

Capital Accumulation and Structural Transformation*

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Abstract

Several scholars argue that high agricultural productivity growth can retard industrial development as it draws resources towards the comparative advantage sector, agriculture. However, agricultural productivity growth can lead to industrialization through its impact on capital accumulation. We highlight this effect in a simple model where larger agricultural income increases savings and the supply of capital, generating an expansion of the capital-intensive sector, manufacturing. To test the predictions of the model we exploit a large and exogenous increase in agricultural income due to the adoption of genetically engineered soy in Brazil. We find that savings generated in soy-producing regions were not reinvested locally. Instead, agricultural productivity growth generated capital outflows from rural areas. To trace the destination of capital flows we match data on deposit and lending activity of all bank branches in Brazil, bank-firm credit relationships and firm employment. We find that capital reallocated from soy-producing to non-soy producing regions, and from agriculture to non-agricultural activities. The degree of financial integration affects the speed of structural transformation. First, regions that are more financially integrated with soy-producing areas experienced faster growth in non-agricultural lending. Second, firms that are better connected to soy-producing areas through their pre-existing banking relationships experienced larger growth in borrowing and employment.

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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.¹ However, the experience of some low-income countries appears inconsistent with the idea that agricultural productivity growth leads to economic development.² 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.³ Second, market frictions might constrain factor reallocation.⁴ The recent empirical literature has focused on understanding how these mechanisms shape the process of labor reallocation.⁵ However, there is scarce direct empirical evidence on the process of capital reallocation from the rural agricultural sector to the urban industrial sector.⁶

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.⁷ This positive effect of agricultural productivity on industrialization has been overlooked by the literature and will be the main focus of our empirical analysis. We refer to it as the capital supply effect.

¹See, for example, Crafts (1985) and Crouzet (1972). See also Rosenstein-Rodan (1943), Nurkse (1953), Rostow (1960).

²For example, Foster and Rosenzweig (2004) show that, after the Green Revolution, regions in rural India with faster agricultural productivity growth experienced slower industrialization.

³Corden and Neary (1982), Matsuyama (1992).

⁴Banerjee and Newman (1993), Murphy, Shleifer, and Vishny (1989), Galor and Zeira (1993), Acemoglu and Zilibotti (1997). 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).

⁵For labor reallocation across sectors see McCaig and Pavcnik (2013), Foster and Rosenzweig (2004, 2007), 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: Bryan and Morten (2015), Moretti (2011), Munshi and Rosenzweig (2016). For labor reallocation across sectors and regions see: Michaels, Rauch, and Redding (2012), Fajgelbaum and Redding (2014).

⁶A notable exception is Banerjee and Munshi (2004) who document larger access to capital for entrepreneurs belonging to rich agricultural communities in the garment industry in Tirupur, India.

⁷Manufacturing is capital-intensive relative to agriculture because it uses more capital per unit of land.

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 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.⁸ 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. 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

⁸We 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.

bank branch networks. We use this variation to assess whether destination municipalities more connected to origin municipalities experiencing agricultural productivity growth received larger capital inflows. We find that municipalities with relatively larger presence of banks receiving funds from the soy boom experienced faster increases in credit supply. Interestingly, these funds went entirely to non-soy producing regions and were channeled to non-agricultural activities.

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 an increase in land rents, which result in larger savings.⁹ If rural areas are in financial autarky, this increase in local capital supply generates 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, a reduction in the autarky interest rate and capital outflows. Urban regions financially integrated to areas experiencing agricultural technical change receive capital inflows, which generates an expansion of the manufacturing sector.¹⁰

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: agricultural productivity growth generates a reallocation of capital from the rural agricultural sector towards the urban industrial sector. 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 75 to 84 percent in the average non-soy producing municipality. However, the degree of capital reallocation away from agriculture varied extensively across municipalities. Our estimates imply that a standard deviation difference in the degree of financial integration with soy-producing municipalities can explain 11 percent of a standard deviation in the increase in the share of non-agricultural lending across non-soy municipalities.¹¹

As mentioned above, our findings are consistent with the capital supply mechanism emphasized by the model. However, to the extent that destination municipalities which

⁹The increase in land rents increases savings because it is partly temporary. This is because in the second period environmental regulation increases production costs.

¹⁰In the model we assume that rural regions are small, thus they do not affect international goods prices nor the international rental price of capital. As a result, if rural or urban regions were fully open to international capital flows, technical change in the rural regions would not have any effect on urban regions. Then, we consider the case in which 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.

¹¹A standard deviation in the increase in the share of non-agricultural lending across non-soy municipalities is 24 percentage points.

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.

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 more exposed banks experienced a larger increase in borrowing from those banks. We can use our estimates to calculate the elasticity of firm borrowing to bank deposits due to the soy shock. We find that firms with a pre-existing relationship with banks experiencing a 2.3 percentage points larger annual deposit growth rate due to soy technical change – corresponding to one standard deviation – experienced 0.4 percentage points faster annual growth in borrowing in the post-GE soy legalization period. Consistent with the aggregate results described above, we also 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 whose pre-existing lenders have a larger exposure to the soy boom experienced larger growth in employment and wage bill. Consistent with the evidence on firm borrowing, the effects on employment growth are concentrated in firms operating in manufacturing and services.

Taken together, our empirical findings imply that agricultural productivity growth can lead to structural transformation in open economies through its impact on capital

accumulation. The size of this effect depends on several features of the environment. First, it depends on the relative strength of the capital supply and capital demand effects of agricultural technical change, which work in opposite directions. The model indicates that the capital supply effect is strong when the land income share is large as this amplifies the effect of higher land rents on savings. In turn, the capital demand effect is weak when land and capital are complements in agricultural production, which is consistent with our estimates.¹² In this case, the fixed land endowment puts a limit to the amount of capital that can be used in agriculture, decreasing returns set in quickly and the excess capital supply goes to manufacturing. A second key feature of the environment is the degree of financial integration across rural and urban areas. In the model, agricultural productivity growth increases the opportunity cost of land in rural areas, thus it is optimal to reallocate manufacturing activities towards areas with low agricultural productivity. Still, if rural areas are in financial autarky, capital is invested in local manufacturing activities and the local return to capital falls. Instead, if rural areas are financially integrated, there are capital outflows towards regions not experiencing technical change. In the data, we observe capital outflows from soy producing regions. In addition, we find that capital reallocates towards non-soy producing regions financially integrated with the soy boom area through bank branch networks. Lastly, we observe that these regions experience faster structural transformation.

Finally, 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 a decrease 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. The presence of these frictions suggests that 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 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 might not be optimal. In particular, credit constraints can generate a reversal of

¹²Our estimates indicate that land rents increased more than investment per hectare in response to agricultural technical change which, in the context of our model, implies that the elasticity of substitution between land and capital in agricultural production is smaller than one.

capital flows relative to the neoclassical benchmark as emphasized by Gertler and Rogoff (1990), Song, Storesletten, and Zilibotti (2011), Buera and Shin (2017). In section VII of the paper we discuss the evidence discussed above in light of these alternative models.

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 2014). 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 2014, Moretti 2011, Bryan and Morten 2015, Munshi and Rosenzweig 2016). In contrast, our knowledge of the process of capital reallocation is extremely limited.¹³

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.¹⁴ 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. We proceed in two steps. First, we exploit differences in the potential benefits of adopting GE soy across regions in Brazil to find the causal effects of agricultural technical change in local capital markets. This empirical strategy was first used in Bustos et al. (2016) to study the effect of agricultural technical change in local labor markets. However, the large capital mobility across regions found in the data requires a different empirical strategy which permits to track capital flows

¹³See 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.

¹⁴For a detailed discussion of the literature which points out this limitation, see Foster and Rosenzweig (2007).

from origin to destination municipalities. Thus, we propose a new 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 (2015) 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 2001, Banerjee, Duflo, Glennerster, and Kinnan 2013). Second, the finance literature studying the effects of bank liquidity shocks. This literature has 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 2013). 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. To the best of our knowledge, this is the first study to undertake this task.

Our model builds on Jones (1965)'s version of the Heckscher-Ohlin model and the dynamic extensions studied by Stiglitz (1970), Findlay (1970) and Ventura (1997). With respect to previous literature, we emphasize how an increase in agricultural productivity can have opposite effects on capital allocation across sectors. The demand effect generates a reallocation of capital towards agriculture, the comparative advantage sector.¹⁵ The supply effect, instead, generates a reallocation of capital towards the capital-intensive sector, manufacturing. This is the well-known Rybczynski theorem (Rybczynski, 1955).¹⁶ Therefore, the net effect of agricultural technical change depends on the relative strength of the demand and the supply effects, an aspect overlooked by the previous literature.

Our model also builds on the literature studying capital flows in the context of the Heckscher-Ohlin model. Mundell (1957) noted that because trade generates factor price

¹⁵This effect has been emphasized by the theoretical literature linking larger agricultural productivity to de-industrialization (Corden and Neary 1982 and Matsuyama 1992).

¹⁶Note that 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).

equalization, trade and capital flows are substitutes. However, Markusen (1983) highlighted that this conclusion is reversed in models where comparative advantage emanates from forces other than differences in factor endowments, for example Ricardian technology differences. In this case, in the trading equilibrium the home relative price of the factor used intensively in the import sector is lower than abroad. Thus, factor mobility must lead to an outflow of this production factor. This force is also present in our model, where agricultural technical change generates specialization in agriculture, a reduction in the autarky interest rate and capital outflows. The main difference is that we add the capital supply effect to this framework, which is crucial to obtain an increase in the national supply of capital and structural transformation at the national level instead of just a reallocation of capital and manufacturing activities across regions. Finally, Antras and Caballero (2009) present a model where, in the presence of credit frictions, trade integration increases the return to capital and thus the incentives for capital to flow to less developed regions. Our focus is on a different comparative statics exercise where we keep the level of trade integration constant and study the effects of agricultural technical change.

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. We study the first and second channels in Bustos et al. (2016). We do not find evidence of demand effects, partly because agricultural and manufacturing goods are traded. Instead, we find that the new technology was labor-saving and induced a reallocation of labor away from agriculture and 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.¹⁷ In this paper, we focus on the third channel: the effect of agricultural productivity growth on savings and the allocation of capital. Consistent with the higher mobility of capital relative to labor, we find that capital reallocated both across sectors and across regions. In particular, capital mostly 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. This is because destination regions are only affected by agricultural technical change through its effects on capital inflows.¹⁸

¹⁷More recently, Bustos, Castro Vincenzi, Monras, and Ponticelli (2019) document that, when using a larger unit of observation to capture local labor markets – such as Brazilian micro-regions – soy technical change has no effect on migration patterns in Brazil.

¹⁸Note that, in the case of origin regions, both the labor channel documented in Bustos et al. (2016)

In the conclusions of the paper we attempt to quantify the relative importance of the labor and capital channels of structural transformation. More specifically, we compute how much of the increase in manufacturing employment share driven by agricultural productivity growth in Brazil between 2000 and 2010 can be attributed to each channel. We estimate that the capital channel can explain around 1/4 of the variation in manufacturing employment share that is explained by the labor channel. Notice that 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.

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 where 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. 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. 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

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.

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. Then, 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).¹⁹ In turn, 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 start then by considering the intertemporal equilibrium in asset markets to obtain a solution for savings and the capital stock in the second period. First, note that savings are a constant fraction of lifetime wealth, given log preferences. In turn, lifetime income streams reflect asset values and rents because households only derive income from the two assets T and K. In equilibrium, asset returns must be equal, thus the price of land is determined by the ratio of the rental prices of land and capital. This implies that savings decisions depend only on factor prices and endowments. Hence, given international goods prices and technology we sequentially solve for factor prices, savings and the capital stock in period 2. Finally, we use the factor market clearing conditions in each period to solve for the allocation of factors across sectors, manufacturing and agricultural outputs. See Appendix A for details.

II.C COMPARATIVE STATICS: THE EFFECTS OF AGRICULTURAL TECHNICAL CHANGE

In this section we discuss the effects of a permanent increase in agricultural productivity. That is, we compare the equilibrium level of sectoral outputs in two scenarios. The first scenario we study is a benchmark economy which is in a steady state equilibrium with constant technology, international goods prices and consumption. The second scenario we consider is an economy that adopts the new agricultural technology in period 1, but expects an increase in the cost of operating the technology in period 2 due to stricter environmental regulation. The increase in the cost of operating the new technology in period 2 is captured in the model by the parameter γ_2 , which represents the share

¹⁹See 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).

of agricultural output that has to be spent in abatement costs. Thus, if environmental regulation becomes stricter, agricultural technical change generates a larger increase in income in period 1 than in period 2. Instead, if environmental regulation is unchanged in period 2, the income increase is permanent.²⁰

II.C.1 Factor Prices

First, we assess how agricultural technical change affects factor prices using the zero profit conditions in both sectors to obtain:

$$r_{\hat{T},t} = \frac{1 - \theta_{TM}}{\theta_{TA} - \theta_{TM}}(1 - \gamma_t)\hat{A}, \quad (1)$$

$$r_{\hat{K},t} = \frac{-\theta_{TM}}{\theta_{TA} - \theta_{TM}}(1 - \gamma_t)\hat{A}, \quad (2)$$

where hats indicate percent deviations from the benchmark steady state equilibrium and θ_{TA} (θ_{TM}) is the land cost share in agriculture (manufacturing) in the benchmark equilibrium. We find that, if agriculture is land-intensive ($\theta_{TA} > \theta_{TM}$), agricultural technical change ($\hat{A}$) increases the return to land ($r_{T,t}$) and reduces the return to capital ($r_{K,t}$).²¹ This is because agricultural productivity growth raises the profitability of agricultural production and, thus, land rents must increase to satisfy the zero profit condition. However, because manufacturing also uses some land, the increase in land rents reduces its profitability and the return to capital falls.²² Note that this second effect is expected to be small to the extent that the land share in manufacturing (θ_{TM}) is small. Finally, note that when environmental regulation becomes stricter in period 2 ($\gamma_2 > 0$ and $\gamma_1 = 0$), the increase in operating costs erodes part of the land rents generated by technical change in early adopters. As a result, land rents in period 2 do not increase as much as in period 1. We summarize this discussion below.

Result 1: *If agriculture is land-intensive, agricultural technical change increases the return to land and reduces the return to capital. If the technology improvement is partly eroded by abatement costs in the second period, the increase in land rents is larger in the first period.*

²⁰An alternative scenario in which technology adoption would generate a temporary increase in income would be one where the economy is an early adopter of a new agricultural technology in the sense that it adopts in period 1, while other countries adopt in period 2. When the technology is adopted by other countries, the international price of the agricultural good falls. We can then parametrize the international technology adoption rate (γ) in such a way that if all countries in the world adopt the technology the international price of agricultural goods falls in proportion to the productivity improvement. This implies that agricultural technical change generates a temporary increase in income for the early adopter. Instead, if no other country adopts in period 2 the income increase is permanent.

²¹In Appendix Section A.C.2 we show that if agriculture is land-intensive ($\theta_{TA} > \theta_{TM}$), then capital per unit of land is higher in manufacturing than in agriculture: $K_M/T_M > K_A/T_A$.

²²The mechanics of these effects are similar to the Stolper-Samuelson effect of changes in commodity prices on factor prices.

II.C.2 The Supply of Capital

To obtain the effects of agricultural technical change on the supply of capital, we compare the benchmark economy which is in a steady state with constant consumption to the economy where there is agricultural technical change. We start by differentiating the capital accumulation condition, substitute for the factor price changes obtained above, and evaluate at the steady state, which yields:

$$\hat{K}_2 = \frac{\alpha_{T,1}\gamma_2 - \theta_{TM}}{(\theta_{TA} - \theta_{TM})(1 - \alpha_{T,1})} \hat{A}. \quad (3)$$

This condition reflects the opposite effects of changes in factor prices induced by agricultural technical change. First, if $\gamma_2 > 0$ 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 ($\alpha_{T,1}$). Second, the reduction in the rental price of capital has a negative effect on savings. As mentioned above, this effect is proportional to the land share in manufacturing (θ_{TM}). Thus, it is expected to be small.

Result 2: *Agricultural technical change increases the supply of capital in period 2 if the aggregate land income share is large relative to the land share in manufacturing and the technology improvement generates an increase in income which is to some extent temporary.*

II.C.3 Agricultural and Manufacturing Output

Next, we analyze the effect of agricultural technical change on agricultural and manufacturing output by using the factor market clearing condition in each sector. We obtain changes in output as a function of changes in factor supplies and agricultural productivity:

$$\hat{X}_M - \hat{X}_A = \frac{1}{\lambda_{KM} - \lambda_{TM}} (\hat{K} - \hat{T}) + \sigma_s (\hat{p}_M - \hat{p}_A - \hat{A}), \quad (4)$$

where X_M is manufacturing output and $\tilde{X}_A = X_A/A$ is agricultural output in efficiency units. The first term on the r.h.s. of equation (4) represents the capital supply effect of agricultural technical change while the second term represents the capital demand effect. The first effect takes place when agricultural technical change increases savings and the relative supply of capital ($\hat{K} - \hat{T} > 0$), which leads to an increase in the supply of manufacturing, the capital-intensive sector ($\lambda_{KM} > \lambda_{TM}$).²³ This is because, given factor prices, capital intensities are fixed within each sector. Then, the only way to equilibrate factor markets is to assign the new capital to the capital-intensive sector,

²³Note that λ_{ji} is the share of factor j employed in sector i . In Appendix Section A.C.2 we show that if agriculture is land-intensive ($\theta_{TA} > \theta_{TM}$), then capital per unit of land is higher in manufacturing than in agriculture: ($K_M/T_M > K_A/T_A$), and the share of capital employed in manufacturing is higher than the share of land employed in manufacturing ($\lambda_{KM} > \lambda_{TM}$).

as in the Rybczinsky theorem. The second term represents the capital demand effect, which 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 strength of this effect is governed by σ_s , the supply elasticity of substitution between commodities.

Because the capital supply and demand effects work in opposite directions, to understand the effects of agricultural productivity growth on manufacturing output we need to substitute for the effect of technical change on the supply of capital given by equation (3) into equation (4). This implies that manufacturing output expands if the following is true:

$$\frac{\alpha_{T,1}\gamma - \theta_{TM}}{1 - \alpha_{T,1}} - (\delta_K + \delta_T)(1 - \gamma_2) > 0.$$

The first term reflects the strength of the capital supply effect. As discussed above, this effect is stronger the larger is the aggregate land income share (α_T) relative to the land income share in manufacturing (θ_{TM}). Thus, we expect this effect to be strong to the extent that the land-intensive sector, agriculture, is large. The second term reflects the strength of the capital demand effect: as agriculture becomes more productive, land rents increase and the rental rate of capital falls. As a result, both sectors use more capital per unit of land. Thus, the capital intensive sector must contract. The strength of this effect is governed by δ_K and δ_T , the factor demand elasticities, which tend to be low when land and capital are not good substitutes in production.²⁴ Finally, note that the income shock is more temporary the closer is γ_2 to one. A more temporary income shock reinforces the capital supply effect due to stronger savings and reduces the capital demand effect due to lower profitability of producing agricultural goods in the second period.

Result 3: *Agricultural technical change generates a reallocation of capital towards the manufacturing sector if the capital supply effect is stronger than the capital demand effect. The capital supply effect is strong when there is a sizable difference in land-intensity between sectors, the income share of agriculture is large, and the technology improvement generates an increase in income that is to some extent temporary. The capital demand effect is weak when land and capital are not good substitutes in both agricultural and manufacturing production.*

²⁴To be more precise, δ_K is the aggregate percent increase in capital input demand resulting from adjustment to more capital-intensive techniques in both sectors in response to a one percent reduction in r_K/r_T , and the second is the aggregate percent reduction in land input demand resulting from adjustment to less land-intensive techniques in both sectors in response to a one percent reduction in r_K/r_T . See Appendix A for more details.

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

We start by considering the case in which the origin region is open to international trade but in financial autarky. In this case, the benchmark equilibrium is described in section II.B above. In addition, Figure I.a illustrates the benchmark equilibrium (e) in factor markets. The y-axis measures the rental price of capital relative to land rents (r_K/r_T), and the x-axis measures the relative supply of capital (K/T). We assume that in the benchmark equilibrium the origin region produces both goods. As a result, equilibrium factor prices $(r_K/r_T)^*$ are determined by international goods prices and technology. In turn, because there is no factor mobility, the relative supply of capital is determined by local endowments ($\bar{K}/\bar{T}$). The aggregate relative factor demand (RFD) crosses the relative factor supply ($\bar{K}/\bar{T}$) at the equilibrium point e . Figure I.a also depicts the relative factor demand in agriculture (RFD_A) and manufacturing (RFD_M), which are obtained as the ratio of the marginal product of capital to the marginal product of land in each sector. Note that because we assumed that manufacturing is capital-intensive, this sector demands more capital per unit of land at any factor price, thus RFD_M is depicted to the right of RFD_A . Finally, note that the equilibrium RFD is a weighted average between the relative factor demand in agriculture and manufacturing, where the weights are given by the share of land allocated to each sector. As a result, the distance between RFD_A and the equilibrium point e , depicted in red, is proportional to the share of land allocated to manufacturing (λ_{TM}) while the distance between RFD_M and the equilibrium point e , depicted in blue, is proportional to the share of land allocated to agriculture (λ_{TA}). Then, these distances can be used as a measure of structural transformation.

