municipalities

The results presented in section IV show that the adoption of new agricultural technologies in soy production generates more profits than investments in the agricultural sector, as well as capital outflows from origin municipalities. This suggests that the capital supply effect dominates the capital demand effect. In this case, our theoretical framework predicts that destination municipalities financially integrated with origin municipalities facing larger agricultural technical change should experience both larger capital inflows and faster reallocation of capital towards manufacturing.

In this section we test these predictions. We focus on two main outcome variables: the total level of bank lending and the share of bank lending to non-agricultural sectors in destination municipalities. These two outcomes capture, respectively, capital inflows and capital reallocation towards manufacturing in the model. Table IV reports the results of estimating equation (6) with these two outcomes. We find that municipalities served by banks more exposed to the soy driven deposit growth through their branch network, experienced a larger increase in bank lending. Recall from the discussion in section III.B that our measure of municipality exposure is a (weighted) average of the exposure of the banks operating in that municipality. Our estimates then imply that a destination municipality with a standard deviation higher increase in exposure is a municipality whose banks experienced, on average, a 4 percentage points faster annual growth in national deposits due to soy technical change in the post-GE soy legalization period (2003-2010).[38]

[37] Note that, if the land endowment was not fixed, higher land rents would give rise to incentives to expand the supply of land. This could increase the demand for capital in agriculture, resulting in capital inflows in the soy producing municipalities. We test this prediction in Appendix Table C3. First, in column 1, we show that municipalities with a standard deviation larger increase in soy technical change were 6 percentage points more likely to experience an expansion in agricultural land (the average probability is 36 percent). Next, in columns 2 and 3 we separately estimate the effect of soy technical change on capital outflows for municipalities that experienced an increase in land endowment (*Frontier*) and for those that did not (*Non-Frontier*). Soy technical change has a positive effect on capital outflows in both samples, with point estimates being smaller in *Frontier* municipalities, as predicted by the model.

[38] To obtain this number we multiply a standard deviation in the increase in municipality exposure (0.18) by our estimate of the effect of bank exposure on deposit growth at bank level – i.e. the coefficient

The magnitude of the estimated coefficient reported in column 1 of Table IV indicates that a municipality whose banks had a 4 percentage points faster annual growth in deposits due to soy technical change experienced a 0.7 percentage points faster annual growth in bank lending in the post-GE soy legalization period.[39]

If banks were to operate in financial autarky and could only invest in loans, these should grow at the same rate as deposits. However, banks can lend to individuals and firms abroad, or can invest them in assets other than loans. Thus, we expect deposits and loans not to grow at the same rate. In addition, the existence of an interbank market implies that some of the capital outflow from origin regions might flow to destination regions that are not directly connected via bank branches. Thus, the coefficients presented in Table IV are likely to underestimate the true effect of soy technical change on capital inflows in destination municipalities.

Next, in columns 2 and 3 of Table IV, we split the sample in soy-producing and non-soy producing municipalities.[40] Each of these groups accounts for around half of the observations used in column 1. The estimated coefficient in the soy-producing sample is positive but small in size (0.054) and not statistically significant, while the estimated coefficient on the non-soy producing sample is ten times larger (0.580) and strongly significant. These results indicate a reallocation of capital towards non-soy producing regions, as predicted by the model when the capital supply effect is larger than the capital demand effect in soy producing regions.

We then study whether this increase in lending has been directed towards agricultural or non-agricultural sectors. Since rural loans are observable in the ESTBAN dataset, we use as outcome variable the share of bank loans to sectors other than agriculture. As shown in column 4 we find that municipalities more financially integrated with soy producing regions experienced a larger increase in non-agricultural lending as a share of total lending: 1.7 percentage points for a standard deviation difference in the increase in municipality exposure. This effect is present in both soy-producing and non soy-producing

β in equation (4), which we estimate in Table V to be 1.75 – and then divide this product by the number of years in the post-GE soy legalization period for which data is available (2003-2010). Note also that a standard deviation in the annual growth rate of bank deposits across Brazilian municipalities in the post-GE soy legalization period was 23.1 percent.

[39] To obtain this number we multiply a standard deviation in the increase in municipality exposure (0.18) by the estimated coefficient in column 1 of Table IV, and then divide this product by the number of years in the post-GE soy legalization period for which data is available (2003-2010). Note that, taken together, our estimates imply that a destination municipality connected to a set of origin municipalities experiencing a (weighted average) one percent increase in bank deposits due to agricultural technical change will face a 0.16 percent increase in loans. As shown in Appendix section B.B.3, this elasticity of 0.16 can be obtained by dividing the coefficient μ in equation (6) by the coefficient β in equation (4). Empirically, this elasticity can be obtained by dividing the estimated coefficient in column 1 of Table IV by the estimated coefficient in column 4 of Table V. Table V studies the relationship between national deposits of bank b and the increase in aggregate deposits for the same bank that is predicted by our measure of bank exposure.

[40] Non-soy producing municipalities are those with no agricultural area farmed with soy at any point in time between 1996 and 2010.

regions, although largely concentrated in the latter, as shown in columns 5 and 6.[41,42]

The findings discussed above are consistent with the capital supply mechanism emphasized by the model: agricultural technical change can increase savings in soy-producing regions and lead to capital outflows towards non-soy producing regions where capital reallocates towards the capital intensive sector, manufacturing. Our empirical analysis permits to quantify this effect by comparing the speed of capital reallocation across sectors in non-soy producing municipalities with different degrees of financial integration with the soy boom area. During the period under study (1996-2010), the share of non-agricultural lending increased from 74.6 to 83.5 percent in the average non-soy producing municipality. However, the degree of capital reallocation away from agriculture varied extensively across municipalities. A standard deviation in the change in the share of non-agricultural lending across non-soy municipalities is 24 percentage points. Our estimates imply that the differences in the degree of financial integration with the soy boom area can explain 11 percent of the observed differences in the increase in the non-agricultural lending share across non-soy producing municipalities.[43]

Overall, the results presented in Table IV are consistent with the predictions of the model and indicate that new agricultural technologies can generate structural transformation in regions not directly affected by such technologies. Two caveats with this specification are in order. First, this specification does not allow us to distinguish the direct effect of capital reallocation from the labor supply or product demand channels of agricultural productivity growth. For example, destination municipalities served by more exposed banks might also be better connected to soy-producing regions through transportation or migrant networks. Therefore, in section VI, we use an identification strategy that aims

[41] The estimates reported in Table IV are representative for the average Brazilian municipality and not the aggregate Brazilian economy. In order to obtain estimates of the elasticity of capital reallocation to soy-driven deposit growth that are representative of a municipality with similar characteristics as the aggregate economy we weight observations by aggregate bank lending in the initial period. These estimates are reported in columns 5 and 6 of Appendix Table C4. As shown, the point estimate of the effect of soy technical change on non-agricultural lending is similar in magnitude when weighting by initial bank lending (it increases only marginally from 0.090 to 0.111). This is consistent with the effects presented in Table IV being driven by urban municipalities, which represent the majority of bank lending in Brazil as a whole. In the same Appendix Table C4 we also show that the main results on the effect of soy technical change on agricultural profits per hectare and on capital outflows are robust to weighting municipalities by their relative importance in terms of the relevant aggregate quantities.

