Online Appendix for:

Capital Accumulation and Structural Transformation

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Abstract

This appendix contains the theoretical model and a set of additional results and robustness checks. It is organized as follows. Section A contains a detailed exposition of the model with all derivations. Section B presents the derivations that link the model's predictions with the empirical specifications used in the empirical analysis. Section C presents additional results and robustness checks.

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. The 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). 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. The exposition follows the same ordering as section II in the main text so that each subsection in this appendix provides the derivations fundamenting the verbal discussion in the corresponding subsection of the main text. In what follows, we omit time subscripts whenever equations refer to relationships between variables within the same time period.

A.A Setup

Consider a small open economy where individuals only live for two periods. 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. Factors of production are internationally immobile, but freely mobile across sectors. All markets are perfectly competitive.

A.A.1 Preferences

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

$$U\left(y_1^h, y_2^h\right) = ln y_1^h + \beta \, ln y_2^h$$

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:

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

$$y_2^h = r_{T,2} t_2^h + [r_{K,2} + (1-\delta)]\, k_2^h$$

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

A.A.2 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:

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

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

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

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 (r_T, r_K):

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

Agricultural Productivity We can consider Hicks-neutral increases in agricultural productivity within this framework by modifying 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:

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

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

A.B Equilibrium

In this section we list the equilibrium conditions of the model. We start by stating the intra-temporal equilibrium conditions in goods and factor markets. Note that 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). 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. Then, to find the equilibrium we first solve for factor prices using the zero profit conditions. Next, we consider the intertemporal equilibrium in asset markets to obtain a solution for savings and the capital stock in the second period as a function of factor prices. Finally, given factor supplies, we use the factor market clearing conditions in each period to solve for the allocation of factors across sectors, manufacturing and agricultural outputs.

A.B.1 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

$$D_i = \alpha_i(p_a, p_m)\,(r_K K + r_T T) \tag{A1}$$

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

$$p_M \leq c_M(r_T, r_K), \text{ with strict equality if } X_M > 0; \tag{A2}$$

$$p_A \leq \frac{1}{A} c_A(r_T, r_K), \text{ with strict equality if } X_A > 0. \tag{A3}$$

In turn, factor market clearing requires:

$$a_{TA}(r_T, r_K)\tilde{X_A} + a_{TM}(r_T, r_K)X_M = T \tag{A4}$$

$$a_{KA}(r_T, r_K)\tilde{X_A} + a_{KM}(r_T, r_K)X_M = K \tag{A5}$$

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

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 equilibrium conditions (A1) to (A5) are satisfied, given international goods prices p_A and p_M and factor endowments K and T. 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).[1]

A.B.2 Intertemporal equilibrium

Portfolio choice In this economy there are two assets, land and capital. Thus, individuals choose the optimal portfolio by comparing 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. Then, we can write the demand of land by household h in period 2 as follows:

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

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

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

[1] In this case, equations A2 and A3 can be used to solve for factor prices as a function of technology and goods prices. Setting the zero-profit equations in A2 and A3 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 $\left[c_M(r_T, r_K), \frac{1}{A}c_A(r_T, r_K)\right]$, 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.

Consumption If we substitute the price of land obtained above in the savings equation and replace s^h in the budget constraint for period 1 both described in subsection A.A.1 we can obtain the intertemporal budget constraint:

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

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 log preferences, is a constant fraction of lifetime wealth:

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

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

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

Capital Supply To obtain the aggregate capital supply, we use the equilibrium conditions in asset markets. First, land market equilibrium implies:

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

Savings equals Investment yields:

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

Next we substitute for s^h and q to obtain:

$$K_2 = \frac{\beta}{1+\beta} [r_{K,1} + (1-\delta)]\, K_1 + \frac{1}{1+\beta} \left[\beta r_{T,1} - \frac{r_{T,2}}{r_{K,2} + (1-\delta)} \right] T \tag{A6}$$

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

Note that equation (A6) permits to obtain the equilibrium aggregate capital stock in period 2 as a function of factor prices and period one factor endowments. Thus, equations (A1) to (A6) are sufficient to solve for the equilibrium of the model.

Steady State In the following section, we obtain the effects of agricultural technical change on the supply of capital. For this purpose, we compare the economy where there is agricultural technical change to a benchmark economy which is on a steady state equilibrium with constant international prices. The steady state equilibrium features constant consumption. Then, the Euler equation implies that parameter values should be such that $\beta\left[r_K + (1-\delta)\right] = 1$. In this case, the capital accumulation condition (A6) 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.

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

In this section we discuss the effects of an 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 is an economy that adopts the new agricultural technology in period 1, but expects a reduction in the profitability of the technology in period 2. This can be the case, for example, if environmental regulation is expected to become stricter in the future. 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.[2]

A.C.1 Factor Prices

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.*

Proof: To assess how agricultural technical change affects factor prices we use the zero-profit conditions (A2) and (A3), which permit to solve for factor price changes as a

[2] An alternative scenario in which technology adoption would generate a temporary increase in income 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.