Figure I.b illustrates the effects of agricultural technical change in the origin region, as described in section II.C above. First, larger agricultural productivity implies that the economy can continue producing both goods at zero profits only if land rents increase and the rental price of capital falls to the financial autarky (a) equilibrium level $(r_K/r_T)^a$. As a result, if there was no capital accumulation, the new equilibrium point would be e^d and the manufacturing sector would shrink, as its size is proportional to the distance between RFD_A and the equilibrium point e^d . This is the capital demand effect. However, under the

parameter restriction discussed in Result 3, the supply of capital increases to $\bar{K}^a$ and the capital-intensive sector, manufacturing, expands. The factor share of the manufacturing sector is proportional to the distance between RFD_A and the new equilibrium point e^a and is depicted in red.

In turn, what are the effects of agricultural technical change in the origin on the destination region? First, note that because the origin region is a small economy, agricultural technical change in this region does not affect world prices. Thus, the destination region is not affected by technical change in the origin region.

II.D.2 Financial Integration

To study the financial integration equilibrium we make the additional assumption that in the benchmark steady state equilibrium all countries and regions share the same technology and 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 there is a small cost ε for capital movements across regions so that the equalization of the rental rate of capital implies that capital flows are zero in the benchmark steady state equilibrium. Under this assumption, the benchmark equilibrium is the same under financial autarky and financial integration, which simplifies the analysis.

Origin Region When the origin region faces agricultural technical change the return to land increases, as in the financial autarky equilibrium. In turn, the rental price of capital is constant at r_K^* , which is larger than the financial autarky equilibrium rate r_K^a . But the autarky rental rate is the only one consistent with positive production in both sectors at zero profits under the new technology, given international goods prices. As a result, in the financial integration equilibrium (e^i) the origin region fully specializes in agriculture and factor prices are given by r_K^*/r_T^i , where r_T^i solves the zero profit condition in the agricultural sector under the new technology. Note that because the equilibrium rental price of capital is higher than in the autarky equilibrium, there are capital outflows. This situation is depicted in Figure II.a, in which capital outflows occur for two reasons. First, although the demand for capital in agriculture increases, the capital intensive sector, manufacturing, closes. As a result, aggregate capital demand in the region falls. Second, the capital supply increases.

In what follows, we solve for the effects of technical change on each of these variables. As mentioned above, the origin region fully specializes in agriculture. Then, factor prices are given by r_K^*/r_T^i , where r_T^i solves the zero profit condition in the agricultural sector under the new technology. Thus, the growth rate of equilibrium land rents in the origin region is:

$$(r_{T,t}^{\hat{}})_o^i = \frac{(1 - \gamma_t)}{\theta_{TA}} \hat{A}_o. \quad (5)$$

At the same time, because the increase in land-rents is partly temporary, and there is no change in the interest rate, savings and the relative supply of capital increase. The growth rate of capital supply is:

$$\left(\hat{K}^s\right)_o^i = \frac{\gamma}{\theta_{TA}} \frac{\alpha_{T,1}}{1 - \alpha_{T,1}} \hat{A}_o. \quad (6)$$

Note that capital supply increases more in the financial integration equilibrium than in autarky. This is because in autarky the return to capital falls, reducing savings.

Finally, we obtain an analytical expression for the change in capital demand with respect to the benchmark equilibrium. For this purpose, we make the simplifying assumption that the land endowment in the benchmark equilibrium is just large enough to make the origin economy fully specialized in agriculture. This case is depicted in Figure II.b, where the relative factor supply in the benchmark equilibrium $\frac{\bar{K}}{\bar{T}}$ intersects the relative factor demand in the agricultural sector at the international factor prices $(r_k/r_T)^*$.²⁵ The equilibrium change in capital demand is:

$$\left(\hat{K}^d\right)_o^i = \sigma_A \frac{(1 - \gamma)}{\theta_{TA}} \hat{A}_o. \quad (7)$$

By comparing the growth in capital demand and capital supply we can show that capital outflows are increasing in agricultural productivity growth if

$$\frac{\alpha_{T,1}}{1 - \alpha_{T,1}} \frac{\gamma}{(1 - \gamma)} > \sigma_A,$$

that is, the land income share is large, the shock is temporary, and the elasticity of substitution between land and capital in agricultural production is low.

Result 4: *Under financial integration, agricultural technical change in the origin region generates full specialization in the agricultural sector. In addition, it generates capital outflows if the capital supply effect is stronger than the capital demand effect. The capital supply effect is strong when the land income share is large and the agricultural technology shock produces a temporary increase in income. The capital demand effect is weak when land and capital are not good substitutes in agricultural production.*

²⁵We make this assumption to guarantee that the origin economy is fully specialized in agriculture both in the benchmark equilibrium and when there is technical change. Otherwise, we would need to compare the full specialization equilibrium with a benchmark equilibrium where the economy produces both goods. In this case, we can not use differentiation to derive an analytical expression for the change in capital demand because it would be a discontinuous function of technology. We study this general case in Appendix A where we show that qualitative results are similar. In particular, the origin economy fully specializes in agriculture and there are capital outflows.

Destination Region Finally, we consider a destination region which is open to international trade but does not experience technical change. First, note that because the origin region is small, it does not affect international goods prices nor the international rental price of capital. As a result, if the destination region was in financial autarky or open to international capital flows, technical change in the origin would not have any effect on the destination region. Then, we consider the more interesting case in which the two regions are financially integrated but in financial autarky with respect to the rest of the world. The equilibrium in the destination region is depicted in Figure III. First, note that because this region did not experience technical change, factor prices stay at the level $(r_K/r_T)^*$ given by initial technology and international goods prices. As a result, the equilibrium in the origin region is the same as if it was integrated in international capital markets, depicted in Figure II. This is because capital leaving the origin region can flow in 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.

Note that the increase in capital supply in the destination region equals capital outflows in the origin region:

$$\left(\hat{K}^s\right)_d^i = \omega_{od} \left(\hat{K}^s - \hat{K}^d\right)_o^i \quad (8)$$

where $\omega_{od} = K_o/K_d$ is the ratio of capital stocks in the benchmark equilibrium. Thus, we can write:

$$\left(\hat{X}_M - \hat{X}_A\right)_d^i = \frac{1}{\lambda_{KM} - \lambda_{TM}} \omega_{od} \left(\hat{K}^s - \hat{K}^d\right)_o^i. \quad (9)$$

Thus, the expansion in manufacturing output in the destination region is proportional to the growth in capital supply. This is because the destination region faces a pure Rybczinsky effect with no changes in technology.

Result 5: *Under financial integration, agricultural technical change in the origin region generates a reallocation of capital towards the destination region if the capital supply effect is stronger than the capital demand effect. In turn, 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 described by equations (1) to (6) in the model, which describe the general equilibrium response of each endogenous variable to exogenous agricultural technical change under autarky and financial integration. Subsection III.A provides background information on the changes introduced by genetically engineered (GE) soy in Brazilian agriculture, describes the data and the 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 [See equations (6) to (9)]. 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. We test a generalized version of this prediction to the case of many regions (municipalities) with different levels of financial integration.²⁶ 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

²⁶In the data there are several regions and we can only track capital flows which are intermediated through banks. Thus, in Appendix B.A, we adapt the model's prediction to our context by introducing banks and many regions.

(*origin*) municipalities to non-soy producing (*destination*) municipalities.^{27, 28} We link each destination 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 firm growth.²⁹ 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 these three steps are then presented in

²⁷As 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.

²⁸The 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.

²⁹Note that this empirical strategy requires that firms that have a pre-existing relationship with a bank are more likely to receive credit. 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).

sections IV, V and VI respectively.

Finally, 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 within Brazil 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 countries than within countries. In practice, some savings likely leak abroad. Second, the model considers the case in which banks are not financially connected. In practice, there is an interbank market. As a result, some savings might leak through the interbank market to municipalities not directly served by banks operating in soy-producing regions. Note, however, that these violations of the model’s assumptions make us underestimate the aggregate effects 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.³⁰

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

³⁰The adoption of GE soy seeds increases profitability also because it requires fewer herbicide applications: fields cultivated with GE soybeans require an average of 1.55 sprayer trips against 2.45 of conventional soybeans (Duffy and Smith 2001; Fernandez-Cornejo, Klotz-Ingram, and Jans 2002). Finally, no-tillage allows greater density of the crop on the field (Huggins and Reganold 2008).

Brazil (2003) as source of time variation.³¹ 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, 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 V 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 thus 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 – equation (5) – and local capital supply – equation (6) – we estimate the following specification:

$$y_{jt} = \alpha_j + \alpha_t + \beta \log(A_{jt}^{soy}) + \varepsilon_{jt} \quad (10)$$

where y_{jt} is an outcome that varies across municipalities (j) and time (t).³² A_{jt}^{soy} is our measure of agricultural technical change in soy and it is defined as follows:

$$A_{jt}^{soy} = \begin{cases} A_j^{soy,LOW} & \text{for } t < 2003 \\ A_j^{soy,HIGH} & \text{for } t \geq 2003 \end{cases} \quad (11)$$

where $A_j^{soy,LOW}$ is equal to the potential soy yield under low inputs and $A_j^{soy,HIGH}$ is equal to the potential soy yield under high inputs as reported in the FAO-GAEZ dataset. The

³¹The 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 IV, soy area had been growing since the 1980s, but experienced a sharp acceleration in the early 2000s.

³²Since 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.

timing of the change in potential soy yield from low to high inputs corresponds to the legalization of GE soy seeds in Brazil.

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.³³ Therefore, the vast majority of land rents are included in agricultural profits.³⁴ 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 reports balance sheet information at branch level for all commercial banks operating in the country.³⁵ 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.

It is important at this point to discuss how our empirical strategy can differentiate between the effect of agricultural technical change and other macroeconomic trends that characterized the Brazilian economy in the period under study. Brazil experienced a fast increase in non-agricultural bank lending during the second half of the 2000s.³⁶ In addition to the mechanism underlined in this paper, other forces might have contributed to this trend, including: the introduction of institutional reforms increasing creditors' protection (Ponticelli and Alencar 2016, Assunção, Benmelech, and Silva 2013), favorable international commodity prices, or the increase in trade with China (Costa, Garred, and Pessoa 2016). Our empirical strategy is designed to capture variation across municipalities that are similarly affected by these macroeconomic forces but differentially affected by soy technical change. 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.³⁷ Thus, 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 (in logs), population density (in logs) and literacy rate.³⁸

³³See Agricultural Census of Brazil, IBGE (2006), Table 1.1.1, pag.176.

³⁴It 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.

³⁵We observe three main categories of deposits: checking accounts, savings accounts and term deposits.

³⁶See Appendix Figure C5.

³⁷See Table 5 in Bustos et al. (2016) for a comparison of baseline characteristics across municipalities with different potential increases in soy yields.

³⁸All controls are sourced from the 1991 Population Census.

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 –proxied by Brazilian 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 by introducing many banks and many regions. 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. Destination municipality exposure is higher for municipalities served by banks more exposed to the GE-soy driven increase in deposits through their branch network.

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 VI we show the geographical location of the branches of two Brazilian banks with different levels of 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.³⁹ 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 our 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:

$$Deposits_{bt} = \sum_{o \in O_{bt}} deposits_{bot} \quad (12)$$

³⁹A 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.

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 . Next, we would like to obtain an equation for the increase in national deposits of each bank due to technical change in soy. In Appendix B.A we show that the growth rate of national deposits for a bank in the financially integrated equilibrium is a weighted average of the growth rate of deposits in each of the municipalities where the bank has branches. The local growth rate of deposits is itself a function of local growth in agricultural productivity. Thus, we can obtain a log-linear approximation of the change in aggregate deposits at bank level as follows (all derivations reported in Appendix B.A):

$$\log Deposits_{bt} = \gamma_b + \gamma_t + \underbrace{\beta \left[\sum_{o \in O_b} \omega_{bo,t=0} \left(\frac{T_o^a}{T_o} \right)_{t=0} (\log A_{ot}^{soy}) \right]}_{BankExposure_{bt}} + \eta_{bt} \quad (13)$$

Equation (13) describes the relationship between actual national deposits of bank b at any point in time and the increase in national deposits of bank b that is predicted by a change in the vector of potential soy yields in all municipalities due to the legalization of GE soy. We define the summation in brackets as our measure of bank exposure. Note that the elements inside the summation are the empirical mapping of equation (6) in the model, which describes the growth in capital supply in the origin region as a function of agricultural productivity growth ($\hat{A}$) and the land income share (α_T). Agricultural productivity growth is captured by A_{ot}^{soy} , our measure of soy technical change; while the land income share is captured by $\left(\frac{T_o^a}{T_o} \right)_{t=0}$, the share of agricultural land in municipality o in the initial year of our sample, which we source from the 1996 Agricultural Census.⁴⁰ The weights $\omega_{bo,t=0}$ are the share of local deposits over national deposits of bank b , and capture the importance of each *origin* municipality as a source of deposits for bank b in the initial period.⁴¹

Finally, we construct a measure of the capital flow to destination municipalities as described in equation (8) in the model. 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

⁴⁰Since we do not have information on income shares at the municipality level, we proxy for the land income share with the share of land employed by the agricultural sector. See Appendix B.B for a discussion of this point.

⁴¹Focusing 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.

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.⁴² The empirical counterpart of this measure of destination municipality exposure can be written as follows:

$$MunicipalityExposure_{dt} = \sum_{b \in B_d} w_{bd,t=0} BankExposure_{bt} \quad (14)$$

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).⁴³ The weighting should capture the total exposure of destination municipality d to funds coming from origin municipalities through bank networks. Note that, in order to link origin and destination municipalities, we assume that bank's 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 VII 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 (14) 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:

$$\log(loans_{dt}) = \alpha_d + \alpha_t + \mu MunicipalityExposure_{dt} + \varepsilon_{dt} \quad (15)$$

Where $loans_{dt}$ are total loans originated by bank branches located in destination munic-

⁴²See equation (54) in Appendix B.A.

⁴³We compute lending market shares of each bank in 1996, before the new soy technology was legalized in Brazil (or patented in the US).

ipality d at time t , as observed in ESTBAN.⁴⁴ Note that equation (15) is the empirical counterpart of equation (8) in the model, which links changes in capital supply in the destination region with capital outflows from the origin region.⁴⁵ Appendix B.B reports the derivations to obtain equation (15).

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 2010.⁴⁶ 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.⁴⁷ Using worker level data, we constructed the following set of variables

⁴⁴Additionally, we estimate a version of equation (15) where the outcome variable is the share of bank loans to the non-agricultural sectors.

⁴⁵As can be seen by replacing equations (6) and (7) into equation (8) in the model, capital outflows in the origin region are a function of agricultural technical change ($\hat{A}$). Thus, equation (15) is effectively a reduced form version of the relationship described by equation (8) in the model.

⁴⁶The 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.

⁴⁷Employers are required by law to provide detailed worker information to the Ministry of Labor. See Decree n. 76.900, December 23rd 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

at firm-level: employment, wage bill, sector of operation and geographical location.⁴⁸ One advantage of our dataset is that we observe both the universe of credit relationships and the universe of formal firms.⁴⁹ That is, we observe both firms with access to credit and 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 a reduced form version of equation (8) in the model as follows:

$$\log(loans_{ibdst}) = \nu_i + \nu_b + \nu_{dt} + \nu_{st} + \mu BankExposure_{bt} + \varepsilon_{ibdst} \quad (16)$$

This equation relates borrowing of firm i from bank b to the measure of bank exposure presented in equation (13), which is a function of soy technical change and land income share.⁵⁰ The subscript d indexes the destination municipality where the firm is located, and s the industry in which the firm operates.⁵¹

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

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).

⁴⁸When 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.

⁴⁹See also Bottero, Lenzu, and Mezzanotti (2015) for a study that uses similar datasets for Italy.

⁵⁰One can see that this estimating equation is a reduced form version of equation (8) by replacing the definition of $\hat{K}^s$ and $\hat{K}^d$ into equation (8) to obtain capital supply in destination regions (or firms) as a function of the soy technical change.

⁵¹Sector 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.

affected by GE soy legalization because they supply or buy inputs from the soy sector. To address these concerns, we include in equation (16) 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.⁵²

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:

$$\log(L_{idst}) = \nu_i + \nu_{dt} + \nu_{st} + \lambda FirmExposure_{it} + \varepsilon_{idst} \quad (17)$$

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.⁵³

⁵²All 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 results are available from the authors upon request.

⁵³Note 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.

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 described in equations (1) and (5) where land cost shares in agricultural and manufacturing production (θ_{TA} and θ_{TM}) are the same for all municipalities due to factor price equalization in the benchmark equilibrium and γ is a parameter measuring the degree of persistence of the increase in agricultural profitability. As described in section III.A, we proxy for land rents with agricultural profits sourced from the Agricultural Census of Brazil. Data is collected through direct interviews with the managers of each agricultural establishment and it is available aggregated at municipality level. 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 (10):

$$\Delta y_j = \Delta\alpha + \beta\Delta\log(A_j^{soy}) + \Delta\varepsilon_j \quad (18)$$

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 (18) when the outcome is agricultural profits per hectare.⁵⁴ 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.

According to our model, the ratio between the estimate of the effect of the new technology on investment and profits identifies the elasticity of substitution between land and capital in agricultural production (σ_A), which we estimate to be $1/3$.⁵⁵ One implication

⁵⁴Using 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.

⁵⁵To see this, note that our estimates of the effect of the new technology on agricultural profits per

of this low elasticity of substitution is that the parameter condition for the capital supply effect to dominate the capital demand effect is more likely to hold, especially in rural municipalities where the land income share is large.⁵⁶

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, as described in equations (3) and (6) where land cost shares (θ_{TA} and θ_{TM}) are the same for all municipalities but the land income share (α_T) varies across municipalities depending on their land and capital endowments. To test this prediction, we estimate equation (10) where the outcome variable is the log of the total value of bank deposits in bank branches located in municipality j .⁵⁷ We define bank deposits as the sum of deposits in checking accounts, savings accounts and term deposits.⁵⁸ 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 column 2 indicates that a municipality with a one standard deviation higher increase in soy technical change experienced an 8 percent larger increase in bank deposits in local branches.⁵⁹

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 (10) in which we allow the effect of $\Delta \log(A_j^{soy})$ to vary over time. Figure VIII plots the time varying estimated coefficients on $\Delta \log(A_j^{soy})$ and ninety-nine-percent confidence intervals when the outcome variable is the log of de-

hectare (our proxy for land rents) are based on equation (5) in the model, while our estimates of the effect of the new technology on investment per hectare can be thought of as an estimate of equation (7), which describes the equilibrium change in capital demand.

⁵⁶Although we do not have direct estimates of this share, the average GDP share of agriculture in soy producing municipalities is 0.47 which suggests that the land share is also large. In Appendix we show that the land share α_T can be written as the weighted sum of the land shares in agriculture and manufacturing, where the weights are the income shares of each sector. Thus, the land share is likely to be large in soy producing municipalities where both the land share in agriculture and the income share of agriculture are large.

⁵⁷Note that when estimating equation (10) 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.

⁵⁸Data on bank outcomes is sourced from the ESTBAN dataset, which has detailed information on balance sheet and location of branches of all commercial banks operating in Brazil. As such, our analysis in this section focuses on municipalities with at least one bank branch. During the period under study we have data on bank branches located in 3154 AMCs (75 percent of all Brazilian AMCs).

⁵⁹In 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.

posits in local bank branches.⁶⁰ 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.⁶¹ 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 IV. This figure documents a break in the trend of the expansion of the area planted with soy starting in 2002, consistent with contraband of GE soy seeds at a large scale from Argentina (USDA 2003).

In the case of financial integration, our model predicts that municipalities with faster agricultural productivity growth experience capital outflows if the capital supply effect is larger than the capital demand effect. To test this prediction, we estimate equation (10) when the outcome variable is the total value of loans originated by bank branches located in municipality j .⁶² 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. To test the model prediction more formally, in columns 5 and 6 of Table III we estimate equation (10) 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.⁶³

⁶⁰These estimated coefficients are net of municipality controls interacted with time fixed effects as in column 2 of Table III.

⁶¹These 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 VIII addresses the concern that the long-lived dynamics of the trade liberalization of the early 1990s has a confounding effect on our results.

⁶²Note 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.