[42] Note that, in the case of origin regions, both the mechanism emphasized in Bustos et al. (2016) and the mechanism emphasized in this paper are at play. First, the labor-saving new technology generates a reallocation of labor towards manufacturing, increasing the demand for capital in this sector. Second, agricultural productivity growth reinforces the comparative advantage in agriculture, inducing capital to reallocate towards this sector. As a result, the net effect on capital allocation across sectors in origin municipalities is ambiguous. The findings in Table IV are consistent with these two opposing effects being at play in origin regions. In particular, we find some evidence of capital reallocation towards non-agricultural sectors in soy-producing regions, but these effects are small compared to those observed in financially connected non-soy producing regions, which only experience the capital supply effect.

[43] That is, one standard deviation in our measure of municipality exposure explains 11 percent of a standard deviation in the increase in the non-agricultural lending share across non-soy producing municipalities.

at identifying the capital supply channel separately from other channels using loan-level and firm-level data. Second, the ESTBAN dataset used to construct the agricultural and non-agricultural lending shares used as outcomes in this section includes lending to both firms and individuals. This has the advantage of capturing loans to farmers who take personal loans to invest in their farm, but the disadvantage of also including mortgages and other personal consumption loans. Therefore, in section VI, we use loan-level data to more precisely identify credit flows to firms in different sectors.

VI Capital reallocation towards destination firms

In this section we bring the analysis to the firm level and study how increases in bank deposits due to soy technical change affected capital supply to firms in destination municipalities. We proceed as follows. First, we document that our measure of bank exposure predicts aggregate deposit growth at the bank level. Next, we study whether firms that are more financially integrated with origin municipalities through their pre-existing banking relationships experienced larger growth in borrowing and employment.

VI.A Bank exposure and aggregate deposits

We start by testing the relationship between aggregate deposits of bank b and the increase in aggregate deposits for the same bank that is predicted by our measure of bank exposure. Table V reports the results of estimating equation (4) when the outcome variable is aggregate deposits of bank b, and bank-year observations are weighted by initial bank size (assets). Aggregate deposits for each bank are obtained summing branch level deposits. The point estimate on $BankExposure$ is positive and significant, which indicates that banks more exposed to soy technical change through their branch network experienced higher increase in aggregate deposits. The magnitude of the estimated coefficient reported in column 1 is 1.43. It indicates that a 1 percent increase in aggregate deposits of bank b predicted by the change in the vector of potential soy yields corresponds to a 1.43 percent increase in actual national deposits of the same bank. In other words, changes in our measure of predicted deposits are associated with changes in actual deposits of similar magnitude.[44] Columns 2 to 4 show that this effect is not driven by differential growth trends across banks with different initial characteristics. Finally, in Figures VI (a) and (b) we report partial correlations between changes in bank exposure and changes in the log of aggregate deposits at bank level, weighting and without

[44] We think that one reason why our estimate of β is larger than one is that our measure of Bank exposure is a first order approximation to changes in aggregate deposits holding the bank branch network constant. Thus, changes in the bank branch network are in the error term. It is very likely that the soy boom might have led banks to open new branches which capture deposits. Thus, our measure of bank exposure might underestimate the effect of the soy shock on aggregate deposits.

weighting by initial bank size, respectively.[45] As shown, our estimates are not driven by extreme observations or weighting by bank size.

VI.B Bank-firm level specification

We then study the effect of bank exposure on firm borrowing from that same bank.[46] Table VI shows the results of estimating equation (7) when the outcome variable is the log of the monetary value of outstanding loan balance of firm i from bank b. We start by estimating a specification with firm, bank and time fixed effects. The estimated coefficient on the variable $BankExposure$ is positive, indicating that firms with pre-existing relationships with more exposed banks experienced a larger increase in borrowing from those banks. In column 2 we add municipality and sector fixed effects, both interacted with time fixed effects. Note that we find similar point estimates when controlling for municipality-time and industry-time fixed effects, which should capture any labor supply or product demand shocks affecting firms which operate in the same destination municipality or industry. This suggests that the increase in firm borrowing is driven by the capital supply effect of agricultural technical change and not labor-supply or product demand shocks.

We can quantify the effect of the soy-driven increase in bank deposits on firm borrowing as follows. The estimated coefficient in column 2 indicates that firms with a pre-existing relationship with a bank experiencing a 4 percentage points faster deposit growth due to soy technical change experienced a 0.7 percentage points faster annual growth in borrowing in the post-GE soy legalization period. Note that the magnitude of this effect is similar to the one documented in Table IV using municipality-level data. This suggests that our municipality level measure of total bank lending well captures lending to firms, and that our effects are driven by the intensive rather than the extensive margin of bank lending.

In column 4 we augment equation (7) with firm fixed effects interacted with time fixed effects. This specification fully captures firm-specific demand shocks, and only exploits variation across banking relationships of the same firm to identify the coefficient on bank exposure (Khwaja and Mian 2008). As a consequence, it can only be estimated using firms with multiple lending relationships in both the pre and the post GE soy legalization period. The estimated coefficient is positive, which implies that firms connected to banks with larger exposure to the soy boom increased their borrowing from those banks but

[45] This is equivalent to a first difference version of equation (4) obtained after partialling out year fixed effects and bank initial characteristics interacted with linear time trends and then averaging bank exposure and log deposits for each bank in the years before (2001-2002) and after (2003-2010) the legalization of GE soy seeds.

[46] In order to minimize sample selection, we focus our analysis at firm-level on the period 2001-2010, i.e. the years after the reporting threshold of the Credit Registry was lowered to 5,000 BRL. As shown in Figure C4 of the Appendix, in 2001 only around 7 percent of Brazilian firms had access to finance when using the 50,000 BRL reporting threshold. In the same year, 31 percent of Brazilian firms had access to finance under the 5,000 BRL reporting threshold.

not from other banks with whom they also had a relationship. The magnitude of the estimated coefficient is similar to the one obtained without firm-time fixed effects on the same sample of firms. This indicates that the effect of bank exposure on firm borrowing is driven by credit supply forces rather than unobservable firm-specific demand shocks correlated with lender exposure.