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 with respect to equilibrium prices in the benchmark steady state equilibrium. 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 technology improves, the change in factor prices with respect to the steady state economy is:

$$\begin{bmatrix} \hat{r_{T,1}} \\ \hat{r_{K,1}} \end{bmatrix} = \begin{bmatrix} \frac{(1-\theta_{TM})\hat{A}}{\theta_{TA}-\theta_{TM}} \\ \frac{-\theta_{TM}\hat{A}}{\theta_{TA}-\theta_{TM}} \end{bmatrix}. \tag{A7}$$

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

$$\begin{bmatrix} \hat{r_{T,2}} \\ \hat{r_{K,2}} \end{bmatrix} = \begin{bmatrix} \frac{(1-\theta_{TM})\hat{A}(1-\gamma_2)}{\theta_{TA}-\theta_{TM}} \\ \frac{-\theta_{TM}\hat{A}(1-\gamma_2)}{\theta_{TA}-\theta_{TM}} \end{bmatrix}. \tag{A8}$$

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.

A.C.2 The Supply of Capital

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.*

Proof: To obtain the effects of technical change on the supply of capital we start by differentiating the capital accumulation condition (A6), 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, we evaluate at the steady state where: $\beta r_{K,2} = \beta r_{K,1} = 1$ and $r_{T,1} = r_{T,2}$, thus $\theta_{TM,1} = \theta_{TM,2} = \theta_{TM}$ and substitute for the factor price changes obtained in equations (A7) and (A8) and denote the land income share as $\alpha_T = r_T T/(r_K K + r_T T)$ to obtain, after some algebra:

$$\frac{dK_2}{K_2} = \frac{\hat{A}}{\theta_{TA} - \theta_{TM}} \frac{1}{1 - \alpha_{T,1}} \{\alpha_{T,1}\gamma_2 - \theta_{TM}\}. \tag{A9}$$

Then, $\hat{K_2} > 0$ if $\alpha_T \gamma_2 > \theta_{TM}$. To interpret this condition, note that if $\gamma_2 > 0$, the LHS 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. This positive temporary income shock due to land rents increasing is larger the higher is the land share of aggregate income. In turn, the RHS 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. This negative temporary income shock due to the reduction in the return to capital is proportional to the land share in manufacturing.

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.[3] 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.3 The allocation of capital across sectors

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*

[3] This is because:

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

effect is weak when land and capital are not good substitutes in both agricultural and manufacturing production.

Proof: we analyze the effect of agricultural technical change on agricultural and manufacturing output by using the factor market clearing conditions (A4) and (A5). Log-differentiating we obtain:

$$\left(1-\lambda_{KM}\right)\hat{\hat{X}}_A+\lambda_{KM}\hat{X_M}+\left(1-\lambda_{KM}\right)\hat{a_{KA}}+\lambda_{KM}\hat{a_{KM}}=\hat{K} \tag{A10}$$

$$\left(1-\lambda_{TM}\right)\hat{\hat{X}}_A+\lambda_{TM}\hat{X_M}+\left(1-\lambda_{TM}\right)\hat{a_{TA}}+\lambda_{TM}\hat{a_{TM}}=\hat{T} \tag{A11}$$

where $\lambda_{iM}=a_{iM}X_M/K$ is the share of factor i employed in sector M.

Note that if manufacturing is capital-intensive the share of capital employed in manufacturing is larger than the share of land employed in manufacturing: $\lambda_{KM}>\lambda_{TM}$.[4] Next, we solve for changes in factor intensities $(\hat{a_{ji}})$ by using the cost minimization conditions, which imply:

$$\theta_{KA}\hat{a_{KA}}+\theta_{TA}\hat{a_{TA}}=0$$

$$\theta_{KM}\hat{a_{KM}}+\theta_{TM}\hat{a_{TM}}=0.$$

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

$$\sigma_A=-\frac{\hat{a_{KA}}-\hat{a_{TA}}}{\hat{r_K}-\hat{r_T}}$$

$$\sigma_M=-\frac{\hat{a_{KM}}-\hat{a_{TM}}}{\hat{r_K}-\hat{r_T}}$$

Using the four equations above we can find the following solutions for $\hat{a_{ji}}$:

$$\hat{a_{Ki}}=-\theta_{Ti}\sigma_i\left(\hat{r_K}-\hat{r_T}\right); \qquad i=A,M. \tag{A12}$$