⁶³Note 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. To see this, consider Figure II (a) in the model, where an

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 using the specification presented in equation (15). We focus on two main outcome variables: total 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. We find that municipalities with a larger exposure to the soy-driven deposit increase 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 GE-soy driven national deposit growth of the banks operating in a given municipality. This implies that a destination municipality with a standard deviation higher exposure is a municipality whose banks experienced, on average, a 2.3 percentage points faster annual growth in national deposits due to soy technical change in the post-GE soy legalization period (2003-2010).⁶⁴ The magnitude of the estimated coefficient reported in column (1) of Table IV indicates that a municipality whose banks had a 2.3 percentage points faster annual growth in deposits due to soy technical change experienced a 0.4 percentage points faster annual growth in bank lending in the post-GE soy legalization period.⁶⁵

increase in the land endowment would shift the relative supply of capital in the financial integration equilibrium to the left, reducing or even reversing capital outflows. 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.

⁶⁴A standard deviation in the increase in municipality exposure across municipalities between the period before and the period after GE soy legalization is 0.18. To obtain the average annual growth we divide this number by the number of years in the post-GE soy legalization period for which data is available (2003-2010). Note also that the average annual growth rate of bank deposits across Brazilian municipalities in the post-GE soy legalization period was 10 percent.

⁶⁵To obtain this annualized growth in lending we multiply a standard deviation in the increase in municipality exposure across municipalities between the period before and the period after GE soy legalization (0.18) by the elasticity of loan growth to deposit growth γ (see equation (54) in Appendix B.A). As shown in Appendix B.B, the elasticity of loan growth to deposit growth (γ) can be obtained by dividing the coefficient μ in equation (15) by the coefficient β in equation (13). This is because $\mu = \gamma\beta$. Empirically, we calculate γ by dividing the estimated coefficient in column (1) of Table IV by the estimated coefficient

According to the extension of our model with many banks and many regions reported in Appendix B.A, loans should move at the same rate as deposits if banks were to operate in financial autarky and could only invest in loans. However, in the real world, banks can lend their deposits in the interbank market, or to individuals and firms abroad, or can invest them in assets other than loans. Thus, we expect deposits and loans not to move 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.

In columns 2 and 3, we split the sample in soy-producing and non-soy producing municipalities.⁶⁶ 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 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 can construct as outcome variable the share of bank lending 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 municipality exposure). This effect is present in both soy-producing and non soy-producing regions, although largely concentrated in the latter, as shown in columns (5) and (6).^{67, 68}

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.

⁶⁶Non-soy producing municipalities are those with no agricultural area farmed with soy at any point in time between 1996 and 2010.

⁶⁷The 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.

⁶⁸Note 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

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.⁶⁹

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 III.C, we propose an identification strategy that aims 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 section IV we showed that regions more affected by technical change in soy production experience capital outflows. In section V we showed that regions that are more

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.

⁶⁹That 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.

financially integrated with soy producing regions through the bank network experience a larger increase in non-agricultural lending. 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 (13) when the outcome variable is aggregate deposits of bank b , and bank-year observations are weighted by initial bank size.⁷⁰ Aggregate deposits for each bank are obtained summing branch level deposits from ESTBAN.⁷¹ 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.⁷² Columns 2 to 4 show that this effect is not driven by differential growth trends across banks of different initial size or the deposit-to-asset ratio. Finally, in Figures IX (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 weighting by initial bank size, respectively.⁷³ As shown, our estimates are not driven by extreme observations or weighting by bank size.

⁷⁰As captured by bank assets in the initial year. Our results do not depend on this weighting, as shown in Figure IX.

⁷¹We focus on the years 2001 to 2010 in order to match the same time period used in the firm-level analysis presented in the next subsections.

⁷²We 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.

⁷³This is equivalent to a first difference version of equation (13) 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.

VI.B BANK-FIRM LEVEL SPECIFICATION

In this section we study the effect of bank exposure on firm borrowing from that same bank.⁷⁴ Table VI shows the results of estimating equation (16) described in section III.C 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 equation (16) in a specification with firm, bank and time fixed effects in column 1. 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 and sector-level shocks, which should capture any labor supply or product demand effects across firms in the same location. This suggests that the increase in firm borrowing is driven by the capital supply effect of agricultural technical change.

Similarly to the destination municipality results presented in section V, we can quantify the effect on firm borrowing for a given increase in bank deposits. First, note that the coefficients on bank exposure presented in Table VI are of similar magnitude of those on municipality exposure presented in Table IV when the outcome was total bank lending in a given municipality. In particular, the estimated coefficient in column (2) indicates that firms with a pre-existing relationship with a bank experiencing a 2.3 percentage points faster deposit growth due to soy technical change experienced a 0.4 percentage points faster annual growth in borrowing in the post-GE soy legalization period. The similarity in point estimates between Table IV and Table VI also implies that our municipality level measure of total bank lending well captures bank 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 (16) with firm fixed effects interacted with time fixed effects. This specification fully captures firm-specific demand shocks, and only exploits variation across banking relationships within 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 banks with larger exposure to the soy-driven deposit shock increased their lending by more to the same firm. 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

⁷⁴In 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 C1 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.

unobservable firm-specific demand shocks correlated with lender exposure.⁷⁵

Next, we study the effect of bank exposure on loans by sector of operation of the borrowing firm. To this end, we estimate equation (16) separately for borrowers operating in agriculture, manufacturing, services, and other sectors.⁷⁶ 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). These magnitudes imply that a standard deviation difference in GE-soy driven deposit growth – which corresponds to a 3.4 percentage points faster annual growth in the post-GE legalization period – translates into 2.2 percentage points faster annual growth in borrowing for firms operating in manufacturing, 2 percentage points for firms operating in services, 1.6 percentage points for firms operating in other sectors and 1.5 percentage points for firms operating in agriculture. 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.⁷⁷

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.

⁷⁵Under certain assumptions regarding the functional form of the underlying model describing borrowing of firm i from bank b , the difference in point estimates between specifications that include firm fixed effects and those that do not captures the size of the bias induced by endogenous matching between firms and banks (see Khwaja and Mian 2008).

⁷⁶Services 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.

⁷⁷This 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.

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 (17) 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 positive real effects on firm size. Firms whose pre-existing lenders have a larger exposure to the soy-driven deposit increase experienced a larger growth in employment and wage bill. 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. This can be seen, for example, by comparing columns 1 and 2 in Table VIII. The coefficient on firm exposure when the outcome is employment goes from 0.269 to 0.159 when adding municipality and sector fixed effects interacted with year fixed effects. This finding indicates that municipalities more connected through bank branch networks might also be more connected through transportation or commercial networks, thus are more likely to receive not only capital supply shocks but also labor supply and product demand shocks due to agricultural productivity growth.⁷⁸

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.

⁷⁸Notice that, to the extent that labor and capital are complements in production, labor supply and local demand shocks should similarly affect firm borrowing and employment. However, the results presented in Table VI and Table VIII indicate that including location and sector fixed effects interacted with year fixed effects has a small impact on the coefficient on bank exposure when the outcome is firm borrowing, while it decreases the coefficient on exposure when the outcome is firm 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.

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.⁷⁹ The presence of these frictions suggests that the 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 re-allocate capital only across regions where it has branches.⁸⁰ 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 (See Appendix A). 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.

⁷⁹Several 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 2011 and Gilje et al. 2013) or monetary policy (Kashyap and Stein 2000, Campello 2002). 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 developing countries, including: US (Chodorow-Reich 2014), Italy (Bottero et al. 2015), 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.

⁸⁰See 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.

In our setting, we argue that 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 rural regions are less developed than urban regions, this mechanism might explain why we observe capital outflows from rural areas.

As an example, let us consider the setup in Song et al. (2011), adapted to our context. In particular, suppose that the new technology can only be adopted by small 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 is farmed by their owners.⁸¹ 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, 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

⁸¹As discussed in section III.A, according to the 2006 Agricultural Census, 93 percent of agricultural land – and 76 percent of agricultural establishments – are farmed by the actual owners of the land (Agricultural Census of Brazil, 2006, Table 1.1.1, pag.176).

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 get 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 indicate 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).⁸² 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 (.01) and statistically significant for both channels of structural transformation.⁸³ To quantify the relative importance of the labor and capital channels we multiply the two estimated coefficients by the (weighted)

⁸²The 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 (14) 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.

⁸³More specifically, the point estimate on local labor-saving technical change is 0.009 with a t-stat of 4.11, while the estimate on municipality exposure to the soy-driven deposit shock is 0.010 with a t-stat of 1.77.

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. Note that 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.

REFERENCES

- Acemoglu, D. and V. Guerrieri (2008). Capital deepening and nonbalanced economic growth. *Journal of political Economy* 116(3), 467–498.
- Acemoglu, D. and F. Zilibotti (1997). “Was Prometheus Unbound by Chance? Risk, Diversification, and Growth”. *Journal of political economy* 105(4), 709–751.
- Antras, P. and R. J. Caballero (2009). Trade and capital flows: A financial frictions perspective. *Journal of Political Economy* 117(4), 701–744.
- Assunção, J. J., E. Benmelech, and F. S. Silva (2013). Repossession and the democratization of credit. *The Review of Financial Studies* 27(9), 2661–2689.
- Banerjee, A., D. Karlan, and J. Zinman (2001). Six randomized evaluations of microcredit: Introduction and further steps. *American Economic Journal: Applied Economics* 7(1), 1–21.
- Banerjee, A. and K. Munshi (2004). “How Efficiently is Capital Allocated? Evidence from the Knitted Garment Industry in Tirupur”. *The Review of Economic Studies* 71(1), 19–42.
- Banerjee, A. V. and E. Duflo (2014). Do firms want to borrow more? testing credit constraints using a directed lending program. *Review of Economic Studies* 81(2), 572–607.
- Banerjee, A. V., E. Duflo, R. Glennerster, and C. Kinnan (2013). The miracle of micro-finance? evidence from a randomized evaluation.
- Banerjee, A. V. and A. F. Newman (1993). “Occupational Choice and the Process of Development”. *Journal of political economy*, 274–298.
- Bottero, M., S. Lenzu, and F. Mezzanotti (2015). Sovereign debt exposure and the bank lending channel: impact on credit supply and the real economy. *Bank of Italy Temi di Discussione (Working Paper) No 1032*.
- Bryan, G. and M. Morten (2015). Economic development and the spatial allocation of labor: Evidence from indonesia. *Manuscript, London School of Economics and Stanford University*.
- Buera, F. J., J. P. Kaboski, and Y. Shin (2015). “Entrepreneurship and Financial Frictions: A Macro-Development Perspective”.
- Buera, F. J. and Y. Shin (2017). Productivity growth and capital flows: The dynamics of reforms. *American Economic Journal: Macroeconomics* 9(3), 147–85.
- Bustos, P., B. Caprettini, and J. Ponticelli (2016). “Agricultural productivity and structural transformation: Evidence from Brazil”. *The American Economic Review* 106(6), 1320–1365.
- Bustos, P., J. M. Castro Vincenzi, J. Monras, and J. Ponticelli (2019). “Structural Transformation, Industrial Specialization, and Endogenous Growth”. *NBER Working Paper No. 25871*.

- Campello, M. (2002). Internal capital markets in financial conglomerates: Evidence from small bank responses to monetary policy. *The Journal of Finance* 57(6), 2773–2805.
- Chodorow-Reich, G. (2014). “The employment effects of credit market disruptions: Firm-level evidence from the 2008–9 financial crisis”. *The Quarterly Journal of Economics* 129(1), 1–59.
- Cole, S. (2009). Financial development, bank ownership, and growth: Or, does quantity imply quality? *The Review of Economics and Statistics* 91(1), 33–51.
- Cong, L. W., H. Gao, J. Ponticelli, and X. Yang (2019). Credit allocation under economic stimulus: Evidence from china. *Review of Financial Studies*.
- Corden, W. M. and J. P. Neary (1982). “Booming Sector and De-Industrialization in a Small Open Economy”. *The Economic Journal* 92(368), 825–848.
- Costa, F., J. Garred, and J. P. Pessoa (2016). Winners and losers from a commodities-for-manufactures trade boom. *Journal of International Economics* 102, 50–69.
- Crafts, N. F. (1985). *British economic growth during the industrial revolution*. Clarendon Press Oxford.
- Crouzet, F. (1972). *Capital Formation in the Industrial Revolution*. Methuen.
- De Mel, S., D. McKenzie, and C. Woodruff (2008). Returns to capital in microenterprises: evidence from a field experiment. *The Quarterly Journal of Economics*, 1329–1372.
- Diamond, D. W. (1984). “Financial intermediation and delegated monitoring”. *The Review of Economic Studies* 51(3), 393–414.
- Dinkelman, T., G. Kumchulesi, and M. Mariotti (2019). “Labor Migration, Capital Accumulation, and the Structure of Rural Labor Markets”.
- Dix-Carneiro, R. and B. K. Kovak (2017). “Trade Liberalization and Regional Dynamics”. *American Economic Review* 107(10), 2908–46.
- Donaldson, D. (2015). Railroads of the raj. *American Economic Review*, forthcoming.
- Donaldson, D. and R. Hornbeck (2016). Railroads and american economic growth: A “market access” approach. *The Quarterly Journal of Economics* 131(2), 799–858.
- Duffy, M. and D. Smith (2001). “Estimated Costs of Crop Production in Iowa”. *Iowa State University Extension Service FM1712*.
- Fajgelbaum, P. and S. J. Redding (2014). External integration, structural transformation and economic development: Evidence from argentina 1870-1914. Technical report, National Bureau of Economic Research.
- Fernandez-Cornejo, J., C. Klotz-Ingram, and S. Jans (2002). “Estimating Farm-Level Effects of Adopting Herbicide-Tolerant Soybeans in the USA”. *Journal of Agricultural and Applied Economics* 34, 149–163.
- Findlay, R. (1970). “Factor Proportions and Comparative Advantage in the Long Run”. *Journal of Political Economy* 78(1), 27–34.

- Findlay, R. and H. Grubert (1959). “Factor Intensities, Technological Progress, and the Terms of Trade”. *Oxford Economic Papers* 11(1), 111–121.
- Foster, A. D. and M. R. Rosenzweig (2004). “Agricultural productivity growth, rural economic diversity, and economic reforms: India, 1970–2000”. *Economic Development and Cultural Change* 52(3), 509–542.
- Foster, A. D. and M. R. Rosenzweig (2007). “Economic development and the decline of agricultural employment”. *Handbook of development economics* 4, 3051–3083.
- Galor, O. and J. Zeira (1993). “Income Distribution and Macroeconomics”. *The review of economic studies* 60(1), 35–52.
- Gertler, M. and K. Rogoff (1990). North-south lending and endogenous domestic capital market inefficiencies. *Journal of monetary Economics* 26(2), 245–266.
- Gilje, E. (2011). “Does Local Access to Finance Matter? Evidence from US Oil and Natural Gas Shale Booms”. *Working paper*.
- Gilje, E., E. Loutskina, and P. E. Strahan (2013). “Exporting Liquidity: Branch Banking and Financial Integration”. *NBER Working paper*.
- Giné, X. and R. M. Townsend (2004). “Evaluation of financial liberalization: a general equilibrium model with constrained occupation choice”. *Journal of Development Economics* 74(2), 269–307.
- Gollin, D. (2010). “Agricultural Productivity and Economic Growth”. *Handbook of Agricultural Economics* 4, 3825–3866.
- Gollin, D., D. Lagakos, and M. E. Waugh (2014). “The Agricultural Productivity Gap”. *Quarterly Journal of Economics*.
- Gourinchas, P.-O. and H. Rey (2014). “External adjustment, global imbalances, valuation effects”. In *Handbook of International Economics*, Volume 4, pp. 585–645. Elsevier.
- Herrendorf, B., R. Rogerson, and A. Valentinyi (2014). “Growth and Structural Transformation”. In *Handbook of Economic Growth*, Volume 2, pp. 855–941. Elsevier.
- Holmstrom, B. and J. Tirole (1997). “Financial intermediation, loanable funds, and the real sector”. *Quarterly Journal of Economics* 112(3), 663–691.
- Huggins, D. R. and J. P. Reganold (2008). “No-Till: the Quiet Revolution”. *Scientific American* 299, 70–77.
- IBGE (2006). “*Censo Agropecuário 2006*”. Rio de Janeiro, Brazil: Instituto Brasileiro de Geografia e Estatística (IBGE).
- Iyer, R., J.-L. Peydró, S. da Rocha-Lopes, and A. Schoar (2013). “Interbank liquidity crunch and the firm credit crunch: Evidence from the 2007–2009 crisis”. *The Review of Financial Studies* 27(1), 347–372.
- Jeong, H. and R. M. Townsend (2008). “Growth and inequality: Model evaluation based on an estimation-calibration strategy”. *Macroeconomic dynamics* 12(S2), 231–284.

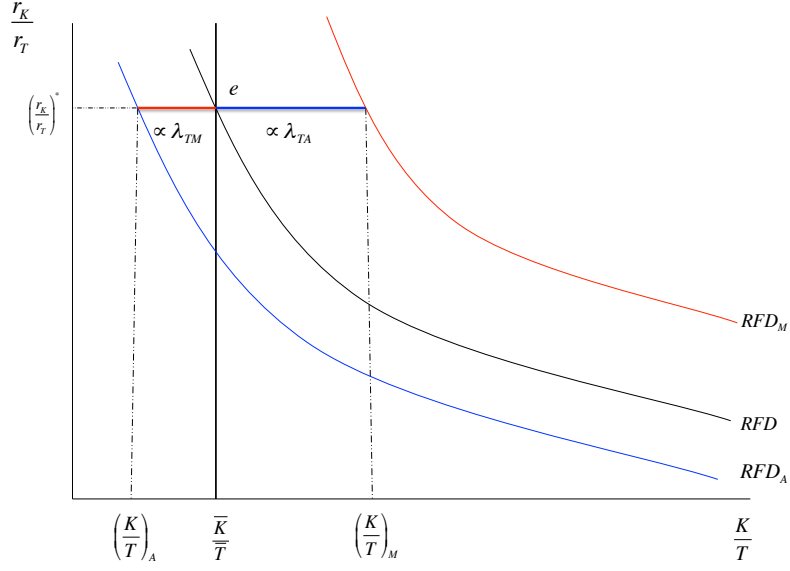
- Jones, R. W. (1965). The structure of simple general equilibrium models. *Journal of political Economy* 73(6), 557–572.
- Kashyap, A. K. and J. C. Stein (2000). What do a million observations on banks say about the transmission of monetary policy? *American Economic Review* 90(3), 407–428.
- Khwaja, A. I. and A. Mian (2008). Tracing the impact of bank liquidity shocks: Evidence from an emerging market. *The American Economic Review*, 1413–1442.
- Marden, S. (2016). The agricultural roots of industrial development: forward linkages in reform era china. *Working Paper*.
- Markusen, J. R. (1983). Factor movements and commodity trade as complements. *Journal of international economics* 14(3-4), 341–356.
- Matsuyama, K. (1992). “Agricultural Productivity, Comparative Advantage, and Economic Growth”. *Journal of economic theory* 58(2), 317–334.
- McCaig, B. and N. Pavcnik (2013). Moving out of agriculture: structural change in vietnam.
- McKenzie, D. and C. Woodruff (2008). Experimental evidence on returns to capital and access to finance in mexico. *The World Bank Economic Review* 22(3), 457–482.
- Michaels, G., F. Rauch, and S. J. Redding (2012). Urbanization and structural transformation. *The Quarterly Journal of Economics* 127(2), 535–586.
- Moll, B. (2014). Productivity losses from financial frictions: Can self-financing undo capital misallocation? *The American Economic Review* 104(10), 3186–3221.
- Moll, B., R. M. Townsend, and V. Zhorin (2017). Economic development, flow of funds, and the equilibrium interaction of financial frictions. *Proceedings of the National Academy of Sciences*, 201707055.
- Moretti, E. (2011). Local labor markets. *Handbook of labor economics* 4, 1237–1313.
- Mundell, R. A. (1957). International trade and factor mobility. *American economic review* 47(3), 321–335.
- Munshi, K. and M. Rosenzweig (2016). Networks and misallocation: Insurance, migration, and the rural-urban wage gap. *The American Economic Review* 106(1), 46–98.
- Murphy, K. M., A. Shleifer, and R. Vishny (1989). Income distribution, market size, and industrialization. *The Quarterly Journal of Economics* 104(3), 537–564.
- Nurkse, R. (1953). *Problems of Capital Formation in Underdeveloped Countries*. Oxford University Press.
- Ponticelli, J. and L. S. Alencar (2016). Court enforcement, bank loans, and firm investment: evidence from a bankruptcy reform in brazil. *The Quarterly Journal of Economics* 131(3), 1365–1413.
- Rosenstein-Rodan, P. N. (1943). Problems of Industrialization of Eastern and South-Eastern Europe. *Economic Journal* 53, 202–211.