Next, we study the effect of bank exposure on loans by sector of operation of the borrowing firm. To this end, we estimate equation (7) separately for borrowers operating in agriculture, manufacturing, services, and other sectors.[47] Table VII reports the results. We find positive coefficients for firms in all sectors. The effects are precisely estimated for firms in manufacturing and services, while not statistically significant for agriculture and other sectors. The magnitude of the estimated coefficients is largest in the manufacturing sector (0.304) and smallest in the agricultural sector (0.204). Taking into account differences in average loan size and number of loans across sectors in the pre GE-soy legalization period, these estimates indicate that out of 1 R$ of new loans in destination municipalities from the soy-driven deposit shock, 1.3 cents were allocated to firms in agriculture, 50 cents to firms in manufacturing, 39.7 cents to firms in services and 9 cents to firms in other sectors.[48]

To sum up, in this section we show that firms more financially integrated with origin municipalities through their pre-existing banking relationships experienced a larger increase in borrowing from those banks. Second, capital flowing from origin to destination municipalities due to soy technical change was mostly allocated to firms operating in the non-agricultural sectors (manufacturing and services). These findings are obtained exploiting variation across firms within destination municipalities, and support the interpretation of the municipality-level results presented in section V as resulting from the capital supply channel.[49]

[47]Services include: construction, commerce, lodging and restaurants, transport, housing services, domestic workers and other personal services. We exclude banks and other firms in the financial sector. Other sectors include: public administration, education, health, international organizations, extraction, and public utilities.

[48]This quantification is obtained as follows. First, we multiply the estimated coefficient on bank exposure by the average loan size in the years 2001 and 2002 in each sector. This gives us the estimated increase in loan size for the average loan in each sector, in response to a unit increase in exposure of the main lender of the borrower. Second, we multiply this estimate by the average number of loans to firms operating in each sector in the years 2001 and 2002. This multiplication gives us an estimate of the *total* increase in the value of loans of firms in each sector in response to a unit increase in exposure of their lenders. Finally, we use these estimates of *total* increase in loan value in each sector to compute the allocation across-sectors of 1 R$ of new loans from the soy-driven deposit shock.

[49]By construction, equation (7) focuses on firms with pre-existing banking relationships. In Appendix Table C5 we study the effect of capital accumulation on credit market participation (extensive margin) using the municipality level exposure measure described in equation (5). Overall, we find positive but small effects of municipality exposure on the share of firms with access to credit. These effects are concentrated in micro and small firms (below 10 employees) operating in non-soy producing municipalities.

VI.C Firm level specification: real effects

Finally, we study the effect of firm exposure to soy technical change through pre-existing bank relationships on firm growth. To this end, we estimate equation (8) as described in section III.C. We focus on two main outcome variables: employment, defined as the log of the yearly average number of workers; and wage bill, defined as the log of the monetary value of the firm total wage bill.

The results are reported in Table VIII. We find that the increase in credit had positive real effects. Firms whose pre-existing lenders have a larger exposure to the soy-driven deposit increase experienced a larger growth in employment and wage bill.[50] Next, we estimate the same equation by sector of operation of each firm. Table IX reports the results. As shown, the average effects of firm exposure on firm size are positive and similar in size in agriculture, manufacturing and services, while small and not statistically significant for firms operating in other sectors. These estimates, along with differences in average firm size and number of firms in each sector, can be used to compute the allocation of extra workers across sectors for a given increase in firm exposure. Our estimated coefficients indicate that out of 100 additional workers in destination municipalities due to the soy-driven deposit shock, 1.9 were employed in agriculture, 39.9 in manufacturing, 54 in services and 4.2 in other sectors. To sum up, our results indicate that reallocation of capital from origin to destination municipalities had real effects on employment, and these effects were concentrated in the manufacturing and services sectors.

VII The Role of Credit Frictions

Our empirical results highlight the importance of credit frictions. In particular, if there were no frictions in the interbank market, regions served by banks with branches in the soy-producing area would not face larger increases in credit supply. Similarly, if there were no frictions in firm-bank borrowing, firms with pre-existing relationships with more exposed banks would not face a larger increase in credit than other firms operating in the same municipality and sector.[51] The presence of these frictions suggests that the

[50] In contrast with the loan estimates discussed in subsection VI.B, we find that our estimated real effects decrease in magnitude when we control for municipality and sector-level shocks. To the extent that labor and capital are complements in production, labor supply and local demand shocks should similarly affect firm borrowing and employment. One potential explanation for this difference is that firms receiving a product demand shock can expand in terms of employment but can not borrow more, due to credit constraints. In other words, while changes in credit supply significantly affect firm borrowing, changes in credit demand (driven by, for example, an increase in local product demand) might not as seamlessly translate into more bank credit.

[51] Several empirical papers in the banking literature have provided evidence consistent with the existence of financial frictions in the inter-bank market. In particular, these studies have documented a positive correlation between loan growth and liquidity shocks from deposit growth (Gilje 2017 and Gilje et al. 2016) or monetary policy (Kashyap and Stein 2000). Similarly, a large empirical literature in corporate finance has documented the stickiness in bank-firm relationships – which is consistent with the existence of financial frictions from asymmetric information – using credit registry data from both developed and

allocation of capital across sectors, regions and firms might not be optimal. As a result, the direction of capital flows might be driven by credit constraints and not by the capital supply effect emphasized in our model. In this section we discuss how the presence of credit frictions can modify the predictions of the model and the interpretation of the empirical results.

First, in the presence of credit constraints, the allocation of capital across sectors, regions and firms might not be optimal. Note that this is not the case within the context of our model. In particular, consider the extension of the model presented in Appendix B.A where we incorporate interbank market frictions by assuming that each bank can reallocate capital only across regions where it has branches.[52] The predictions of the model are not affected by the inclusion of this type of credit frictions because the return to capital is equalized across regions thanks to free trade in goods. Thus, banks are indifferent between allocating capital across any destination municipality, which will absorb capital flows by expanding manufacturing output at constant interest rates. Similarly, introducing constraints in firm-bank borrowing in our model is inconsequential because firms are homogeneous and face constant returns to scale, thus the size of firms is indeterminate. This implies that within the context of our model, credit frictions can help us to empirically identify the capital supply effect but do not imply capital misallocation. However, in models with trade costs, increasing returns or firm heterogeneity, credit constraints imply that the allocation of capital across sectors, regions and firms might not be optimal, as we discuss below.

In our model agricultural productivity growth generates capital outflows from rural areas because it reduces the autarky interest rate, thus capital optimally flows towards the urban manufacturing sector. However, the international finance literature has shown that the presence of credit constraints can reverse the direction of capital flows relative to the prediction of neoclassical models. In particular, Gertler and Rogoff (1990) showed that when borrowing requires the use of wealth as collateral, autarky interest rates might be lower in capital-scarce regions than in capital-abundant ones, even if the marginal product of capital is higher. To the extent that financial markets are less developed in rural than in urban regions, this mechanism might explain why we observe capital outflows from rural areas.

Let us consider the setup in Song, Storesletten, and Zilibotti (2011), to assess to what

developing countries, including: US (Chodorow-Reich 2014), Italy (Bottero et al. 2019), Portugal (Iyer, Peydró, da Rocha-Lopes, and Schoar 2013), China (Cong, Gao, Ponticelli, and Yang 2019), Pakistan (Khwaja and Mian 2008). Finally, note that our empirical results highlight also the importance of international capital market imperfections. See Gourinchas and Rey (2014) for a recent review on the relationship between changes in domestic savings and investment.