- Rostow, W. (1960). *The Stages of Economic Growth: A Non Communist Manifesto*. Cambridge University Press, London.
- Rybczynski, T. M. (1955). “Factor Endowment and Relative Commodity Prices”. *Economica* 22(88), 336–341.
- Samuelson, P. A. (1949). International factor-price equalisation once again. *The Economic Journal* 59(234), 181–197.
- Sharpe, S. A. (1990). “Asymmetric information, bank lending, and implicit contracts: A stylized model of customer relationships”. *The Journal of Finance* 45(4), 1069–1087.
- Song, Z., K. Storesletten, and F. Zilibotti (2011). Growing like china. *American economic review* 101(1), 196–233.
- Stiglitz, J. E. (1970). “Factor Price Equalization in a Dynamic Economy”. *Journal of Political Economy* 78(3), 456–488.
- Stiglitz, J. E. and A. Weiss (1983). Incentive effects of terminations: Applications to the credit and labor markets. *American Economic Review* 73(5), 912–927.
- USDA (2003). “Brazil Oilseeds and Products Annual”. United States Department of Agriculture, Foreign Agricultural Service.
- USDA (2012). “Agricultural Biotechnology Annual”. United States Department of Agriculture, Economic Research Service.
- Ventura, J. (1997). “Growth and Interdependence”. *The Quarterly Journal of Economics* 112(1), 57–84.
- Williamson, S. D. (1987). Costly monitoring, loan contracts, and equilibrium credit rationing. *The Quarterly Journal of Economics* 102(1), 135–145.

FIGURES AND TABLES

FIGURE I: FINANCIAL AUTARKY

(a) Benchmark Equilibrium in Factor Markets



(b) Effect of Agricultural Technical Change in Origin Region

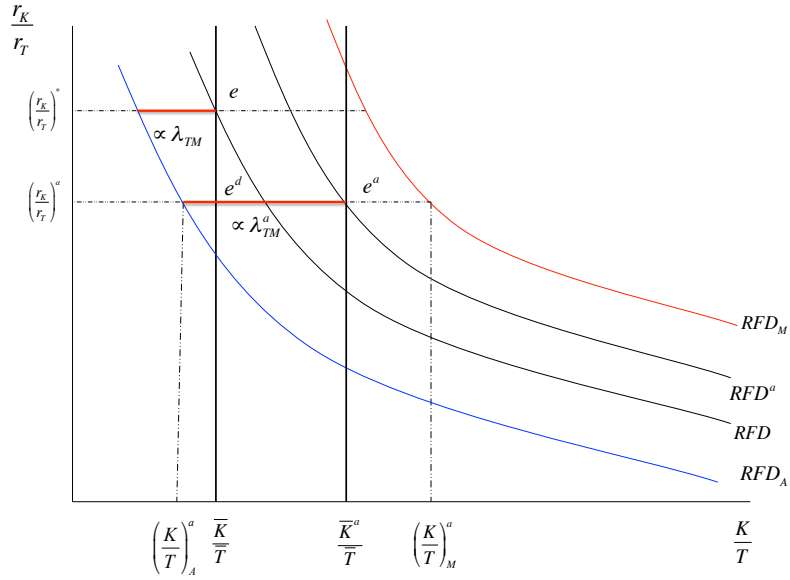
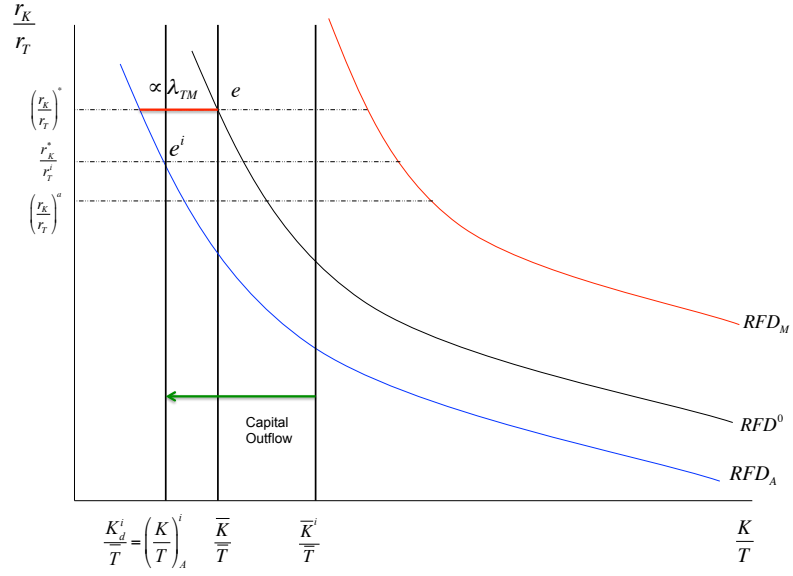


FIGURE II: FINANCIAL INTEGRATION: ORIGIN REGION

(a) Incomplete Specialization in the Benchmark Equilibrium



(b) Complete Specialization in the Benchmark Equilibrium

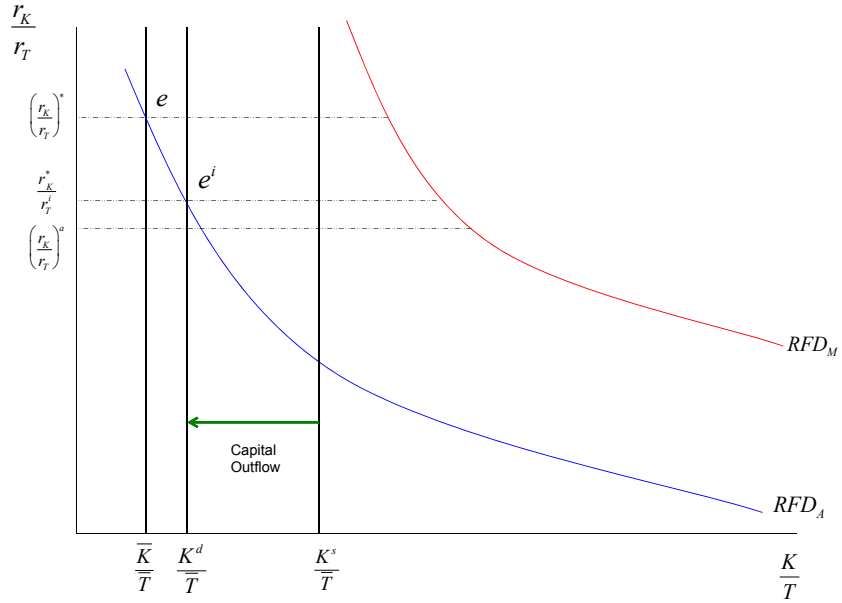


FIGURE III: FINANCIAL INTEGRATION: DESTINATION REGION

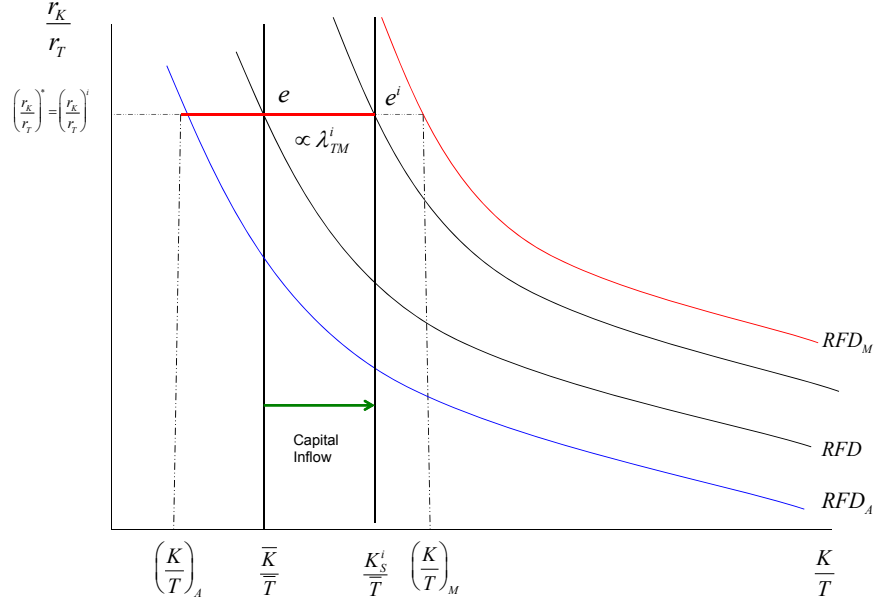
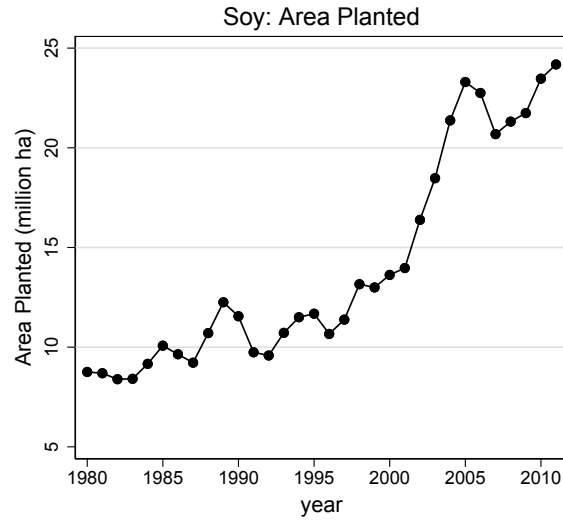
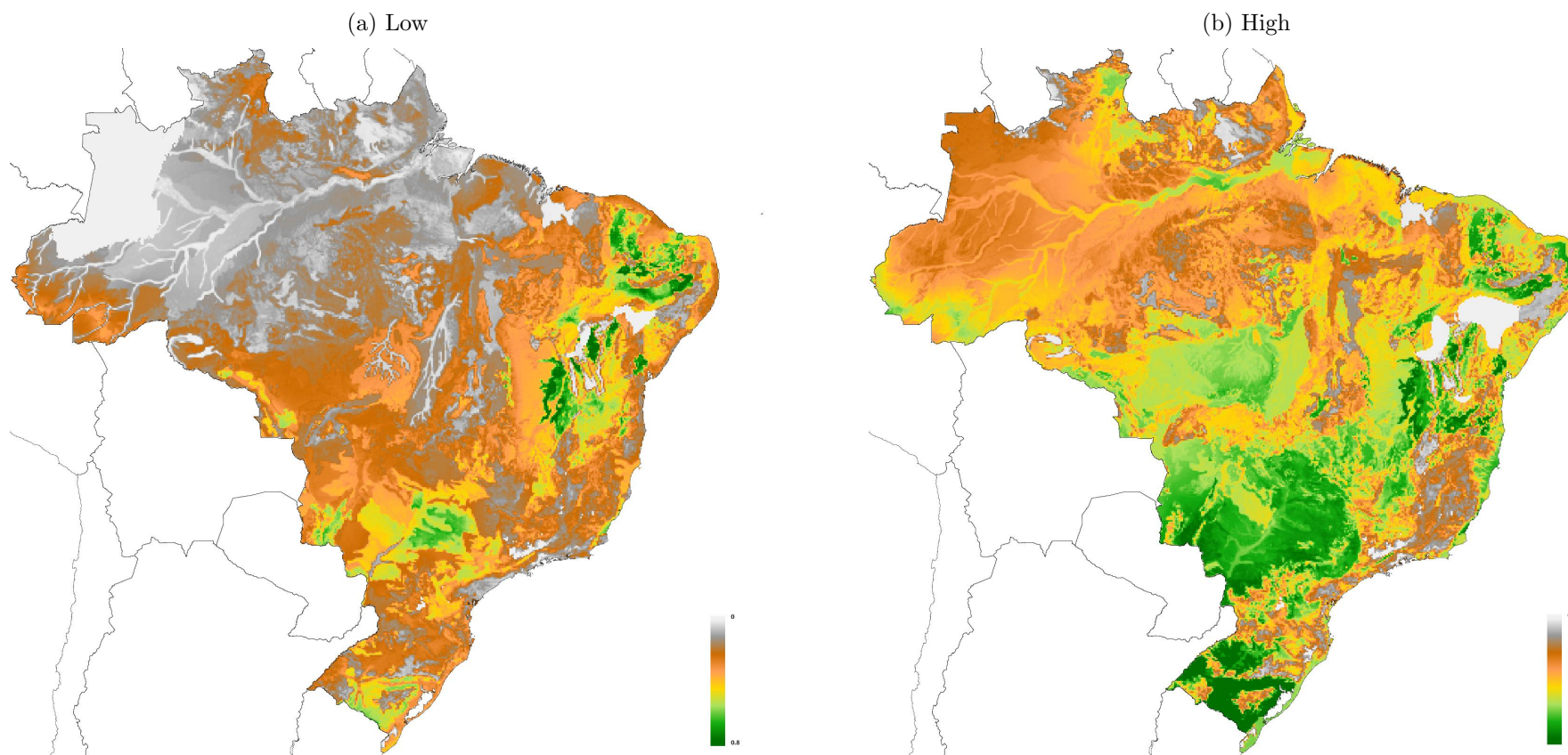


FIGURE IV: EVOLUTION OF AREA PLANTED WITH SOY IN BRAZIL



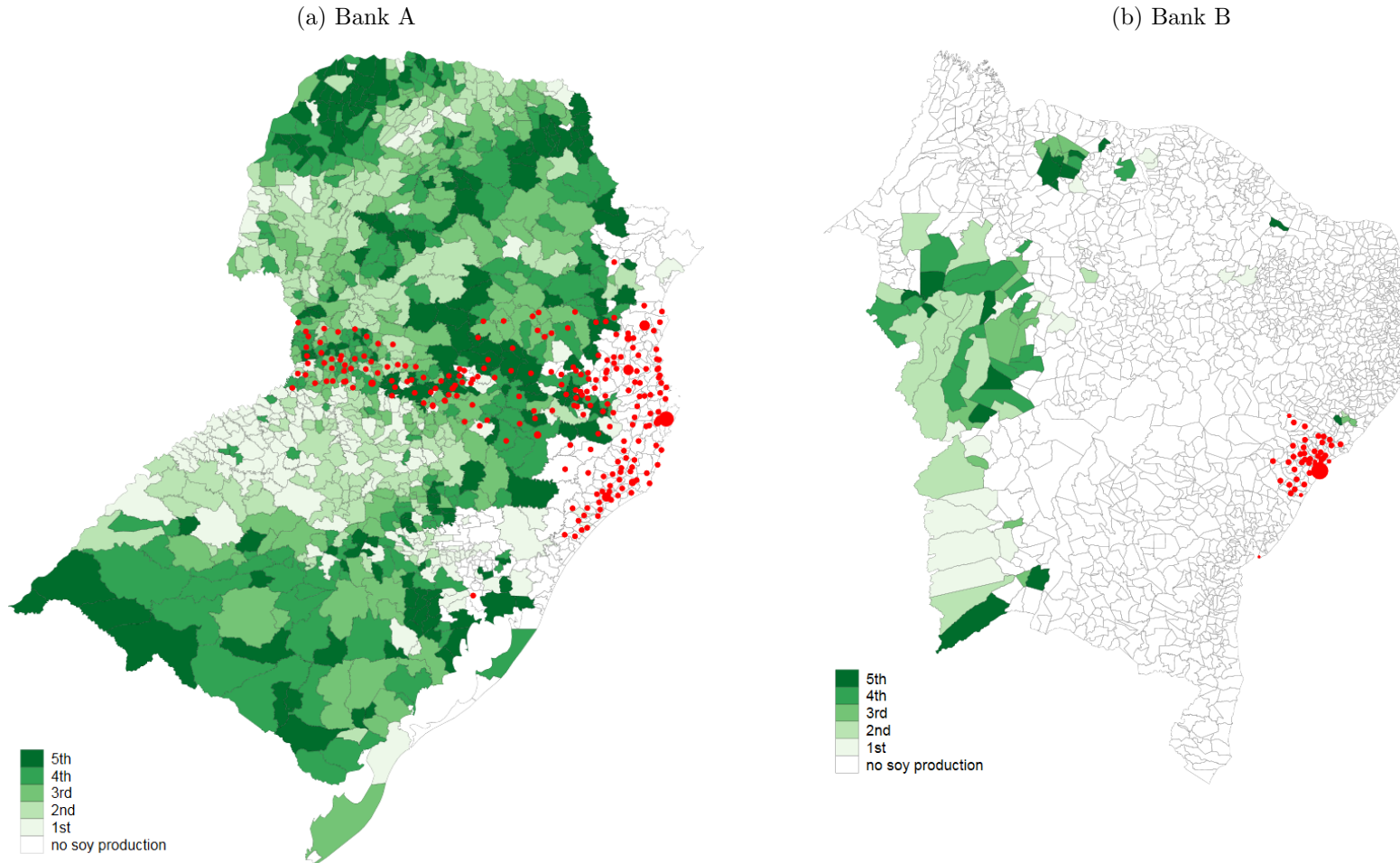
Notes: Data source is CONAB, *Companhia Nacional de Abastecimento*, which is an agency within the Brazilian Ministry of Agriculture. CONAB carries out monthly surveys to monitor the evolution of the harvest of all major crops in Brazil: the surveys are representative at state level and are constructed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

FIGURE V: POTENTIAL SOY YIELD UNDER LOW AND HIGH AGRICULTURAL TECHNOLOGY



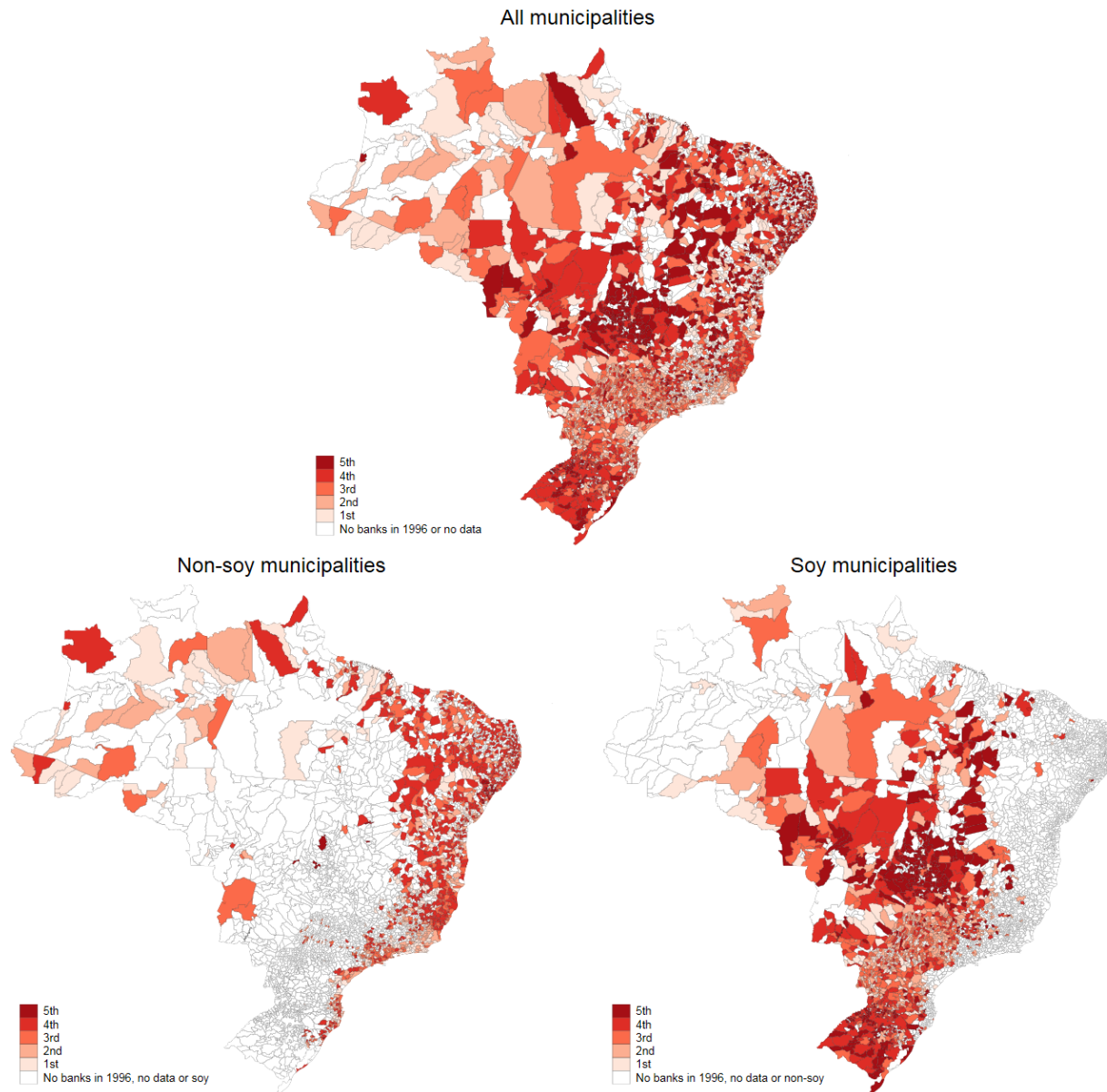
Notes: Data source is FAO-GAEZ. Units are tons per hectare.

FIGURE VI: BANK NETWORKS AND INCREASE IN SOY REVENUES



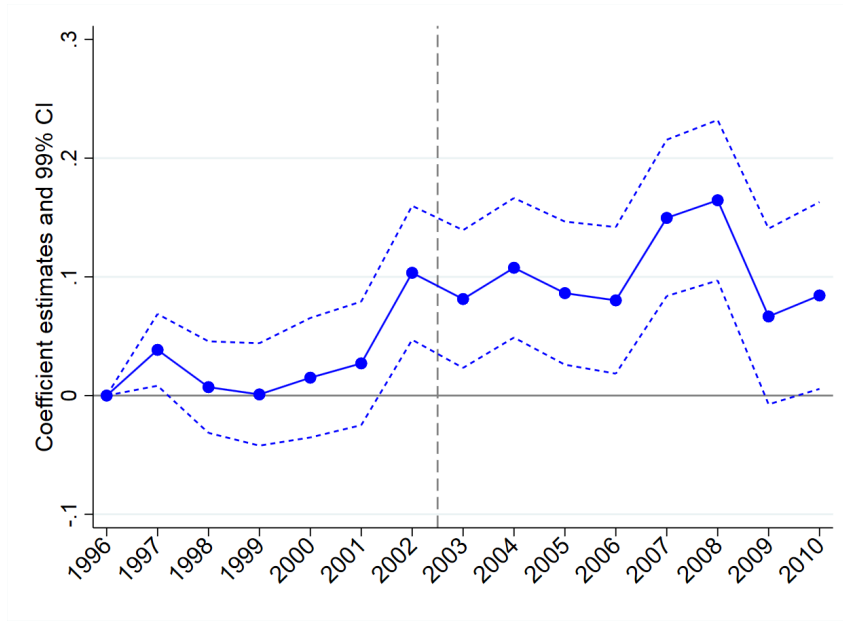
Notes: Red dots indicate bank presence in a given municipality, dot size captures number of bank branches in a given municipality. Green areas are soy producing municipalities: darker green indicates larger percentage increase in soy revenues between the years before and after GE soy legalization. Data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

FIGURE VII: DESTINATION MUNICIPALITY EXPOSURE



Notes: The maps show the geographical distribution of destination municipality exposure across Brazil. Destination municipality exposure is defined as in equation (14) in the paper. Soy municipalities are those with positive soy production at any point in time between 1996 and 2010 according to the Municipal Agricultural Production survey (PAM).

FIGURE VIII: TIMING OF THE EFFECT OF SOY TECHNICAL CHANGE ON DEPOSITS



Notes: The graph reports the time varying estimated coefficients β_t , along with their 99% confidence intervals from the following equation:

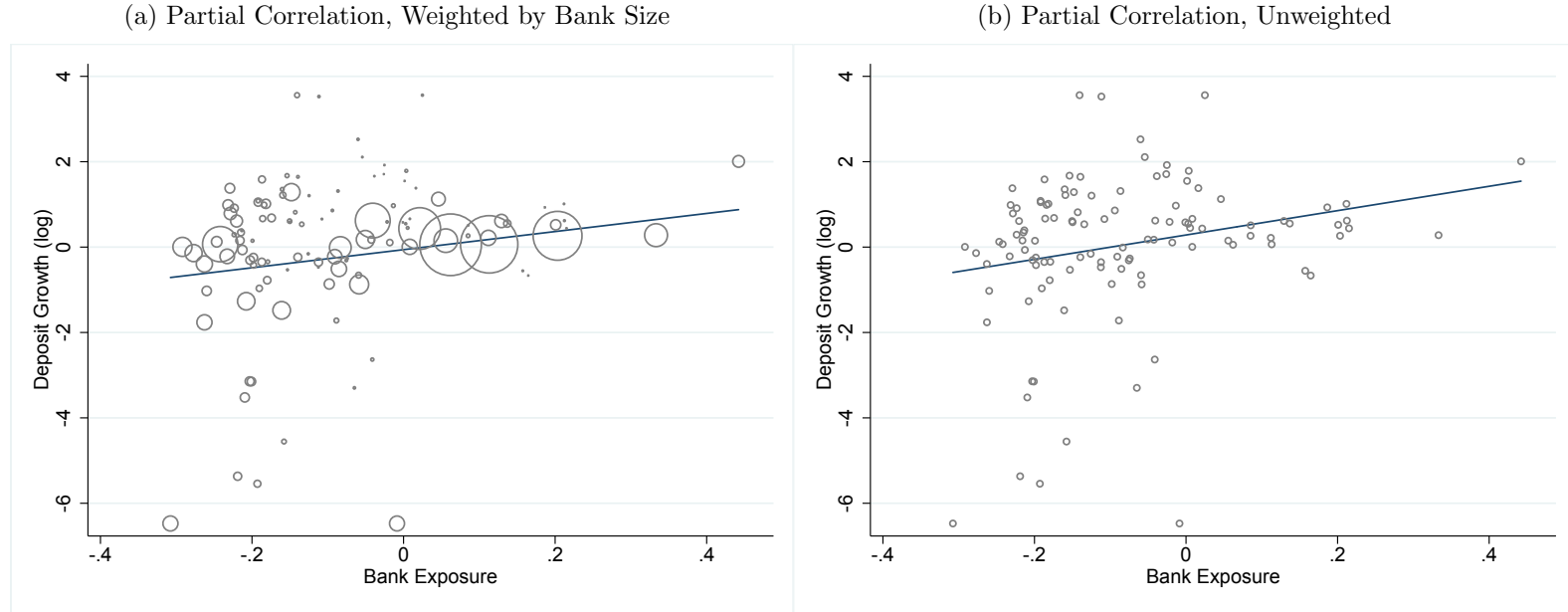
$$\log deposits_{jt} = \alpha_t + \alpha_j + \sum_{t=1996}^{2010} \beta_t \Delta \log(A_j^{soy}) + \varepsilon_{jt}$$

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 IX: BANK DEPOSITS AND BANK EXPOSURE



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 (13). The results of estimating equation (13) 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:			
$\Delta \log(A_{jt}^{soy})$	1.917	0.466	3,020
$\log(A_{jt}^{soy})$	-0.285	1.136	44,406
<i>MunicipalityExposure</i>	-0.041	0.242	44,406
<i>BankExposure</i>	0.069	0.198	1,052
outcome variables at municipality-level:			
$\Delta \frac{GESoyArea}{AgriArea}$	0.015	0.064	3,020
Δ Agri Profits per he (pct points)	0.319	1.867	3,020
Δ Agri Investment per he (pct points)	0.475	1.042	3,020
Δ Agri Productivity	0.504	0.695	3,020
Soy Area / Agricultural Area	0.051	0.136	44,406
log(deposits)	15.693	1.809	44,406
log(loans)	15.459	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*** [0.071]	0.229*** [0.079]	0.181*** [0.044]	0.214*** [0.048]
rural pop _{t=1991}	y	y	y	y
AMC 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 (10):

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

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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time.

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*** [0.016]	0.070*** [0.016]	-0.077*** [0.029]	-0.061** [0.029]	0.305*** [0.062]	0.297*** [0.065]
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
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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time.

TABLE IV: CAPITAL REALLOCATION ACROSS MUNICIPALITIES
LENDING AND NON-AGRICULTURAL LENDING SHARE

outcome: sample:	log(loans)			$\frac{\text{non-agricultural loans}}{\text{total loans}}$		
	all	soy region	non-soy region	all	soy region	non-soy region
	(1)	(2)	(3)	(4)	(5)	(6)
$MunicipalityExposure_{dt}$	0.283*** [0.090]	0.054 [0.124]	0.580*** [0.131]	0.090*** [0.016]	0.046* [0.024]	0.139*** [0.023]
AMC fe	y	y	y	y	y	y
year fe	y	y	y	y	y	y
rural pop $_{t=1991} \times$ year fe	y	y	y	y	y	y
AMC controls $_{t=1991} \times$ 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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time.

TABLE V: BANK DEPOSITS AND BANK EXPOSURE

outcome:	log deposits			
	(1)	(2)	(3)	(4)
<i>BankExposure_{bt}</i>	1.427** [0.587]	1.664*** [0.562]	1.580** [0.761]	1.750** [0.688]
Log Assets _{b,t=0} × <i>t</i>		-0.012 [0.010]		-0.010 [0.012]
Deposits/Assets _{b,t=0} × <i>t</i>			-0.085 [0.140]	-0.068 [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
LOAN VALUE

outcome:	log loan			
	(1)	(2)	multi-lender (3)	(4)
$BankExposure_{bt}$	0.257 [0.124]**	0.290 [0.108]***	0.280 [0.108]**	0.228 [0.095]**
fixed effects:				
firm	y	y	y	y
year	y	y	y	y
bank	y	y	y	y
AMC $\times$ year		y	y	y
Sector $\times$ year		y	y	y
firm $\times$ 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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time. 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
LOAN VALUE

outcome:	log loan			
	Agriculture (1)	Manufacturing (2)	Services (3)	Other (4)
<i>BankExposure_{bt}</i>	0.204 [0.168]	0.304 [0.153]**	0.282 [0.099]***	0.226 [0.170]
fixed effects:				
firm	y	y	y	y
year	y	y	y	y
bank	y	y	y	y
AMC $\times$ year	y	y	y	y
Sector $\times$ 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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time. 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)
<i>FirmExposure_{it}</i>	0.269 [0.047]***	0.159 [0.043]***	0.417 [0.057]***	0.214 [0.046]***
fixed effects:				
firm	y	y	y	y
year	y	y	y	y
AMC $\times$ year		y		y
Sector $\times$ 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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time. 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: indep var: $FirmExposure_{it}$	log employment	log wage bill
	(1)	(2)
Agriculture	0.163 [0.105]	0.230 [0.111]**
Observations	18,282	18,282
R-squared	0.927	0.937
N clusters	70	70
Manufacturing	0.212 [0.052]***	0.322 [0.056]***
Observations	587,290	587,290
R-squared	0.888	0.911
N clusters	111	111
Services	0.152 [0.042]***	0.191 [0.043]***
Observations	2,220,615	2,220,615
R-squared	0.870	0.891
N clusters	112	112
Other	0.023 [0.056]	0.095 [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 $\times$ year	y	y
Sector $\times$ 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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time. Sector dummies correspond to the 87 2-digit sectors according to the Brazilian CNAE 2.0 classification.

A THEORETICAL FRAMEWORK: DERIVATIONS

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.

A.A SETUP

Consider a small open economy where there is one final good which can be used for consumption and investment. In addition, there are two intermediate goods used in the production of the final good. The first intermediate is a manufacturing good and the second is an agricultural good. The final good is non-traded while the two intermediate goods are freely traded. Finally, there are two production factors, land (T) and capital (K). The supply of land is fixed for both periods but the supply of capital can vary in the second period due to capital accumulation. Factors of production are internationally immobile, but freely mobile across sectors. All markets are perfectly competitive.

A.A.1 Production technology

There is a perfectly competitive final goods sector with the following production technology:

$$Q_F = H(Q_A, Q_M)$$

where Q_F denotes production of the final good, Q_A denotes purchases of the agricultural intermediate good and Q_M denotes purchases of the manufactured intermediate good. The production function features constant returns to scale and continuously diminishing marginal products.

In turn, production of the manufactured and the agricultural intermediate goods requires both capital and land, features constant returns to scale, continuously diminishing marginal products and no factor intensity reversals (in a sense to be discussed below). Denote by $c_i(r_T, r_K)$ the unit cost function in sector $i = A, M$, given factor prices r_T and r_K , defined as:

$$c_i(r_T, r_K) = \min_{T_i, K_i} \{r_T T_i + r_K K_i \mid F_i(K_i, T_i) \geq 1\}$$

where $F_i(\cdot)$ denotes the production function in intermediate goods sector i . It can be shown that given the properties of $F_i(\cdot)$ outlined above, $c_i(\cdot)$ will also be homogeneous of degree 1 and twice continuously differentiable. Finally, denote by $a_{ji}(r_T, r_K)$ the unit demand of factor $j = K, T$ in the production of good i . From the envelope theorem, we have

$$a_{Ti}(r_T, r_K) = \frac{\partial c_i(r_T, r_K)}{\partial r_T}; \quad a_{Ki}(r_T, r_K) = \frac{\partial c_i(r_T, r_K)}{\partial r_K}.$$

Finally, we assume that technologies do not feature factor intensity reversals. In particular, agriculture is more land-intensive than manufacturing for all possible factor prices:

$$\frac{a_{TA}(r_T, r_K)}{a_{KA}(r_T, r_K)} > \frac{a_{TM}(r_T, r_K)}{a_{KM}(r_T, r_K)}$$

for all (r_T, r_K) .

Agricultural Productivity

We can consider Hicks-neutral increases in agricultural productivity within this framework by modifying the the production function in agriculture, so that it can be written as:

$$G_A(A, K_A, T_A) = AF_A(K_A, T_A).$$

In this case, the unit cost function in agriculture is $b(A, r_T, r_K) = \frac{1}{A}c_A(r_T, r_K)$ and unit factor demands are:

$$\frac{\partial b(A, r_T, r_K)}{\partial r_T} = \frac{1}{A}a_{Ti}(r_T, r_K); \quad \frac{\partial b(A, r_T, r_K)}{\partial r_K} = \frac{1}{A}a_{Ki}(r_T, r_K)$$

where a_{TA} and a_{KA} can be interpreted as unit factor demands in efficiency units.

A.A.2 Preferences

Individuals in this economy only live for two periods, thus their utility function is:

$$U(y_1^h, y_2^h) = \ln y_1^h + \beta \ln y_2^h \quad (19)$$

where y_t^h is final good consumption of individual h in period $t = 1, 2$. Consumption in period 1 is the numeraire. There are two assets, land (t) and capital (k). The rental rate of land is r_T and its price at the end of period 1 is q . Because the world ends at the end of period 2, land will then have a price of zero. In turn, the rental rate of capital is $r_{K,1}$ and its depreciation rate is δ . Capital is reversible in the sense that it can be turned into consumption at the end of period 1, thus its price is equal to one. Then, the individual budget constraints in periods 1 and 2 are:

$$\begin{aligned} y_1^h &= (r_{T,1} + q) t_1^h + [r_{K,1} + (1 - \delta)] k_1^h - s^h \\ y_2^h &= r_{T,2} t_2^h + [r_{K,2} + (1 - \delta)] k_2^h \end{aligned}$$

where $s^h = qt_2^h + k_2^h$ are savings.

A.B EQUILIBRIUM

In this section we list and solve for the equilibrium conditions of the model. We start by considering the intertemporal equilibrium in asset markets to obtain a solution for the capital stock in the second period as a function of factor prices. Next, we solve for factor prices in each period using the intra-temporal equilibrium conditions in goods and factor markets. Note that due to the factor price equalization theorem, factor prices are fully determined by technology and international prices (Samuelson, 1949). Thus, factor prices are independent of savings decisions and local factor supplies.

A.B.1 Intertemporal equilibrium

Portfolio choice Note that because there are two assets, there is an optimal portfolio choice where individuals compare the return of each asset in terms of second period consumption divided by its price in terms of first period consumption. Only when asset returns are equal, individuals are willing to hold both assets in equilibrium:

$$t_2^h = \begin{cases} 0 & \text{if } \frac{r_{T,2}}{q} < r_{K,2} + (1 - \delta) \\ [0, s^h] & \text{if } \frac{r_{T,2}}{q} = r_{K,2} + (1 - \delta) \\ s^h & \text{if } \frac{r_{T,2}}{q} > r_{K,2} + (1 - \delta) \end{cases}$$

Let's assume the solution is interior. Then, the equilibrium price of land at the end of the first period is:

$$q = \frac{r_{T,2}}{r_{K,2} + (1 - \delta)}$$

Savings If we substitute the price of land in the savings equation, we can write it as:

$$s^h = \frac{r_{T,2}}{r_{K,2} + (1 - \delta)} t_2^h + k_2^h.$$

Then, replace s^h in the budget constraint for period 1 by the r.h.s. of the equation just above to obtain:

$$y_1^h + \frac{y_2^h}{r_{K,2} + (1 - \delta)} = (r_{T,1} + q) t_1^h + [r_{K,1} + (1 - \delta)] k_1^h.$$

Note that the l.h.s. of the equation above is the present value of lifetime consumption and the r.h.s. is the present value of wealth. This is because this individual only derives income from the two assets t and k , thus their current rents plus prices reflect their lifetime income streams. Then, optimal consumption in period 1, given Cobb-Douglas preferences, is a constant fraction of lifetime wealth:

$$y_1^h = \frac{1}{1 + \beta} \{ (r_{T,1} + q) t_1^h + [r_{K,1} + (1 - \delta)] k_1^h \}.$$

In turn, optimal consumption in period 2 can be obtained from the Euler equation:

$$\frac{y_2^h}{y_1^h} = \beta [r_{K,2} + (1 - \delta)].$$

Aggregation Land Market Equilibrium implies:

$$\sum_h t_1^h = \sum_h t_2^h = T.$$

Savings equals Investment yields:

$$\sum_h s^h = K_2 + qT.$$

Substitute for s^h and q to obtain

$$K_2 = \frac{\beta}{1 + \beta} [r_{K,1} + (1 - \delta)] K_1 + \frac{1}{1 + \beta} \left[\beta r_{T,1} - \frac{r_{T,2}}{r_{K,2} + (1 - \delta)} \right] T \quad (20)$$

where K_t denotes the aggregate capital stock in period t and T is the aggregate land endowment.

A.B.2 Intratemporal equilibrium

Final good The representative firm in the final goods sector minimizes production costs given demand for the final good, which must equal income, thus intermediate good demands are

$$D_i = \alpha_i(p_a, p_m) (r_K K + r_T T) \quad (21)$$

where $\alpha_i(p_a, p_m)$ is the share of spending on intermediate good i . Time subscripts are omitted for simplicity. Note that because the final goods sector is competitive, the price of the final good must equal unit production costs. Thus, even if the final good is non-traded, its price is given by the international prices of traded intermediates.

Intermediate goods Free trade and perfect competition in the intermediate goods sectors imply that prices equal average (and marginal) production costs in each sector. Denote by $X_i > 0$ the amount of intermediate good i produced in the country. Perfect competition and free trade imply that for each intermediate good $i = A, M$, we must have

$$p_M \leq c_M(r_T, r_K), \text{ with strict equality if } X_M > 0; \quad (22)$$

$$p_A \leq \frac{1}{A} c_A(r_T, r_K), \text{ with strict equality if } X_A > 0. \quad (23)$$

In turn, factor market clearing requires:

$$a_{TA}(r_T, r_K) \tilde{X}_A + a_{TM}(r_T, r_K) X_M = T \quad (24)$$

$$a_{KA}(r_T, r_K) \tilde{X}_A + a_{KM}(r_T, r_K) X_M = K \quad (25)$$

where $\tilde{X}_A = X_A/A$ is agricultural output in efficiency units.