[52] See Appendix B.A. The role of banks as intermediaries between depositors and firms has been justified due to their advantage in monitoring firms in the context of asymmetric information (Diamond 1984, Holmstrom and Tirole 1997). As our main objective is to use banks to measure the degree of financial integration across regions, we do not explicitly provide micro-foundations of the role of banks here.

extent the alternative mechanism discussed above can explain our results. In particular, suppose that the new technology can only be adopted by rural entrepreneurs who do not have access to credit. When the technology arrives, rural entrepreneurs adopt it and use the profits to re-invest and rent land from land owners. Land owners can not invest, thus they save their rents in local banks which do not lend money locally because entrepreneurs with high returns are credit constrained. As a result, local banks lend to the manufacturing sector which is concentrated in urban areas with less credit frictions. In this case, the direction of capital flows is reversed by credit constraints and the allocation of capital across regions and sectors is not optimal. We think that this alternative explanation does not fit the data studied in this paper for two reasons. First, 93 percent of Brazilian agricultural land was farmed by their owners in 2006 (see discussion of Agricultural Census in section III.A). This implies that rural producers who adopt GM soy are the beneficiaries of the increase in land rents. Thus, there is no separation between those who can save and those who can invest in the new techology, as required by the international finance models discussed above. Second, soy technical change increases agricultural profits per hectare 3 times more than it increases investment per hectare (see Table II). This suggests that rural producers who adopt GM are not credit constrained, as if they were they would reinvest a larger share of their profits. Then, the evidence appears inconsistent with the idea that capital outflows from the rural agricultural sector to the urban industrial sector were the result of credit constraints in agriculture.

The evidence discussed above suggests that the reallocation of capital away from agriculture into manufacturing and from soy producing to non-soy producing municipalities was an optimal response to agricultural technical change as it generated an increase in the supply of savings larger than the induced demand for capital in agriculture. However, this does not imply that the allocation of capital across destination municipalities or manufacturing firms is optimal. In particular, it is possible that municipalities connected to the soy-producing area through bank branch networks had a lower marginal product of capital than non-connected municipalities. Similarly, it is possible that firms connected to banks with branches in the soy-producing area were less productive than other firms operating in the same sector and municipality. The simplest way to measure the extent of misallocation is to estimate the marginal product of capital, using the exogenous credit supply shocks we construct in our empirical strategy. This requires data on outputs, while we only observe labor inputs in the social security data. Thus, we leave this interesting question for future work.

VIII Concluding Remarks

The literature on structural transformation has underlined three main channels through which productivity growth in agriculture can foster structural transformation: increasing demand for industrial goods and services, releasing labor and generating savings that are reinvested in industrial projects. In Bustos et al. (2016) we exploit the recent introduction of genetically engineered soy in Brazil to document that, when new agricultural technologies are labor-saving, they can induce a reallocation of labor from agriculture to manufacturing. We also document that this effect primarily occurred within the local labor market. This paper contributes to this broad research agenda by providing evidence on the capital channel of structural transformation.

Taken together, the evidence presented in the two papers indicates that both the labor and the capital channels had a significant impact on structural transformation in Brazil. We think it is important to discuss the relative importance of these two effects for the aggregate economy. This can be done by estimating a simple specification similar to equation (12) in Bustos et al. (2016) where the outcome variable is the decadal change in manufacturing employment share at municipality-level between 2000 and 2010. We regress this outcome on both our measure of local labor-saving agricultural technical change (which captures the labor channel) and on our measure of municipality exposure to the soy-driven deposit shock (which captures the capital channel).[53] As we are interested in estimating these effects for a municipality with similar characteristics as the aggregate Brazilian economy we weight observations by the share of aggregate employment. We find point estimates that are positive, of similar magnitude and statistically significant for both channels of structural transformation. To quantify the relative importance of the labor and capital channels we multiply the two estimated coefficients by the (weighted) average of the respective explanatory variables. Our estimates imply that a municipality with the same characteristics as the Brazilian aggregate economy and with average exposure to the GE-soy driven growth in agricultural productivity experienced a 2 percentage points larger increase in the manufacturing employment share between 2000 and 2010. We find that approximately 80 percent of this increase is driven by the labor channel and 20 percent is driven by the capital channel of structural transformation. The magnitude of the capital channel is likely to be a lower bound of the true effect as it does not take into account the capital reallocation occurring through the interbank market.

[53]The measure of local labor-saving technical change is ΔA_j^{soy} used in Bustos et al. (2016), while the measure of municipality exposure to the soy-driven deposit shock is reported in equation (5) in this paper. This specification also includes all municipality controls included in equation (12) in Bustos et al. (2016), which are: technical change in maize production, share of rural population, log income per capita, log population density and literacy rate, all observed at municipality level and sourced from the 1991 Population Census.

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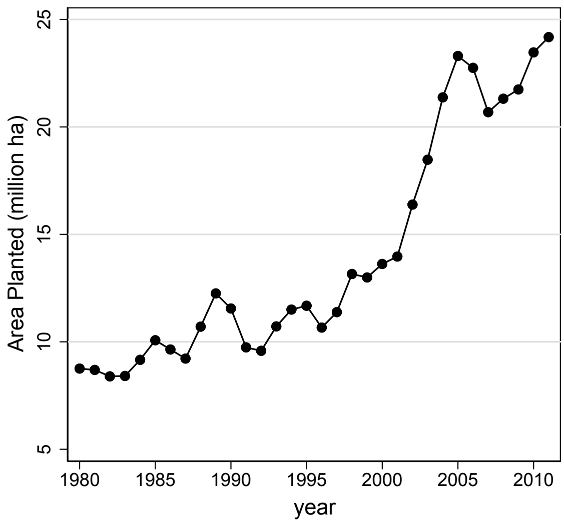
Figures and Tables