We consider the case of a small open economy that faces exogenously given goods prices p_A and p_M . An intra-temporal equilibrium of a small open economy is a demand vector $D = (D_A, D_M)$, a production vector $X = (X_A, X_M)$ and a factor-price vector $\omega = (r_T, r_K)$ such that (3), (4), (5), (6) and (7) are satisfied. Note that provided that the small open-economy produces both goods and technologies feature no factor intensity reversals, factor prices will be uniquely pinned down by goods prices, regardless of factor endowments. This is the Factor Price Insensitivity result by Samuelson (1949).⁸⁴

A.C COMPARATIVE STATICS: THE EFFECTS OF AGRICULTURAL TECHNICAL CHANGE

In this section we discuss the effects of a permanent increase in agricultural productivity. That is, we compare the equilibrium level of sectoral outputs in two scenarios. The first scenario we study is a benchmark economy which is in a steady state equilibrium with constant technology, international goods prices and consumption. The second scenario we consider is an economy that adopts the new agricultural technology in period 1, but expects an increase in the cost of operating the technology in period 2 due to stricter

⁸⁴In this case, equations (4) and (5) can be used to solve for factor prices as a function of technology and goods prices. Setting the zero-profit equations in (4) and (5) to equality, we have a system of two equations that implicitly define (r_T, r_K) in terms of (p_A, p_M) . From Gale and Nikaido (1965), the mapping from (r_T, r_K) to (p_A, p_M) is one-to-one provided that the Jacobian of $[c_M(r_T, r_K), \frac{1}{A} c_A(r_T, r_K)]$, which we call the technology matrix, is nonsingular and $a_{ji}(r_T, r_K) > 0$. Note that in this case technologies do not feature factor intensity reversals.

environmental regulation. The increase in the cost of operating the new technology in period 2 is captured in the model by the parameter γ_2 which represents the share of agricultural output that has to be spent in abatement costs. Thus, if environmental regulation becomes stricter, $\gamma_2 \in (0, 1)$, agricultural technical change generates a larger increase in income in period one than in period two. In turn, if $\gamma_2 = 1$ agricultural technical change generates a temporary increase in income, as we show below. Instead, if $\gamma_2 = 0$, the income increase is permanent.⁸⁵

A.C.1 Factor Prices

First, we need to assess how agricultural technical change affects factor prices. For this purpose, we use the zero-profit conditions (4) and (5), which permit to solve for factor price changes as a function of goods prices and agricultural technology. Log-differentiating them we obtain that changes in goods prices are a weighted average of changes in factor prices:

$$\hat{p}_A + \hat{A} = \theta_{TA} \hat{r}_T + (1 - \theta_{TA}) \hat{r}_K$$

$$\hat{p}_M = \theta_{TM} \hat{r}_T + (1 - \theta_{TM}) \hat{r}_K$$

where $\theta_{Ti} = r_T a_{Ti} / c_i$ is the land cost share in sector i and hats denote percent changes. We omit time subscripts for convenience. Next, we can use Cramer's rule to solve for the changes in factor prices taking into account that the goods prices are the same in both economies ($\hat{p}_M = 0$ and $\hat{p}_A = 0$). Thus, in period 1, when only technology changes the change in factor prices with respect to the steady state economy is:

$$\begin{bmatrix} \hat{r}_{T,1} \\ \hat{r}_{K,1} \end{bmatrix} = \begin{bmatrix} \frac{(1-\theta_{TM})\hat{A}}{\theta_{TA}-\theta_{TM}} \\ \frac{-\theta_{TM}\hat{A}}{\theta_{TA}-\theta_{TM}} \end{bmatrix}. \quad (26)$$

In period 2, both technology and environmental regulation change, then the change in factor prices with respect to the steady state economy is

$$\begin{bmatrix} \hat{r}_{T,2} \\ \hat{r}_{K,2} \end{bmatrix} = \begin{bmatrix} \frac{(1-\theta_{TM})\hat{A}(1-\gamma_2)}{\theta_{TA}-\theta_{TM}} \\ \frac{-\theta_{TM}\hat{A}(1-\gamma_2)}{\theta_{TA}-\theta_{TM}} \end{bmatrix}. \quad (27)$$

Then, agricultural technical change increases the return to land and reduces the return to capital because agriculture is land-intensive ($\theta_{TA} > \theta_{TM}$). This result is similar to the Stolper-Samuelson theorem because agricultural productivity growth rises the profitability of agricultural production in the same way as increases in agricultural prices. Note that when $\gamma_2 > 0$, agricultural technical change increases land rents in period 1 more than in period 2 when abatement costs increase.

⁸⁵An alternative scenario in which technology adoption would generate a temporary increase in income would be one where the economy is an early adopter of a new agricultural technology in the sense that it adopts in period 1, while other countries adopt in period 2. When the technology is adopted by other countries, the international price of the agricultural good falls. We can then parametrize the international technology adoption rate (γ_2) in such a way that if all countries in the world adopt the technology the international price of agricultural goods falls in proportion to the productivity improvement. This implies that agricultural technical change generates a temporary increase in income for the early adopter. Instead, if no other country adopts in period 2 the income increase is permanent.

A.C.2 Agricultural and manufacturing output

Next, we analyze the effect of agricultural technical change on agricultural and manufacturing output by using the factor market clearing conditions (6) and (7). Log-differentiating we obtain:

$$(1 - \lambda_{KM}) \hat{X}_A + \lambda_{KM} \hat{X}_M + (1 - \lambda_{KM}) a_{\hat{K}A} + \lambda_{KM} a_{\hat{K}M} = \hat{K} \quad (28)$$

$$(1 - \lambda_{TM}) \hat{X}_A + \lambda_{TM} \hat{X}_M + (1 - \lambda_{TM}) a_{\hat{T}A} + \lambda_{TM} a_{\hat{T}M} = \hat{T} \quad (29)$$

where $\lambda_{iM} = a_{iM}X_M/K$ is the share of factor i employed in sector M . We can show that $\lambda_{KM} > \lambda_{TM}$ if and only if sector M is capital intensive relative to A . To see this note that we define factor shares as $\theta_{TA} = r_T a_{TA}/c_A$ and $\theta_{KA} = r_K a_{KA}/c_A$. Then, $\theta_{TA}/\theta_{KA} = r_T a_{TA}/r_K a_{KA} = r_T T_A/r_K K_A$ and similar for manufacturing. Then, we can write

$$\frac{\theta_{TA}/\theta_{KA}}{\theta_{TM}/\theta_{KM}} = \frac{r_T T_A/r_K K_A}{r_T T_M/r_K K_M} = \frac{T_A/K_A}{T_M/K_M}$$

Note that the assumption that agriculture is land-intensive ($\theta_{TA} > \theta_{TM}$) implies that manufacturing is capital intensive ($\theta_{KA} = 1 - \theta_{TA} < 1 - \theta_{TM} = \theta_{KM}$). Then, $\theta_{TA}/\theta_{KA} > \theta_{TM}/\theta_{KM}$ and thus capital per unit of land is higher in manufacturing than in agriculture: $K_M/T_M > K_A/T_A$. Finally, taking the ratio of the factor market clearing conditions (6) and (7) we can show that, in equilibrium, the aggregate relative demand for capital is a weighted average between the relative demand in agriculture and the relative demand in manufacturing:

$$\frac{K_A}{T_A} (1 - \lambda_{TM}) + \frac{K_M}{T_M} \lambda_{TM} = \frac{K}{T},$$

which implies that $K_M/T_M > K/T > K_A/T_A$. Note that the first part of this inequality implies that $K_M/K > T_M/T$, i.e. $\lambda_{KM} > \lambda_{TM}$. Then, if manufacturing is capital-intensive the share of capital employed in manufacturing is smaller than the share of land employed in manufacturing.

We solve for changes in factor intensities by using the cost minimization conditions, which imply:

$$\theta_{KA} a_{\hat{K}A} + \theta_{TA} a_{\hat{T}A} = 0 \quad (30)$$

$$\theta_{KM} a_{\hat{K}M} + \theta_{TM} a_{\hat{T}M} = 0. \quad (31)$$

Elasticities of substitution across factors in each sector can be defined as:

$$\sigma_A = -\frac{a_{\hat{K}A} - a_{\hat{T}A}}{r_{\hat{K}} - r_{\hat{T}}} \quad (32)$$

$$\sigma_M = -\frac{a_{\hat{K}M} - a_{\hat{T}M}}{r_{\hat{K}} - r_{\hat{T}}} \quad (33)$$

Using equations (12) to (15) we can find the following solutions for $a_{\hat{j}i}$:

$$a_{\hat{K}i} = -\theta_{Ti} \sigma_i (r_{\hat{K}} - r_{\hat{T}}); \quad i = A, M.$$

$$a_{Ti} = \theta_{Ki} \sigma_i (r_K - r_T). \quad i = A, M.$$

These solutions for $\hat{a}_{ji}$ can be substituted in equations (10) and (11) to obtain:

$$(1 - \lambda_{KM}) \hat{\hat{X}}_A + \lambda_{KM} \hat{X}_M = \hat{K} + \delta_K (r_K - r_T) \quad (34)$$

$$(1 - \lambda_{TM}) \hat{\hat{X}}_A + \lambda_{TM} \hat{X}_M = \hat{T} - \delta_T (r_K - r_T) \quad (35)$$

where

$$\delta_K = \lambda_{KM} \theta_{TM} \sigma_M + \lambda_{KA} \theta_{TA} \sigma_A$$

$$\delta_T = \lambda_{TM} \theta_{KM} \sigma_M + \lambda_{TA} \theta_{KA} \sigma_A.$$

Next, to obtain relative outputs, subtract (17) from (16) to get:

$$\hat{X}_M - \hat{\hat{X}}_A = \frac{1}{\lambda_{KM} - \lambda_{TM}} (\hat{K} - \hat{T}) + \frac{(\delta_K + \delta_T)}{\lambda_{KM} - \lambda_{TM}} (r_K - r_T). \quad (36)$$

Finally, let's substitute changes in factor prices by changes in commodity prices or technology, using the zero profit condition to obtain:

$$\hat{X}_M - \hat{\hat{X}}_A = \frac{1}{\lambda_{KM} - \lambda_{TM}} (\hat{K} - \hat{T}) + \sigma_s (\hat{p}_M - \hat{p}_A - \hat{A}), \quad (37)$$

where

$$\sigma_s = \frac{(\delta_K + \delta_T)}{\lambda_{KM} - \lambda_{TM}} \frac{1}{\theta_{KM} - \theta_{KA}};$$

σ_s represents the supply elasticity of substitution between commodities, that is, the percent change in the relative supply of manufacturing goods for a given change in the relative price of manufacturing.

The first term in the r.h.s. of equation (19) represents the capital supply effect of agricultural technical change while the second term represents the capital demand effect. The first effect takes place when agricultural technical change increases savings and the supply of capital. In this case $\hat{K} > 0 = \hat{T}$ and $\lambda_{KM} > \lambda_{TM}$, then $\hat{X}_M > \hat{K} > 0 > \hat{\hat{X}}_A$. This is an application of the Rybczinsky theorem which states that an increase in the supply of capital increases the supply of manufacturing, the capital-intensive sector. This is because, given factor prices, the only way to equilibrate factor markets is to assign the new capital (and some additional capital and land) to the capital-intensive sector. The second term represents the capital demand effect, which 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. Because the capital supply and demand effects work in opposite directions, to understand the effects of agricultural productivity growth on manufacturing output we need to solve for effect of technical change on the supply of capital, which we do next.

A.C.3 The Supply of Capital

Steady State In this section, we obtain the effects of agricultural technical change on the supply of capital. For this purpose, we compare the benchmark economy which is

on a steady state with constant consumption to the economy where there is agricultural technical change. Let's start by describing the steady state equilibrium. If this equilibrium features constant consumption, then the Euler equation implies that initial steady state parameter values should be such that $\beta[r_K + (1 - \delta)] = 1$. In this case, the capital accumulation condition (2) can be simplified to reflect this parameter restriction and constant factor prices, as follows:

$$K_2 = \frac{1}{1 + \beta} K_1.$$

Note that in this case, the capital stock falls over time because the world ends at the end of period 2. Thus, consumers eat part of the capital stock in each period. Capital behaves as an endowment, part of which is consumed each period to smooth consumption.

Effects of agricultural technical change To obtain the effects of technical change on the supply of capital we start by differentiating the capital accumulation condition (2), under the assumption that depreciation is equal to one:

$$dK_2 = \frac{\beta}{1 + \beta} \left(\frac{dr_{K1}}{r_{K1}} r_{K1} K_1 + \frac{dr_{T,1}}{r_{T,1}} r_{T,1} T \right) - \frac{1}{1 + \beta} \left\{ \frac{dr_{T,2}}{r_{T,2}} - \frac{dr_{K,2}}{r_{K,2}} \right\} \frac{r_{T,2}}{r_{K,2}} T.$$

Next, from equations (8) and (9) we can obtain that the time path of factor price changes satisfies: $\hat{r}_{j,2} = \hat{r}_{j,1}(1 - \gamma_2)$ for $j = T, K$ and substitute in the equation above, which yields:

$$dK_2 = \frac{\beta}{1 + \beta} \left(\frac{dr_{K1}}{r_{K1}} r_{K1} K_1 + \frac{dr_{T,1}}{r_{T,1}} r_{T,1} T \right) - \frac{\beta}{1 + \beta} (1 - \gamma_2) \left\{ \frac{dr_{T,1}}{r_{T,1}} - \frac{dr_{K1}}{r_{K1}} \right\} \frac{r_{T,2}}{\beta r_{K,2}} T.$$

Next, we evaluate at the steady state where: $\beta r_{K,2} = \beta r_{K,1} = 1$ and $r_{T,1} = r_{T,2}$, thus $\theta_{TM,1} = \theta_{TM,2} = \theta_{TM}$ to obtain:

$$dK_2 = \frac{\beta}{1 + \beta} \frac{dr_{T,1}}{r_{T,1}} r_{T,1} T \gamma_2 + \frac{\beta}{1 + \beta} \frac{dr_{K1}}{r_{K1}} (r_{K1} K_1 + (1 - \gamma_2) r_{T,1} T).$$

Note that if $\gamma_2 > 0$, the first term is positive. In this case, agricultural technical change increases land rents in period 1 more than in period 2. Thus, the increase in period 1 income is partly temporary, which increases savings and the capital stock in period 2, relative to the steady state. The second term, instead, is negative as it represents the effect of the reduction in the rental price of capital due to agricultural technical change. This reduces first period income and the discount rate, which generates an increase in the present value of second period land income. Thus, the reduction in the rental rate of capital reallocates income towards the second period, which reduces savings and the capital stock. To understand which effect dominates, we need to substitute for the factor price changes obtained in equation (8) and denote the land income share as $\alpha_T = r_T T / (r_K K + r_T T)$ to obtain, after some algebra:

$$\frac{dK_2}{K_2} = \frac{\hat{A}}{\theta_{TA} - \theta_{TM}} \frac{1}{1 - \alpha_{T,1}} \{ \alpha_{T,1} \gamma_2 - \theta_{TM} \}. \quad (38)$$

Then, $\hat{K}_2 > 0$ if $\alpha_T \gamma_2 > \theta_{TM}$. When the productivity shock is purely transitory ($\gamma_2 = 1$), the condition for the capital supply to increase is that the land share in the aggregate economy is larger than the land share in manufacturing. This condition always holds if agriculture is land-intensive. To see this, note that the land share can be written as $\alpha_T = \theta_{TA} \phi_A + \theta_{TM} (1 - \phi_A)$ where ϕ_A is the income share of the agricultural sector.⁸⁶

The interpretation of this condition is that the positive temporary income shock due to land rents increasing is larger the higher is the land share of aggregate income, while the negative temporary income shock due to the reduction in the return to capital is proportional to the land share in manufacturing. If the shock is to some extent temporary, $\gamma_2 \in (0, 1)$, the condition is more likely to hold if the difference in land-intensity between sectors is high, the income share of agriculture is high, and the shock is not too temporary. Finally, if the shock is permanent ($\gamma_2 = 0$) the condition never holds.

A.C.4 Capital supply and capital demand effects

The final step is to substitute the solution for $\hat{K}_2$ given by (20) into equation (19) to evaluate the relative strenghts of the capital supply vs capital demand effects, to obtain:

$$\hat{X}_M - \hat{X}_A = \frac{1}{\lambda_{KM} - \lambda_{TM}} \frac{\hat{A}}{\theta_{KM} - \theta_{KA}} \left\{ \frac{1}{1 - \alpha_{T,1}} \{ \alpha_{T,1} \gamma_2 - \theta_{TM} \} - (\delta_K + \delta_T) (1 - \gamma_2) \right\} \quad (39)$$

Because manufacturing is capital intensive $\lambda_{KM} > \lambda_{TM}$ and $\theta_{KM} > \theta_{KA}$. Thus, manufacturing output expands if the term in brackets is positive:

$$\frac{1}{1 - \alpha_{T,1}} \{ \alpha_{T,1} \gamma_2 - \theta_{TM} \} - (\delta_K + \delta_T) (1 - \gamma_2) > 0$$

The first term in the expression above reflects the capital supply effect: an increase in the supply of capital increases manufacturing output (Rybczinsky effect). This effect is strongest the larger the aggregate land share (α_T) relative to the land share in manufacturing (θ_{TM}). Because the difference in land share between manufacturing and agriculture is high and agriculture is large sector in Brazil, we expect this term to be large in our context. The second term is the capital demand effect: as agriculture becomes more productive land rents grow and the rental rate of capital falls. As a result, both sectors use less land and more capital. Thus, the capital intensive sector must contract. The strength of this effect is governed by δ_K and δ_T . The first is the aggregate percent increase in capital input demand associated with a one percent reduction in r_K/r_T resulting from adjustment to more capital-intensive techniques in both sectors, and the second is the aggregate percent reduction in land input demand associated with a one percent reduction in r_K/r_T resulting from adjustment to less land-intensive techniques in both sectors. These terms are larger the larger is the elasticity of substitution across factors in agricultural and manufacturing production (σ_M and σ_A). Because land and capital play very different roles both in agricultural and manufacturing production, we expect

⁸⁶This is because

$$\begin{aligned} \alpha_T &= \frac{r_T T}{r_K K + r_T T} = \frac{r_T a_{TA} p_A X_A}{c_A [r_K K + r_T T]} + \frac{r_{T,1} a_{TM} p_M X_M}{c_M [r_K K + r_T T]} = \theta_{TA} \frac{p_A X_A}{[r_K K + r_T T]} + \theta_{TM} \frac{p_M X_M}{[r_K K + r_T T]} \\ &= \theta_{TA} \frac{r_K K_A + r_T T_A}{[r_K K + r_T T]} + \theta_{TM} \frac{r_K K_M + r_T T_M}{[r_K K + r_T T]} = \theta_{TA} \phi_A + \theta_{TM} (1 - \phi_A). \end{aligned}$$

these elasticities to be quite low. Thus, the supply effect is likely to dominate the demand effect. Still, this is an empirical question that we answer in the following section. Finally, note that the income shock is more temporary the closer is γ_2 to one. A more temporary income shock reinforces the capital supply effect due to stronger savings and reduces the capital demand effect due to lower profitability of producing agricultural goods in the second period.

A.D CAPITAL FLOWS

We can use the model developed above to think about the consequences of financial integration across regions. To simplify the exposition, suppose that the country has two regions, Origin (o) and Destination (d), which are open to international trade. The model above can be used to analyze the effects of agricultural technical change in the interior 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.

A.D.1 *Financial Autarky*

We start by considering that the interior region is open to international trade but in financial autarky. In this case, the benchmark equilibrium is described in section 1.2. and the effects of agricultural technical change in the origin region are described in section 1.3. In particular, note that larger agricultural productivity implies that the economy can continue producing both goods at zero profits only if land rents increase and the rental price of capital falls. Under the parameter restriction discussed in Result 3, the supply of capital increases and the capital-intensive sector, manufacturing, expands. In turn, what are the effects of agricultural technical change in the origin on the destination region? First, note that because the origin region is a small open economy, agricultural technical change in this region does not affect world prices. Thus, the destination region is not affected by technical change in the origin region.

A.D.2 *Financial Integration*

Next, we consider the case where the origin region is open to international trade and capital flows. In this case, we make the additional assumption that in the benchmark steady state equilibrium, all countries share the same technology and thus trade in goods leads to factor price equalization at r_K^* and r_T^* . In addition, we assume that there is a small cost ε for capital movements across countries, thus the equality in the rental rate of capital implies that capital flows are zero in the benchmark equilibrium. This assumption implies that the benchmark steady state equilibrium is the same under autarky and financial integration, which simplifies the analysis of the effects of technical change in the integrated equilibrium.

Origin region When the origin region faces agricultural technical change the return to land increases, as in the financial autarky equilibrium. However, the rental price of capital is constant at r_K^* which is larger than the financial autarky equilibrium level r_K^a .⁸⁷ However, r_K^a is the only rental rate consistent with positive production in both sectors

⁸⁷More precisely, the rental price of capital is $r_K^* - \varepsilon$ but as ε is small we will just write r_K^* in what follows.

at zero profits under the new technology, given international goods prices. As a result, in the financial integration equilibrium (i) the interior fully specializes in agriculture and factor prices are given by $r_K^*/(r_T)_o^i$, where $(r_T)_o^i$ solves the zero profit condition in the agricultural sector under the new technology:

$$p_A = \frac{1}{A_o(1 - \gamma_t)} c_A \left((r_{T,t})_o^i, r_K^* \right).$$

Note that because the rental rate of capital does not fall, land rents must increase less than in the financial autarky equilibrium. To see this, differentiate the zero profit condition above to obtain:

$$(r_{\hat{T},t})_o^i = \frac{(1 - \gamma_t)}{\theta_{TA}} \hat{A}_o. \quad (40)$$

Then, by comparing equation (22) and equation (8) we obtain that $(r_{\hat{T},1})^a > (r_{\hat{T},1})_o^i$ iff $\theta_{TM} > \theta_{TA}\theta_{TM}$ which is true because $\theta_{TA} \in (0, 1)$. At the same time, because the increase in land-rents is partly temporary, and there is no change in the interest rate, we can show that the relative supply of capital increases. In addition, it increases more than in the autarky equilibrium. To see this evaluate the capital accumulation condition (2) at the financial integration equilibrium values of the rental rate of capital ($r_{K,1} = r_{K,2} = r_K^* = 1/\beta$) to obtain:

$$K_2^s = \frac{1}{1 + \beta} K_1^s + \frac{\beta}{1 + \beta} [r_{T,1} - r_{T,2}] T. \quad (41)$$

where K_t^s denotes capital supply at period t . Now, differentiate this condition with respect to land rents which are the only r.h.s. variables which change in response to agricultural technical change in the financial integration equilibrium:

$$dK_2^s = \frac{\beta}{1 + \beta} [dr_{T,1} - dr_{T,2}] T. \quad (42)$$

Next, substitute for the benchmark steady state equilibrium values of the capital stock $K_2 = (1/1 + \beta)K_1$ and factor prices $r_{T,1} = r_{T,2}$, $r_{K,1} = r_K^* = 1/\beta$, and rearrange to get:

$$\frac{dK_2^s}{K_2^s} = \left[\frac{dr_{T,1}}{r_{T,1}} - \frac{dr_{T,2}}{r_{T,2}} \right] \frac{r_{T,1}T}{r_{K,1}K_1}. \quad (43)$$

Finally, use equation (22) to substitute for the change in land prices with respect to the benchmark steady state equilibrium in response to technical change to obtain:

$$\left(\hat{K}_2^s \right)_o^i = \frac{\gamma_2}{\theta_{TA}} \frac{\alpha_{T,1}}{1 - \alpha_{T,1}} \hat{A}_o. \quad (44)$$

We can compare $\left(\hat{K}_2^s \right)_o^i$ with the change in the capital stock in the autarky equilibrium $\left(\hat{K}_2 \right)^a$ obtained in equation (20). The growth in capital supply is larger in the integrated equilibrium when

$$\frac{\gamma_2}{\theta_{TA}} > \frac{\gamma_2 - \frac{\theta_{TM}}{\alpha_{T,1}}}{\theta_{TA} - \theta_{TM}}$$

which requires $\frac{\theta_{TA}}{\alpha_{T,1}} > \gamma_2$ which is always true as $\frac{\theta_{TA}}{\alpha_{T,1}} > 1 > \gamma_2$ because $\alpha_{T,1}$ is a weighted average between θ_{TA} and θ_{TM} thus lower than $\theta_{TA} > \theta_{TM}$. Then, in the integrated equilibrium the growth in capital supply is larger than in the autarky equilibrium. This occurs despite the fact that the positive temporary income shock due to land rents increasing is smaller than in autarky. This is because in autarky the reduction in the return to capital had a negative effect in capital accumulation which is absent in the integrated equilibrium.