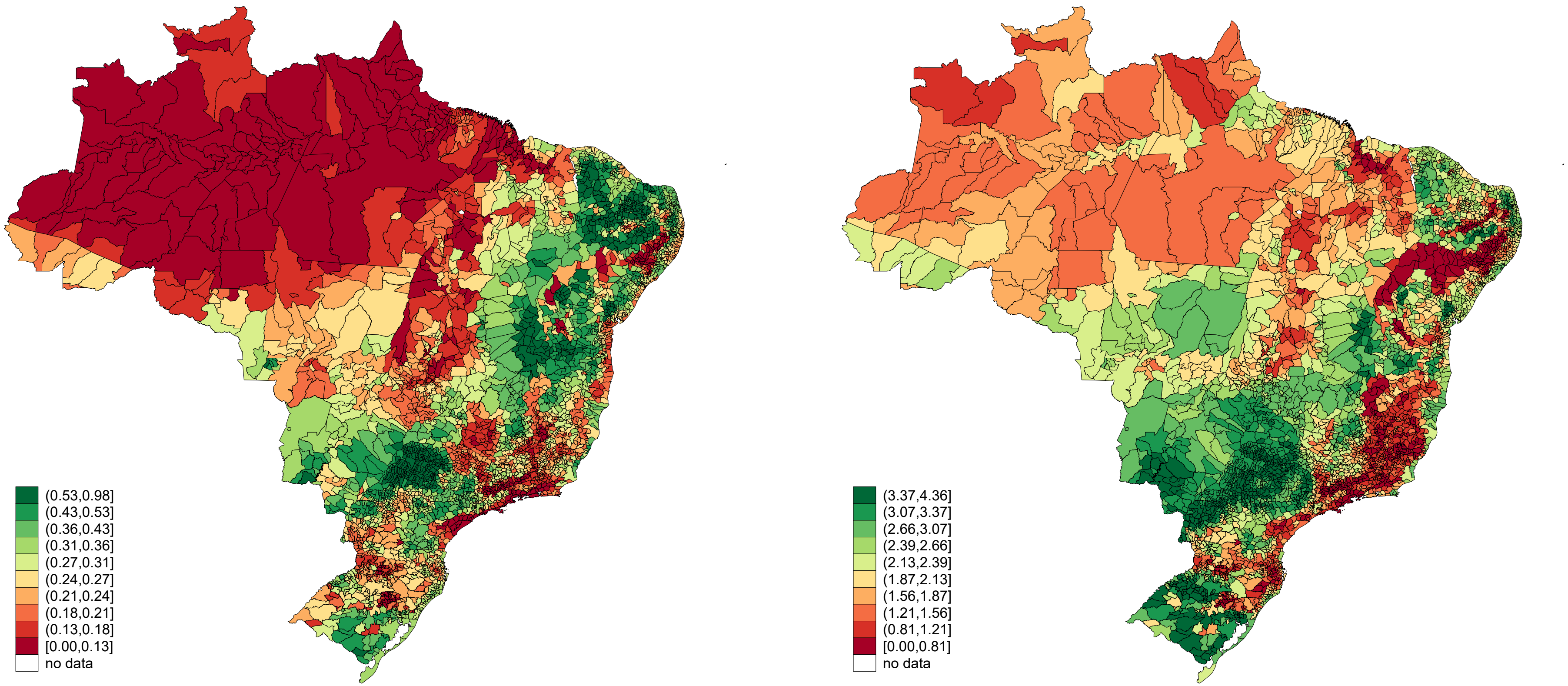
Figure I: Evolution of Area Planted with Soy in Brazil



Notes: Data source is CONAB, *Companhia Nacional de Abastecimento*, which is an agency within the Brazilian Ministry of Agriculture. CONAB carries out monthly surveys to monitor the evolution of the harvest of all major crops in Brazil: the surveys are representative at state level and are constructed by interviewing on the ground farmers, agronomists and financial agents in the main cities of the country.

Figure II: Potential soy yield under low and high agricultural technology

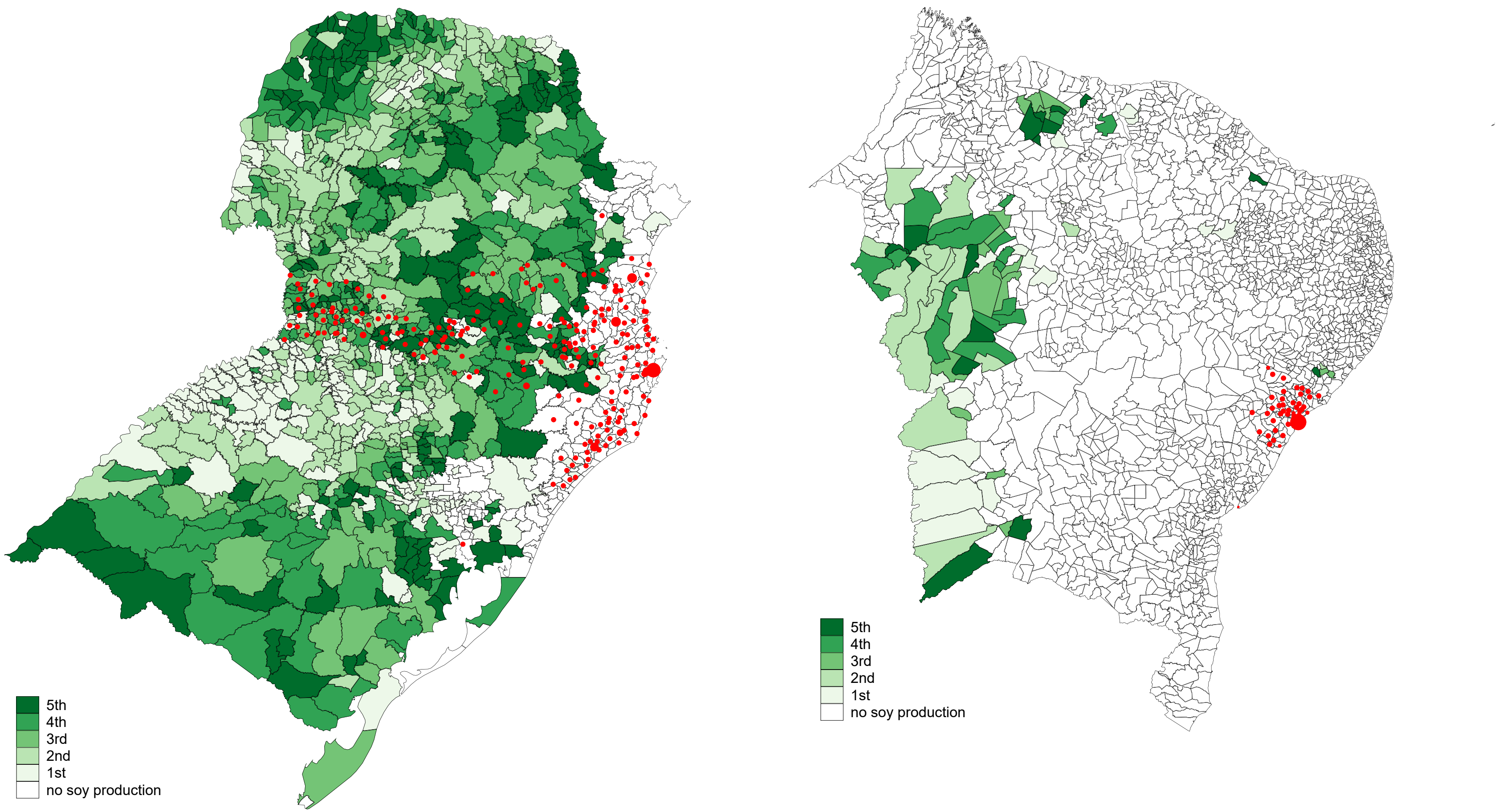
(a) Low (b) High



Notes: Data source is FAO-GAEZ. Units are tons per hectare.