Next, we need to compare the growth in capital demand to the autarky equilibrium. Note that the return to capital is larger in the integrated equilibrium while land rents are lower, as shown just above. Because $(r_k/r_T)_o^a < (r_k/r_T)_o^i$, capital intensity in agriculture is lower in the integrated equilibrium than in autarky. Then, capital demand is lower in the integrated equilibrium than in the autarky equilibrium because $\left(\frac{K^d}{T}\right)_o^i = \left(\frac{K_A}{T_A}\right)_o^i < \left(\frac{K_A}{T_A}\right)_o^a < \left(\frac{K^d}{T}\right)_o^a = \left(\frac{\bar{K}}{T}\right)_o^a$, where the last inequality follows from the factor market clearing condition in autarky, when both sectors produce both goods and agriculture is land-intensive. Then, capital demand is lower in the integrated equilibrium than in autarky. Then in the integrated equilibrium the growth in capital supply is larger than in autarky and the growth in capital demand is lower, thus there must be capital outflows.

Finally, we obtain the change in capital demand with respect to the benchmark equilibrium. For this purpose, we make the simplifying assumption that the capital endowment in the benchmark equilibrium is such that the origin economy is fully specialized in agriculture. This case is depicted in figure 2.b where the relative factor supply in the benchmark equilibrium $\left(\frac{\bar{K}}{T}\right)_o^i$ intersects the relative factor demand in the agricultural sector at the international factor prices $(r_k/r_T)^*$. We make this assumption to guarantee that the origin economy is fully specialized in agriculture both in the benchmark equilibrium and when there is technical change. Otherwise, we would need to compare the full specialization equilibrium with one where the economy produces both goods and capital demand would not change continuously.

To obtain the change in capital demand, note that equilibrium capital intensity in agriculture is given by:

$$\frac{K_A}{T_A} = \frac{a_{KA}(r_T, r_K)}{a_{TA}(r_T, r_K)}.$$

Then, in an equilibrium with full specialization in agriculture capital demand is given by:

$$K^d = \frac{a_{KA}(r_T, r_K)}{a_{TA}(r_T, r_K)} \bar{T}.$$

where we used the factor market clearing condition in the land market. Log-differentiating, we obtain:

$$\hat{K}^d = \hat{a}_{KA} - \hat{a}_{TA} = \theta_{TA}\sigma_A(\hat{r}_T) + \theta_{KA}\sigma_A(\hat{r}_T) = \sigma_A(\hat{r}_T),$$

where the second equality uses the cost minimization conditions (12) to (15). Finally, we substitute for the change in land prices and get the equilibrium change in capital demand:

$$\left(\hat{K}^d\right)_o^i = \frac{(1 - \gamma_2)}{\theta_{TA}} \sigma_A \hat{A}_o.$$

As we have shown above, growth in capital demand is smaller in the integrated equilibrium than in autarky. At the same time, the growth in capital supply is larger. Thus, there are capital outflows. Here we also show that capital outflows are increasing in agricultural productivity growth:

$$\left(\hat{K}^s\right)_o^i - \left(\hat{K}^d\right)_o^i = \left[\frac{\alpha_{T,1}}{1 - \alpha_{T,1}} \gamma_2 - \sigma_A (1 - \gamma_2) \right] \frac{\hat{A}_o}{\theta_{TA}}. \quad (45)$$

Thus, capital outflows are increasing in $\hat{A}$ if

$$\frac{\alpha_{T,1}}{1 - \alpha_{T,1}} \frac{\gamma_2}{(1 - \gamma_2)} > \sigma_A,$$

that is, the land income share is large, the shock is temporary, and the elasticity of substitution between land and capital in agricultural production is low.

Destination Region Finally, we consider a destination region which is open to international trade but does not experience technical change. First, note that because the origin region is a small economy, it does not affect international goods prices nor the international rental price of capital. As a result, if the destination region was in financial autarky or open to international capital flows, technical change in the origin would not have any effect on the destination region. Then, we consider the more interesting case in which the two regions are financially integrated but in financial autarky with respect to the rest of the world. The equilibrium in the destination region is depicted in Figure III. First, note that because the destination region did not experience technical change, factor prices stay at the level $(r_k/r_T)^*$ given by initial technology and international goods prices. As a result, the equilibrium in the origin region is the same as if it was integrated in international capital markets, depicted in Figure II. This is because capital leaving the origin region can flow in 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 this destination region faces a pure Rybczinsky effect with no changes in technology. To see this, log-differentiate the factor market clearing conditions (6) and (7) in the destination region to find that the expansion in manufacturing output in the destination region is proportional to the growth in capital supply:

$$\left(\hat{X}_M - \hat{X}_A\right)_d^i = \frac{1}{\lambda_{KM} - \lambda_{TM}} \left(\hat{K}^s\right)_d^i, \quad (46)$$

where hats denote percent changes of the variables of interest in the destination region in the integrated equilibrium with respect to the benchmark equilibrium where no region faces technical change. Then, because all the increase in capital supply in the destination region comes from capital outflows in the origin region ($\Delta K_d^s = \Delta K_o^s - \Delta K_o^d$) the growth in capital supply in the destination region in the integrated equilibrium is

$$\left(\hat{K}\right)_d^i = \omega_{od} \left(\hat{K}_o^s - \hat{K}_o^d\right)_o^i \quad (47)$$

where $\omega_{od} = K_o/K_d$ is the ratio of capital stocks in the benchmark equilibrium. Thus,

$$\left(\hat{X}_M - \hat{X}_A\right)_d^i = \frac{1}{\lambda_{KM} - \lambda_{TM}} \omega_{od} \left(\hat{K}_o^s - \hat{K}_o^d\right)_o^i, \quad (48)$$

Finally, the change in the share of capital allocated to manufacturing is $\hat{\lambda}_{KM} = \hat{X}_M - \hat{K}$ which yields

$$\left(\hat{\lambda}_{KM}\right)_d^i = \frac{1 - (\lambda_{KM} - \lambda_{TM})}{\lambda_{KM} - \lambda_{TM}} \left(\hat{K}\right)_d^i. \quad (49)$$

B EMPIRICS: DERIVATIONS

This Appendix presents the derivations to obtain the estimates of bank exposure and municipality exposure to the GE soy driven deposit increase presented in equations (13) and (14) respectively in the paper.

B.A FROM MODEL TO DATA

In the model, there are only two regions which are financially integrated with each other and in autarky with respect to the rest of the world. In this case, agricultural technical change generates capital outflows from the origin to the destination region equal to the difference between the growth in capital supply and capital demand in the origin region [see equation (8)]. Recall that these capital inflows do not generate changes in the return to capital in the destination region because free trade in goods implies that factor prices are pinned down by international goods prices. Note that the return to capital being constant in the destination region implies that it is also constant in the origin region due to financial integration. Thus, our empirical analysis will focus on tracking capital flows across regions taking interest rates as given. In the data there are several regions and we can only track capital flows which are intermediated through banks. Thus, we adapt the model's prediction to our context by introducing banks and many regions.

We think of banks as intermediaries that can reallocate savings from depositors to firms. The role of banks as intermediaries 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 for micro-foundations of the role of banks here. 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.

B.A.1 Savings and deposits in origin municipalities

First, we assume that local savings are deposited in local banks. Second, we assume that each bank has a constant market share in each local deposit market (ψ_{bo}). Thus, we can write $deposits_{bo} = \psi_{bo} K_o^s$. This implies that savings deposits in each local bank branch grow at the same rate as local aggregate savings. Thus by using equation (6) we obtain:

$$\hat{deposits}_{bo} = \left(\hat{K}^s \right)_o^i = \phi_{To} \hat{A}_o. \quad (50)$$

where $deposits_{bo}$ are local deposits of bank b in origin municipality o and $\phi_{To} = \left[\frac{\gamma_2}{\theta_{TA}} \frac{\alpha_{T,1}}{1-\alpha_{T,1}} \right]$ is increasing in the land income share at the origin municipality $\alpha_{T,1}$ as all remaining variables are identical for all municipalities due to factor price equalization in the benchmark equilibrium. Next, we would like to obtain an expression for the increase in national deposits of each bank due to technical change in soy. For this purpose, first note that, for each bank b , national deposits can be obtained by aggregating deposits collected in all municipalities where the bank has branches:

$$Deposits_b = \sum_{o \in O_b} deposits_{bo} \quad (51)$$

where $Deposits_b$ are national deposits of bank b , $deposits_{bo}$ are local deposits of bank b in *origin* municipality o , and O_b is the set of all origin municipalities where bank b has branches. Thus, the growth rate of national deposits for a bank in the integrated equilibrium is given by a weighted average of the growth rate of deposits in each municipality where the bank has branches:

$$\hat{Deposits}_b = \sum_{o \in O_b} \omega_{bo} \hat{deposits}_{bo}$$

where the weights $\omega_{bo} = \frac{deposits_{bo}}{Deposits_b}$ capture the share of deposits of bank b coming from *origin* municipality o in the benchmark equilibrium. This weight is a function of both the level of capital supply in each municipality (K_o^s) and the market share of each bank (ψ_{bo}). Then, we can substitute for equation (50) to obtain:

$$\hat{Deposits}_b = \sum_{o \in O_b} \omega_{bo} \phi_{To} \hat{A}_o. \quad (52)$$

The expression above indicates that the growth in national deposits for each bank is a weighted average of the growth in agricultural productivity in each of the municipalities where the bank has branches.

B.A.2 Capital outflows and loans in destination municipalities

In the model, agricultural technical change generates savings which exceed capital demand. As a result, there are capital outflows from the origin municipality – where technology improved – towards the destination municipality – where technology did not change. We assume that banks intermediate these flows. First, they aggregate the excess supply of savings from all the origin municipalities where they have branches. Second, they assign this additional capital across destination municipalities where they have branches.⁸⁸ Recall that capital inflows do not generate changes in the return to capital in the destination region 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, we assume that banks are indifferent between allocating capital across any destination municipality because these will absorb capital by expanding manufacturing output at a

⁸⁸In principle, banks can invest their deposits in different ways, for example they can invest abroad, lend to other financial institutions or directly to firms. In our model we assume that there is perfect financial integration across regions within a country but no financial integration with the rest of the world. This is because if there was perfect financial integration with the world, capital outflows from origin municipalities would have no effect on capital supply in destination municipalities. Similarly, if banks could lend to other financial institutions, all regions within the country would be equally financially integrated and we would not be able to identify the effect of agricultural technical change on capital supply by using differences in financial integration across regions. This implies that to extend the model to the case of many banks and many regions, we need to assume that banks can only reallocate savings to municipalities where they have branches. Note that if some deposits were lent in the interbank market and ended up reallocated in other municipalities, we would underestimate the effect of agricultural productivity growth on structural transformation when we compare destination municipalities connected to the soy area to those who are not connected.

constant interest rate. Thus, we assume that banks increase loans in all destination markets proportionally. This implies that the growth rate of loans in each destination market is proportional to the growth rate of national loans by a given bank:

$$\hat{loan}s_{bd} = \hat{Loan}s_b = \sum_{o \in O_b} \omega_{bo} \varphi_{To} \hat{A}_o. \quad (53)$$

where we used equation (45) to substitute for the excess capital supply in each origin municipality and $\varphi_{To} = \frac{1}{\theta_{TA}} \left[\frac{\alpha_{T,1}}{1-\alpha_{T,1}} \gamma_2 - \sigma_A (1 - \gamma_2) \right]$, thus it is increasing in the land share in municipality o , as all remaining variables are constant across municipalities due to factor price equalization.

Finally, we need to obtain aggregate loans in a given destination municipality. We start by noting that loans in destination d can be written as the sum of loans from all banks present in that destination market:

$$Loans_d = \sum_{b \in B_d} loans_{bd}$$

where B_d is the set of banks with branches in destination d .

Thus, the growth rate of bank loans in destination d can be written as:

$$\hat{Loan}s_d = \sum_{b \in B_d} \omega_{bd} \hat{loan}s_{bd}$$

where $\omega_{bd} = \frac{loans_{bd}}{loans_d}$ is the loan market share of each bank b in destination d . Finally, we substitute for $\hat{loan}s_{bd}$ by using equation (53) to obtain:

$$\hat{Loan}s_d = \sum_{b \in B_d} \omega_{bd} \sum_{o \in O_b} \omega_{bo} \varphi_{To} \hat{A}_o. \quad (54)$$

The equation above implies that the growth of credit in each destination municipality is a weighted average of the growth rate of loans in each bank present in that destination, which in turn is a weighted average of agricultural productivity growth in each origin municipality where the bank has branches.

B.A.3 Loans to firms in destination municipalities

Finally, our empirical work traces capital flows towards firms in destination municipalities. The purpose of this exercise is to isolate the channel through which agricultural productivity growth generates structural transformation in our model, the capital supply channel, from other channels which could generate an increase in capital demand in the industrial sector in destination municipalities like larger demand for goods from richer farmers or labor supply from former agricultural workers. For this purpose, we assume that banks can only lend to connected firms in destination municipalities. This type of relationship lending has been justified in the literature based on asymmetric information.⁸⁹

⁸⁹A large body of theoretical work has shown that, in the presence of asymmetric information, borrowers and lenders form relationships which tend to be persistent over time. See, among others, Williamson (1987), Sharpe (1990), Holmstrom and Tirole (1997). Several empirical papers have tested the persistence of bank-firm relationships and used the fact that firms cannot easily switch lenders as an identification device to trace the impact of bank shocks on firm-level outcomes. See, among others: Khwaja and Mian (2008), Chodorow-Reich (2014), Cong et al. (2019).

We do not intend to micro-found these constraints but we will just assume that each banks can only lend to a subset of firms already connected to it. Note that in our model, this type of credit constraints does not affect the equilibrium. This is because production functions are neoclassical and there is free entry into both industries. As a result, the size of firms is indeterminate in this model. At the equilibrium interest rate any firm size distribution is compatible with the equilibrium. Also, savers are indifferent between putting their capital in a bank or starting their own firm. Then, we can assume that some capital owners start their own firm and they might also borrow from a bank if they are connected. In this setup, banks receiving deposits are indifferent between lending to any connected firm in a destination municipality. Thus, we assume that they increase the loans to all connected firms proportionally, which according to equation (54) implies that the growth rate of loans in a firm i connected to a bank b is the following:

$$\text{loan}\hat{s}_{ibd} = \text{loan}\hat{s}_{bd} = \text{Loan}\hat{s}_b = \sum_{o \in O_b} \omega_{bo} \varphi_{To} \hat{A}_o. \quad (55)$$

B.B EMPIRICAL SPECIFICATION

B.B.1 Bank Exposure

Equation (52) describes the growth rate of deposits in the integrated equilibrium with respect to the benchmark equilibrium. When we take this equation to the data, we assume that the period before the legalization of GE soy is the benchmark equilibrium ($t = \tau$), while the period afterwards is the new equilibrium with technical change. Then, a first order approximation to the (log) level of bank deposits can be written as:

$$\log \text{Deposits}_{b,t} \approx \log \text{Deposits}_{b,\tau} + \sum_{o \in O_b} \omega_{bo} \phi_{To} (\log A_{o,t} - \log A_{o,\tau}) \quad (56)$$

where $\log \text{Deposits}_{b,t}$ is the national level of deposits of bank b at any given point in time t , which we approximate with its initial level at $t = \tau$ plus the weighted sum of changes in deposits in each of the branches of bank b between τ and t .

To estimate equation (56) we need to find measures of each of its components. First, we measure total factor productivity in agriculture (A) with the FAO potential yields per hectare of soy. Note that this measure has the advantage of being exogenous as it refers to potential, not realized yields. In addition, it measures agricultural productivity for only one crop, while the model refers to overall productivity. As a result, if ς is the elasticity of realized agricultural productivity to potential soy yields, we can replace: $\log A_{o,t}$ by $\varsigma \log A_{o,t}^{\text{soy}} + \varepsilon_{o,t}$ where $\varepsilon_{o,t}$ is a classical measurement error term. Second, we need to measure ϕ_{To} which has only one component varying at the municipality level, namely $\alpha_{T,o}$, which is the land income share.⁹⁰ We do not have information on income shares at the municipality level, thus we proxy for the land income share ($\alpha_{T,o}$) with the share of land employed by the agricultural sector.⁹¹ Finally, note that in the data, there are other

⁹⁰The rest of its components are the parameter γ , which measures the propensity of landowners to save from the agricultural productivity shock and θ_{TA} , the land income share in agriculture, which in the model is common across municipalities due to factor price equalization in the benchmark equilibrium.

⁹¹In our empirical analysis we need to find a proxy for $\alpha_{T,o}$ because we do not have information on income shares at the municipality level. Note $\alpha_{T,o} = \theta_{TA} \phi_{Ao} + \theta_{TM} (1 - \phi_{Ao})$ where ϕ_{Ao} is the income share of the agricultural sector. Note that $\alpha_{T,o}$ can be proxied by ϕ_{Ao} in the case where the land share in manufacturing costs is small ($\theta_{TM} \simeq 0$) and the land share in agricultural costs is large ($\theta_{TA} \simeq 1$). In

reasons why bank deposits might grow, thus we add an error term which captures other sources of deposit growth across banks and classical measurement errors. We also include time and bank fixed effects, to obtain:

$$\log Deposits_{bt} = \gamma_b + \gamma_t + \beta \underbrace{\left[\sum_{o \in O_b} w_{bo} \left(\frac{T_o^a}{T_o} \right) (\log A_{o,t}^{soy}) \right]}_{BankExposure_{bt}} + \eta_{bt} \quad (57)$$

where:

$$\gamma_b = \log deposits_{b,\tau} - \beta \sum_{o \in O_b} w_{bo} \left(\frac{T_o^a}{T_o} \right) (\log A_{o,\tau}^{soy}).$$

Notice that the parameter β does not have a structural interpretation in terms of the parameters of the model. This is because it includes, in addition to parameters capturing the propensity to save and the land agricultural income share, parameters capturing differences between the variables in the model and their empirical counterparts.

Equation (57) describes the relationship between actual national deposits of bank b at any point in time and the increase in national deposits of bank b that is predicted by a change in the vector of potential soy yields in all municipalities due to the legalization of GE soy. This equation corresponds to equation (13) in the paper. In the paper we define the summation in brackets inside equation (57) as our measure of bank exposure to the deposit increase driven by soy technical change.

B.B.2 Municipality Exposure

Equation (54) describes the growth of credit in each destination municipality. We derive its empirical counterpart by following the same steps as in the previous section:

$$\log Loans_{dt} = \alpha_d + \alpha_t + \mu \sum_{b \in B_d} w_{bd} \underbrace{\left[\sum_{o \in O_b} w_{bo} \left(\frac{T_o^a}{T_o} \right) (\log A_{o,t}^{soy}) \right]}_{BankExposure_{bt}} + \varepsilon_{dt} \quad (58)$$

where $\frac{\mu}{\beta}$ can be interpreted as the percentage increase in loans at the destination municipalities driven by a one percent increase in savings generated by agricultural technical change in origin municipalities.

B.B.3 Firm Exposure

Equation (55) describes the growth of credit to a given firm i connected to a bank b . We derive its empirical counterpart by following the same steps as in the previous section:

$$\log loans_{ibdt} = \nu_b + \nu_d + \nu_t + \mu \underbrace{\left[\sum_{o \in O_b} w_{bo} \left(\frac{T_o^a}{T_o} \right) (\log A_{o,t}^{soy}) \right]}_{BankExposure_{bt}} + \varepsilon_{ibdt} \quad (59)$$

.

our empirical analysis we proxy for share of income generated by the agricultural sector (ϕ_{Ao}) with the share of land employed by the agricultural sector (λ_{TAo}).

where $\frac{\mu}{\beta}$ can be interpreted as the percentage increase in loans to firm i driven by a one percent increase in aggregate deposits of bank b generated by agricultural technical change in origin municipalities where bank b has branches.

Finally, to study the effect of credit growth on employment, we derive an empirical specification where the exposure of firm i is equal to the weighted average of exposures of the banks to which firm i is connected:

$$\log L_{idt} = \nu_d + \nu_t + \lambda \sum_{b \in B} \pi_{ib} \underbrace{\left[\sum_{o \in O_b} w_{bo} \left(\frac{T_o^a}{T_o} \right) (\log A_{o,t}^{soy}) \right]}_{BankExposure_{bt}} + \varepsilon_{idt} \quad (60)$$

Where the weights π_{ib} are the share of borrowing of firm i from bank b .

C EMPIRICS: ADDITIONAL RESULTS

C.A STYLIZED FACTS FROM RAW MICRO DATA

In this Appendix, we present some broad stylized facts on credit market participation between 1997 and 2010 that can be uncovered using our database matching the Credit Information System of the Central Bank of Brazil with employer-employee dataset of the Ministry of Labor.

Two caveats are in order for a correct interpretation of the stylized facts presented below. First, given the institutional nature of the two datasets and the characteristics of RAIS, our analysis focuses on formal firms with at least one employee.⁹² Second, the Credit Information system has a reporting threshold above which financial institutions are required to transmit loan information to the Central Bank.⁹³ In the years 1997 to 2000, this threshold was set at 50,000 BRL (around 45,000 USD in 1997). Starting from 2001 and until the end of our dataset in 2010, the threshold was lowered to 5,000 BRL (around 2,200 USD in 2001).

Figure C1 shows the total number of formal firms (gray bars) and the share of formal firms with access to bank credit (blue line) by year in the period between 1997 and 2010. In this Figure, we define access to bank credit as an outstanding credit balance equal or above 50,000 1997 BRL. Our objective in choosing the higher threshold for this exercise is twofold: study credit market participation on the longest time period possible given our data, and capture the share of firms that start getting large loans (rather than, for example, an overdraft on their bank account). As shown, according to this definition, 7 percent of formal Brazilian firms had access to bank credit in 1997. This share increased to 14 percent by 2010, with most of the increase occurring in the second half of the 2000s.

Figure C3 shows how the increase in credit access ratio has been largely heterogeneous across sectors, with manufacturing and services experiencing large increases, while the share of firms with access to bank credit in agriculture has been relatively constant in the period under study.⁹⁴ Finally, in Figure C4, we show the evolution of credit access ratio by firm size category. For this purpose, we use the firm size categories proposed by the Brazilian Institute of Geography and Statistics (IBGE). The IBGE defines micro firms those employing between 1 and 9 workers, small firms those employing between 10 and 49 workers, medium firms those employing between 50 and 99 workers, and large firms those employing 100 or more workers. The vast majority of Brazilian firms registered in RAIS are micro firms (84.1 percent of firms in our data in 1997). For these firms, the 50,000 1997 BRL reporting threshold corresponds to 1.6 times their average wage bill, making the definition of access to bank credit particularly demanding. In the years between 1997 and 2010, however, the share of micro firms with access to bank credit has tripled, going from 3 percent in 1997 to 9 percent in 2010. Small firms, for which the 50,000 1997 BRL reporting threshold corresponds to 25 percent of their average wage bill, also experienced a significant increase in credit access ratio, that went from 18 percent in 1997 to 34 percent

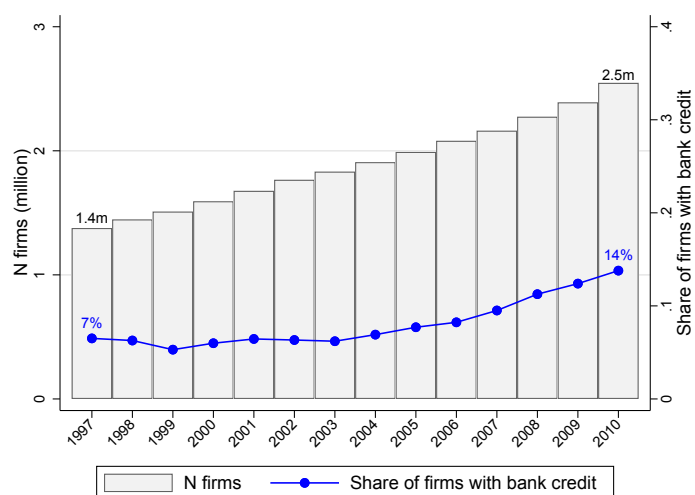
⁹²Self-employed are not required to report information to RAIS.

⁹³To be more precise: the threshold applies to the total outstanding balance of a given client towards a given bank. Whenever the total outstanding balance goes above the threshold set by the Central Bank, the bank is required to transmit information on all credit operations of that client (potentially including loans whose amount is below the threshold).

⁹⁴It should be noted, however, that our data covers only formal firms with at least one employee, and the agricultural sector in Brazil is still characterized by a higher degree of informality and self-employment than the manufacturing and services sectors.

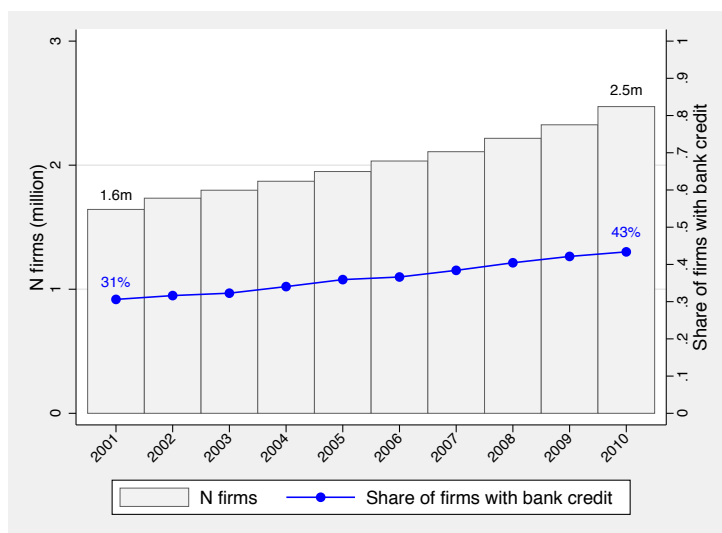
in 2010.

FIGURE C1: SHARE OF FIRMS WITH BANK CREDIT (50,000 BRL THRESHOLD)
BRAZIL: 1997-2010



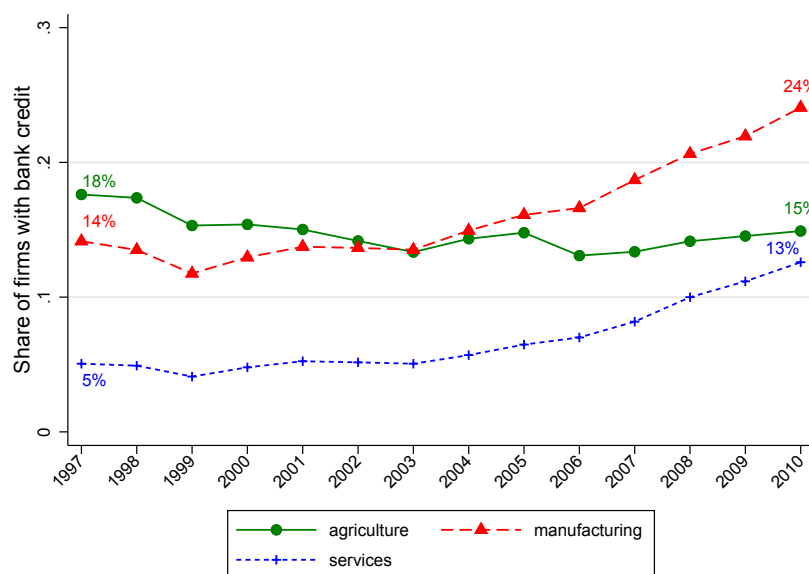
Notes: Sources are the Credit Information System of the Central Bank of Brazil and RAIS. Authors' calculation from micro-data. Access to bank credit is defined as an outstanding credit balance with a financial institution of at least 50,000 1997 BRL.

FIGURE C2: SHARE OF FIRMS WITH BANK CREDIT (5,000 BRL THRESHOLD)
BRAZIL: 2001-2010



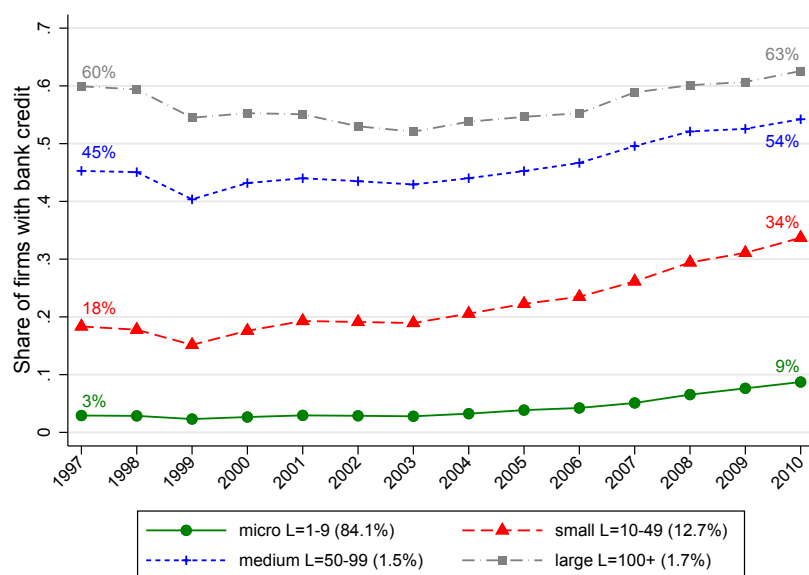
Notes: Sources are the Credit Information System of the Central Bank of Brazil and RAIS, authors' calculation from micro-data. Access to bank credit is defined as an outstanding credit balance with a financial institution of at least 5,000 1997 BRL.

FIGURE C3: SHARE OF FIRMS WITH BANK CREDIT: BY SECTOR
BRAZIL: 1997-2010



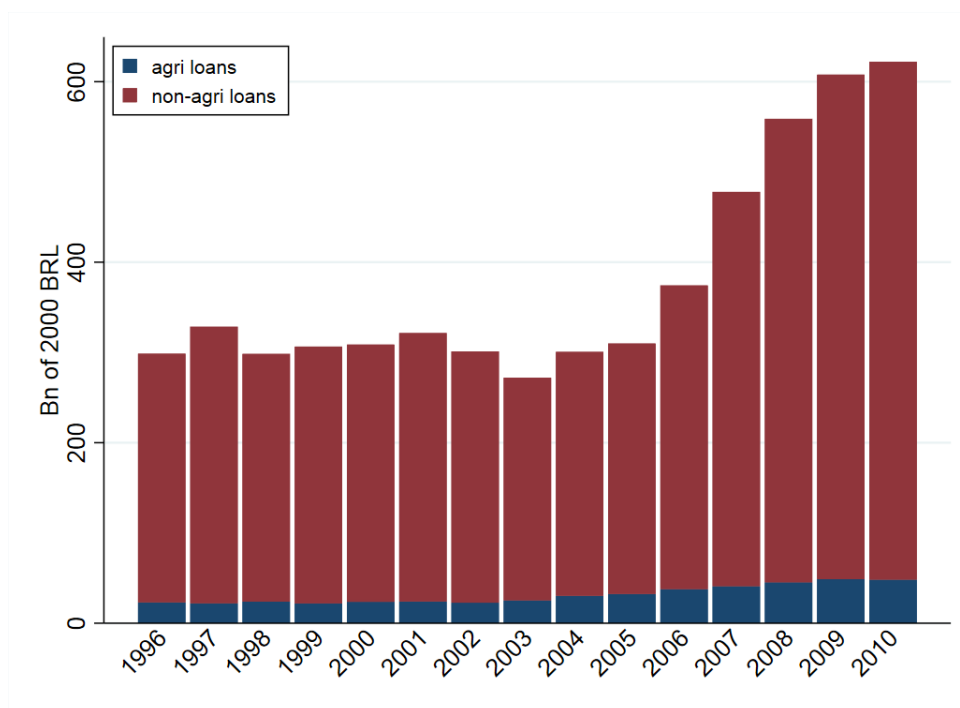
Notes: Sources are the Credit Information System of the Central Bank of Brazil and RAIS, authors' calculation from micro-data. Access to bank credit is defined as an outstanding credit balance with a financial institution of at least 50,000 1997 BRL. Services include: construction, commerce, lodging and restaurants, transport, housing services, domestic workers.

FIGURE C4: SHARE OF FIRMS WITH BANK CREDIT: BY FIRM SIZE
BRAZIL: 1997-2010



Notes: Sources are the Credit Information System of the Central Bank of Brazil and RAIS, authors' calculation from micro-data. Access to bank credit is defined as an outstanding credit balance with a financial institution of at least 50,000 1997 BRL. Numbers in parenthesis are the percentage of firms in each size category in 1997.

FIGURE C5: AGGREGATE TRENDS IN AGRICULTURE VS NON-AGRICULTURE CREDIT
BRAZIL: 1996-2010



Notes: Data sourced from ESTBAN - Central Bank of Brazil.

TABLE C1: SOY TECHNICAL CHANGE AND AGRICULTURAL CENSUS OUTCOMES
ADOPTION OF GE SEEDS AND AGRICULTURAL PRODUCTIVITY

outcome:	$\frac{\text{GE Soy Area}}{\text{Agricultural Area}}$		Δ Agricultural Productivity	
	(1)	(2)	(3)	(4)
$\Delta \log A^{soy}$	0.039*** [0.003]	0.033*** [0.003]	0.119*** [0.028]	0.116*** [0.031]
rural pop _{t=1991}	y	y	y	y
AMC controls _{t=1991}		y		y
Observations	3,020	3,020	3,020	3,020
R-squared	0.082	0.152	0.009	0.011

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 (10):

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

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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time.

TABLE C2: LOCAL EFFECTS OF SOY TECHNICAL CHANGE
EFFECTS BY DEPOSIT TYPE: CHECKING ACCOUNTS, SAVING ACCOUNTS, TERM DEPOSITS

outcome:	log(deposits)	deposit share		
	total (1)	checking accounts (2)	saving accounts (3)	term deposits (4)
$\log A^{soy}$	0.070*** [0.016]	-0.021*** [0.007]	0.018*** [0.006]	0.002 [0.003]
AMC fe	y	y	y	y
year fe	y	y	y	y
rural pop _{t=1991} × year fe	y	y	y	y
AMC controls _{t=1991} × year fe	y	y	y	y
Observations	44,406	44,406	44,406	44,406
R-squared	0.976	0.711	0.682	0.723
N clusters	3145	3145	3145	3145
Average deposit share		27%	59%	14%

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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time.

TABLE C3: SOY TECHNICAL CHANGE, CAPITAL
OUTFLOWS, AND EXPANSION OF LAND
ENDOWMENT

outcomes:	$1(Frontier)$ (1)	$\frac{deposits-loans}{assets}$	
		Frontier (2)	Non-Frontier (3)
$\Delta \log A^{soy}$	0.130*** [0.020]		
$\log A^{soy}$		0.228** [0.115]	0.347*** [0.073]
rural pop _{t=1991}	y	y	y
AMC controls _{t=1991}	y	y	y
Observations	3,020	15,702	28,704
R-squared	0.053	0.679	0.733
N clusters		1114	2031

Notes: The estimate reported in column (1) is obtained using the following specification: $1(Frontier)_j = \alpha + \beta \Delta \log(A_j^{soy}) + \varepsilon_j$ where $\Delta \log(A_j^{soy}) = \log(A_j^{soy,HIGH}) - \log(A_j^{soy,LOW})$. Since the outcome in column (1) is sourced from the Agricultural Censuses of 1996 and 2006, this regression uses the same sample of municipalities used in Table II. The outcome $1(Frontier)$ is an indicator function equal to 1 if a municipality is part of the agricultural frontier. Municipalities that are part of the agricultural frontier are those that, between 1996 and 2006, experienced an increase in agricultural land used for the cultivation of permanent crops, seasonal crops, and cattle ranching. Municipalities that are part of the agricultural non Frontier are those that experienced no increase, or a negative change, in used agricultural land between 1996 and 2006. Robust standard errors reported in brackets in column (1), standard errors clustered at AMC level reported in brackets in columns (2) and (3). 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).

TABLE C4: MAIN REGRESSIONS AT MUNICIPALITY-LEVEL WEIGHTED BY MUNICIPALITY SIZE

weight:	Δ Profits per he (%)		$\frac{\text{deposits}-\text{loans}}{\text{assets}}$		$\frac{\text{non-agricultural loans}}{\text{total loans}}$	
	unweighted	weighted	unweighted	weighted	unweighted	weighted
	(1)	Agricultural Land 1996 (2)	(3)	Bank Assets 1996 (4)	(5)	Total Loans 1996 (6)
$\Delta \log A^{soy}$	0.229*** [0.079]	0.336** [0.158]				
$\log A^{soy}$			0.297*** [0.065]	0.061** [0.025]		
$Municipality Exposure_{dt}$					0.090*** [0.016]	0.111** [0.044]
rural pop _{t=1991}	y	y				
AMC controls _{t=1991}	y	y				
AMC fe			y	y	y	y
year fe			y	y	y	y
rural pop _{t=1991} $\times$ year fe			y	y	y	y
AMC controls _{t=1991} $\times$ year fe			y	y	y	y
Observations	3,020	3,020	44,406	44,406	44,406	44,406
R-squared	0.014	0.011	0.713	0.730	0.843	0.931
N clusters	.	.	3145	3145	3145	3145

Notes: 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).

TABLE C5: MUNICIPALITY EXPOSURE AND ACCESS TO BANK CREDIT
OVERALL, BY REGION AND BY FIRM SIZE CATEGORY

outcome: sample	bank credit access				
	all	non-soy regions	soy regions	non-soy regions	
				micro and small	medium and large
	(1)	(2)	(3)	(4)	(5)
$MunicipalityExposure_{dt}$	0.005 [0.004]	0.012 [0.006]**	-0.003 [0.005]	0.012 [0.006]**	-0.001 [0.025]
AMC fe	y	y	y	y	y
year fe	y	y	y	y	y
rural pop $_{t=1991} \times$ year fe	y	y	y	y	y
AMC controls $_{t=1991} \times$ year fe	y	y	y	y	y
Observations	48,533	25,764	22,769	25,691	24,810
R-squared	0.536	0.476	0.594	0.461	0.554
N clusters	3471	1845	1628	1845	1844

Notes: In this table we study the effect of municipality exposure on credit market participation. The outcome variable is the share of firms with access to bank credit in destination municipality d and year t . We define access to bank credit using the 50,000 1997 R\$ threshold in the Credit Information System. Under this definition, a firm is considered as having access to bank credit if its outstanding loan balance with a bank in a given year is greater or equal to 50,000 1997 BRL. Although the effects are small and not statistically significant when using all municipalities in Brazil, we find that non-soy producing municipalities with larger exposure to the soy boom through the bank network experience larger increase in firm access to bank credit. The magnitude of the estimated coefficient reported in column (2) implies that a municipality with a one standard deviation larger exposure to the soy-driven deposit increase experienced a 0.3 percentage points larger increase in the share of firms with access to bank credit. In columns (4) and (5), we report the results of estimating the same equation in non-soy producing regions when the outcome variable is the share of firms with access to bank credit in different firm size categories: micro and small firms in column 2, medium and large in column 3. Here we find the effect of municipality exposure on access to bank credit is concentrated exclusively in micro and small firms. In unreported results we also studied the effect of municipality exposure on firm entry and exit. We find that more exposed municipalities experienced faster increase in firm entry, although these effects are small in magnitude. These effects are concentrated in non-soy producing regions, while small and not statistically significant in soy producing ones. Finally, we find small and non-significant effects of municipality exposure on firm exit. These results are available from the authors upon request. 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*). AMCs are composed by one or more municipalities and are defined by the Brazilian Statistical Institute (IBGE) as geographical units of observation that can be compared over time.