Figure III: Bank Networks and Increase in Soy Revenues

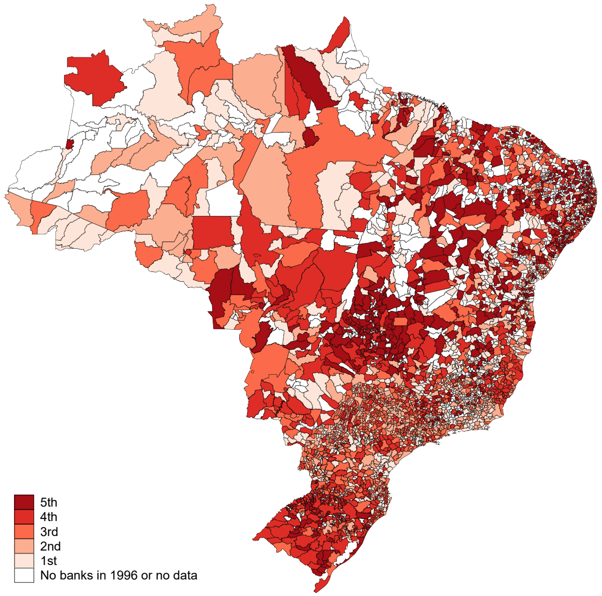
(a) Bank A (b) Bank B



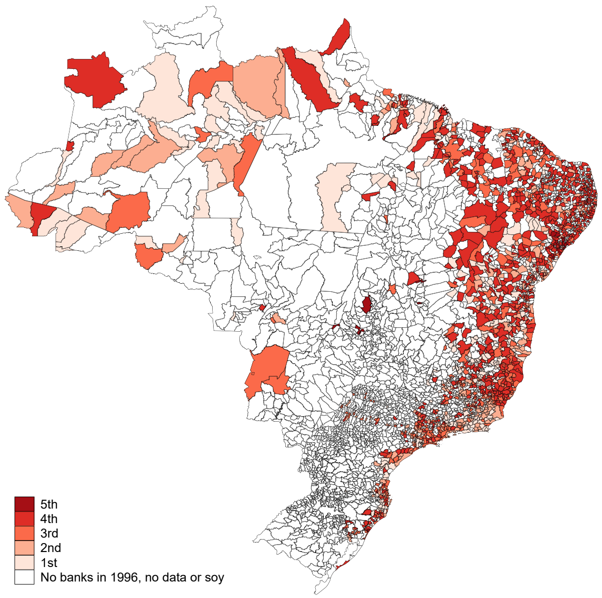
Notes: Red dots indicate bank presence in a given municipality, dot size captures number of bank branches in a given municipality. Green areas are soy producing municipalities: darker green indicates larger percentage increase in soy revenues between the years before and after GE soy legalization. Data sources are ESTBAN for bank branch location and the Municipal Agricultural Production survey (PAM) for revenues from soy production.

Figure IV: Destination Municipality Exposure

(a) all municipalities



(b) non-soy municipalities



(c) soy municipalities

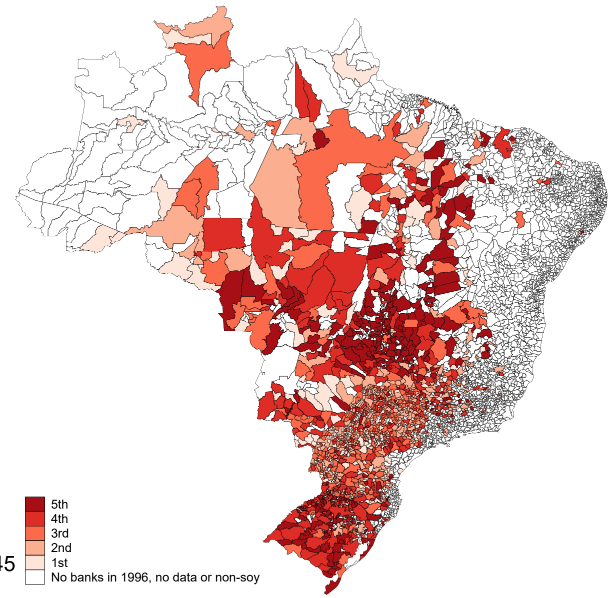
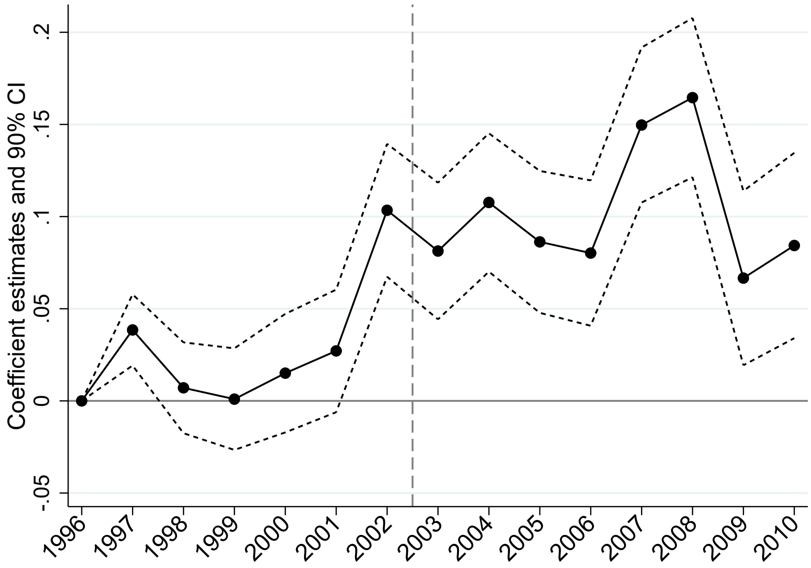


Figure V: Timing of the Effect of Soy Technical Change on Deposits



Notes: The graph reports the time varying estimated coefficients β_t, along with their 90% confidence intervals from the following equation:

$$\log deposits_{jt} = \alpha_t + \alpha_j + \sum_{t=1996}^{2010} \beta_t \Delta \log(A_j^{soy}) + \varepsilon_{jt}$$

where:

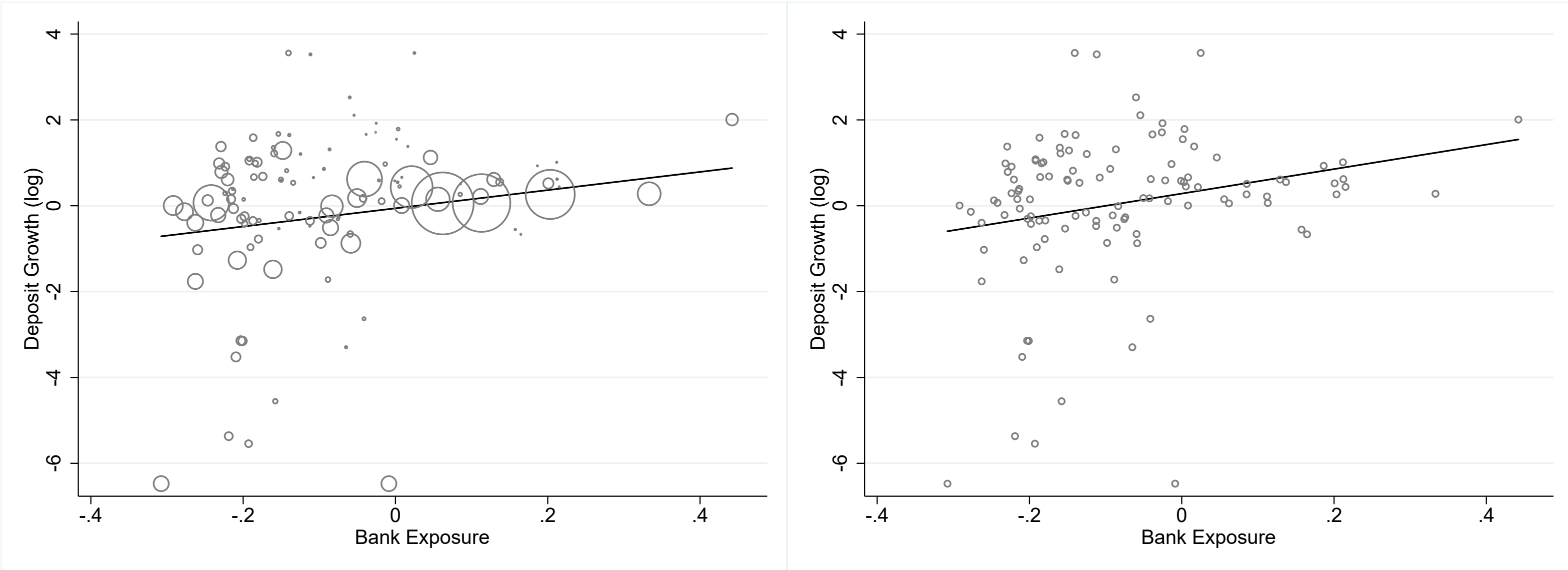
$$\Delta \log(A_j^{soy}) = \log(A_j^{soy,HIGH}) - \log(A_j^{soy,LOW})$$

The excluded year is 1996. The estimated coefficients are net of AMC controls interacted with time fixed effects as in column 4 of Table III. AMC controls include: share of rural adult population, income per capita (in logs), population density (in logs), literacy rate, all observed in 1991 (source: Population Census). Standard errors are clustered at AMC level.

Figure VI: Bank Deposits and Bank Exposure

(a) Partial Correlation, Weighted by Bank Size

(b) Partial Correlation, Unweighted



Notes: The graphs show the partial correlations between changes in bank exposure and changes in log deposits at bank level. Changes are computed after averaging bank exposure and log deposits for each bank before (2001-2002) and after (2003-2010) the legalization of GE soy seeds. Bank exposure and log deposits are averaged after partialling out year fixed effects, as well as log of bank assets and deposit-to-asset ratio (both observed in 1996) interacted with linear time trends. This is therefore equivalent to a first difference version of equation (4). The results of estimating equation (4) in levels are reported in Table V, column 4. In these graphs we focus on bank exposure values (after partialling out fixed effects and bank controls) between -0.5 and +0.5. This is for a more transparent visualization of the data and has negligible effects on the slope of the regression. The estimated slope using the same 121 banks as in Table V is 1.81 (t-stat = 2.25), while if we focus on bank exposure values between -0.5 and +0.5 (N=114), the estimated slope is 2.12 (t-stat=2.44). Panel (b) reports the unweighted version of Panel (a).

Table I: Summary Statistics

variable name	mean	st.dev.	N
independent variables:			
$\Delta log(A^{soy}_{jt})$	1.917	0.466	3,020
$log(A^{soy}_{jt})$	-0.285	1.136	44,406
$MunicipalityExposure$	-0.041	0.242	44,406
$BankExposure$	0.069	0.198	1,052
outcome variables at municipality-level:			
$\Delta \frac{GESoyArea}{AgriArea}$	0.015	0.064	3,020
ΔAgri Profits per he (pct points)	0.319	1.867	3,020
ΔAgri Investment per he (pct points)	0.475	1.042	3,020
ΔAgri Productivity	0.504	0.695	3,020
log(deposits)	15.693	1.809	44,406
log(loans)	15.458	2.112	44,406
(deposits - loans) / assets	0.811	1.977	44,406
Non-agricultural loans / total loans	0.690	0.275	44,406
Bank credit participation	0.056	0.058	26,897
outcome variables at loan-level			
log(loan)			
All sectors	10.378	1.759	4,806,825
All sectors - multi-lender firms	10.677	1.829	2,821,990
Agriculture	11.426	2.064	36,148
Manufacturing	10.924	1.926	1,094,139
Services	10.195	1.652	3,450,876
Other	10.417	1.863	198,879
outcome variables at firm-level:			
log employment			
All sectors	1.987	1.447	2,992,981
Agriculture	2.659	1.651	18,282
Manufacturing	2.594	1.450	587,290
Services	1.776	1.364	2,220,615
Other	2.703	1.664	130,732
log wage bill			
All sectors	8.278	1.692	2,992,981
Agriculture	8.952	1.856	18,282
Manufacturing	8.988	1.710	587,290
Services	8.036	1.593	2,220,615
Other	9.067	1.981	130,732

Notes: All variables are winsorized at 1% in each tail.

Table II: Soy Technical Change and Agricultural Census Outcomes
Agricultural Profits and Investment per hectare

outcome:	Δ Profits per he (%)		Δ Investment per he (%)	
	(1)	(2)	(3)	(4)
$\Delta \log A^{soy}$	0.259***	0.229***	0.181***	0.214***
	[0.071]	[0.079]	[0.044]	[0.048]
rural $\text{pop}_{t=1991}$	y	y	y	y
AMC $\text{controls}_{t=1991}$		y		y
Observations	3,020	3,020	3,020	3,020
R-squared	0.004	0.014	0.014	0.018

Notes: The outcomes in this table are sourced from the Agricultural Censuses of 1996 and 2006. We thus estimate a first-difference version of equation (1):

$$\Delta y_j = \Delta\alpha + \beta\Delta\log(A_j^{soy}) + \Delta\varepsilon_j$$

where the outcome of interest, Δy_j is the change in outcome variables between the last two census years and $\Delta\log(A_j^{soy}) = \log(A_j^{soy,HIGH}) - \log(A_j^{soy,LOW})$. Robust standard errors reported in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The variable rural pop is the share of rural adult population in an AMC according to the 1991 Population Census. AMC controls include: income per capita (in logs), population density (in logs), literacy rate, all observed in 1991 (source: Population Census). AMC stands for Minimum Comparable Area (*Área Mínima Comparável*).

Table III: Local Effects of Soy Technical Change
Deposits, Loans and Capital Outflows

outcome:	log(deposits)		log(loans)		$\frac{deposits-loans}{assets}$	
	(1)	(2)	(3)	(4)	(5)	(6)
$\log A^{soy}$	0.060***	0.070***	-0.077***	-0.061**	0.305***	0.297***
	[0.016]	[0.016]	[0.029]	[0.029]	[0.062]	[0.065]
AMC fe	y	y	y	y	y	y
year fe	y	y	y	y	y	y
rural $\text{pop}_{t=1991}$ × year fe	y	y	y	y	y	y
AMC $\text{controls}_{t=1991}$ × year fe		y		y		y
Observations	44,406	44,406	44,406	44,406	44,406	44,406
R-squared	0.975	0.976	0.951	0.951	0.711	0.713
N clusters	3145	3145	3145	3145	3145	3145

Notes: Standard errors clustered at AMC level are reported in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. The variable rural pop is the share of rural adult population in an AMC according to the 1991 Population Census. AMC controls include: income per capita (in logs), population density (in logs), literacy rate, all observed in 1991 (source: Population Census). AMC stands for Minimum Comparable Area (*Área Mínima Comparável*).

Table IV: Capital Reallocation Across Municipalities
Lending and Non-Agricultural Lending Share

outcome:	log(loans)			$\frac{\text{non-agricultural loans}}{\text{total loans}}$		
sample:	all	soy region	non-soy region	all	soy region	non-soy region
	(1)	(2)	(3)	(4)	(5)	(6)
$MunicipalityExposure_{dt}$	0.283***	0.054	0.580***	0.090***	0.046*	0.139***
	[0.090]	[0.124]	[0.131]	[0.016]	[0.024]	[0.023]
AMC fe	y	y	y	y	y	y
year fe	y	y	y	y	y	y
rural pop$_{t=1991}$ × year fe	y	y	y	y	y	y
AMC controls$_{t=1991}$ × year fe	y	y	y	y	y	y
Observations	44,406	22,550	21,856	44,406	22,550	21,856
R-squared	0.952	0.949	0.953	0.843	0.846	0.779
N clusters	3145	1565	1580	3145	1565	1580

Notes: Standard errors clustered at AMC level are reported in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.The variable rural pop is the share of rural adult population in an AMC according to the 1991 Population Census. AMC controls include: income per capita (in logs), population density (in logs), literacy rate, all observed in 1991 (source: Population Census). AMC stands for Minimum Comparable Area (*Área Mínima Comparável*).

Table V: Bank Deposits and Bank Exposure

outcome:	log deposits			
	(1)	(2)	(3)	(4)
$BankExposure_{bt}$	1.427**	1.664***	1.580**	1.750**
	[0.587]	[0.562]	[0.761]	[0.688]
Log Assets$_{b,t=0} \times t$		-0.012		-0.010
		[0.010]		[0.012]
Deposits/Assets$_{b,t=0} \times t$			-0.085	-0.068
			[0.140]	[0.151]
bank fe	y	y	y	y
year fe	y	y	y	y
Observations	1,052	1,052	1,052	1,052
R-squared	0.913	0.913	0.913	0.913
N clusters	121	121	121	121

Notes: Standard errors clustered at bank level are reported in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. Regressions are weighted by total bank assets in 1996. Bank controls are observed in 1996 (source: ESTBAN) and interacted with linear time trends.

Table VI: The Effect of Bank Exposure on Loans

outcome:	log loan			
			multi-lender	
	(1)	(2)	(3)	(4)
$BankExposure_{bt}$	0.257**	0.290***	0.280**	0.228**
	[0.124]	[0.108]	[0.108]	[0.095]
fixed effects:				
firm	y	y	y	y
year	y	y	y	y
bank	y	y	y	y
AMC × year		y	y	y
Sector × year		y	y	y
firm × year				y
Observations	4,806,825	4,806,825	2,821,990	2,821,990
R-squared	0.549	0.554	0.536	0.664
N clusters	115	115	115	115

Notes: Standard errors clustered at bank level reported in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. AMC stands for Minimum Comparable Area (*Área Mínima Comparável*). Sector dummies correspond to the 87 2-digit sectors according to the Brazilian CNAE 2.0 classification.

Table VII: The Effect of Bank Exposure on Loans by Sector

outcome:	log loan			
	Agriculture (1)	Manufacturing (2)	Services (3)	Other (4)
$BankExposure_{bt}$	0.204	0.304**	0.282***	0.226
	[0.168]	[0.153]	[0.099]	[0.170]
fixed effects:				
firm	y	y	y	y
year	y	y	y	y
bank	y	y	y	y
AMC × year	y	y	y	y
Sector × year	y	y	y	y
Observations	36,148	1,094,139	3,450,876	198,879
R-squared	0.678	0.584	0.526	0.589
N clusters	86	114	115	99

Notes: Standard errors clustered at bank level reported in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. AMC stands for Minimum Comparable Area (*Área Mínima Comparável*). Sector dummies correspond to the 87 2-digit sectors according to the Brazilian CNAE 2.0 classification.

Table VIII: The Effect of Firm Exposure on Firm-level Outcomes
Employment and Wage Bill

outcome:	log employment		log wage bill	
	(1)	(2)	(3)	(4)
$FirmExposure_{it}$	0.269***	0.159***	0.417***	0.214***
	[0.047]	[0.043]	[0.057]	[0.046]
fixed effects:				
firm	y	y	y	y
year	y	y	y	y
AMC × year		y		y
Sector × year		y		y
Observations	2,992,981	2,992,981	2,992,981	2,992,981
R-squared	0.878	0.882	0.898	0.902
N clusters	115	115	115	115

Notes: Standard errors clustered at main lender level reported in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. AMC stands for Minimum Comparable Area (*Área Mínima Comparável*). Sector dummies correspond to the 87 2-digit sectors according to the Brazilian CNAE 2.0 classification.

Table IX: The Effect of Firm Exposure on Firm-level Outcomes - By Sector
Employment and Wage Bill

outcome:	log employment	log wage bill
indep var: $FirmExposure_{it}$	(1)	(2)
Agriculture	0.163	0.230**
	[0.105]	[0.111]
Observations	18,282	18,282
R-squared	0.927	0.937
N clusters	70	70
Manufacturing	0.212***	0.322***
	[0.052]	[0.056]
Observations	587,290	587,290
R-squared	0.888	0.911
N clusters	111	111
Services	0.152***	0.191***
	[0.042]	[0.043]
Observations	2,220,615	2,220,615
R-squared	0.870	0.891
N clusters	112	112
Other	0.023	0.095
	[0.056]	[0.070]
Observations	130,732	130,732
R-squared	0.941	0.949
N clusters	85	85
fixed effects in all specifications		
firm	y	y
year	y	y
AMC × year	y	y
Sector × year	y	y

Notes: Standard errors clustered at main lender level reported in brackets. Significance levels: *** p<0.01, ** p<0.05, * p<0.1. AMC stands for Minimum Comparable Area (*Área Mínima Comparável*). Sector dummies correspond to the 87 2-digit sectors according to the Brazilian CNAE 2.0 classification.