[4] 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 $\theta_{TA}=r_Ta_{TA}/c_A$ and $\theta_{KA}=r_Ka_{KA}/c_A$. Then, $\theta_{TA}/\theta_{KA}=r_Ta_{TA}/r_Ka_{KA}=r_TT_A/r_KK_A$ and similar for manufacturing. Then, we can write

$$\frac{\theta_{TA}/\theta_{KA}}{\theta_{TM}/\theta_{KM}}=\frac{r_TT_A/r_KK_A}{r_TT_M/r_KK_M}=\frac{T_A/K_A}{T_M/K_M}$$

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 (A4) and (A5) 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:

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

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. $\lambda_{KM}>\lambda_{TM}$.

$$\hat{a_{Ti}} = \theta_{Ki}\sigma_i\left(\hat{r_K} - \hat{r_T}\right). \qquad i = A, M. \tag{A13}$$

These solutions for $\hat{a_{ji}}$ together with the solutions for changes in factor prices as functions of changes in technology and goods prices can be substituted in equations (A10) and (A11) to obtain relative outputs, after substracting one equation from the other:

$$\hat{X_M} - \hat{\hat{X}}_A = \frac{1}{\lambda_{KM} - \lambda_{TM}}\left(\hat{K} - \hat{T}\right) + \sigma_s\left(\hat{p}_M - \hat{p}_A - \hat{A}\right), \tag{A14}$$

where

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

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

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

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 (A14) 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 Rybczynski 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 the effect of technical change on the supply of capital, which we do next.

We substitute the solution for $\hat{K_2}$ given by (A9) into equation (A14) to obtain:

$$\hat{X_M} - \hat{\hat{X}}_A = \frac{1}{\lambda_{KM} - \lambda_{TM}}\frac{\hat{A}}{\theta_{KM} - \theta_{KA}}\left\{\frac{1}{1-\alpha_{T,1}}\left\{\alpha_{T,1}\gamma_2 - \theta_{TM}\right\} - (\delta_K + \delta_T)(1-\gamma_2)\right\} \tag{A15}$$

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:

$$\frac{1}{1-\alpha_{T,1}}\left\{\alpha_{T,1}\gamma_2 - \theta_{TM}\right\} - (\delta_K + \delta_T)(1-\gamma_2) > 0 \tag{A16}$$

The first term in the expression above reflects the capital supply effect: an increase in the supply of capital increases manufacturing output (Rybczynski 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 a 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 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 section III of the paper. 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

Result 4: *If the origin region is in financial autarky, agricultural technical change increases the return to land and reduces the return to capital. In addition, it increases the supply of capital in period 2 and generates a reallocation of capital towards the manufacturing sector if the capital supply effect is stronger than the capital demand effect. The destination region is not affected by technical change in the origin region.*

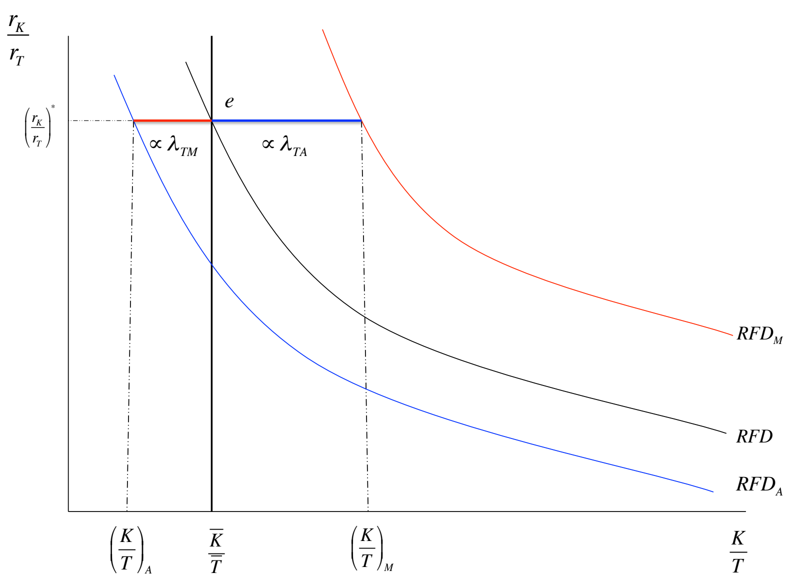
Proof: See proofs for Results, 1, 2 and 3 above. In the financial autarky case, the benchmark equilibrium is described in section A.B and the effects of agricultural technical change in the origin region are described in section A.C. In particular, note that larger agricultural productivity implies that the economy can continue producing both goods at zero profits only if land rents increase and the rental price of capital falls. Under the condition discussed in equation (A16), 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.

To facilitate the analysis of the financial integration equilibrium in the following section, Figure A1.a illustrates the financial autarky benchmark equilibrium (e) in factor markets described in section A.B. 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 ($\overline{K}/\overline{T}$) at the equilibrium point e. Figure A1.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.

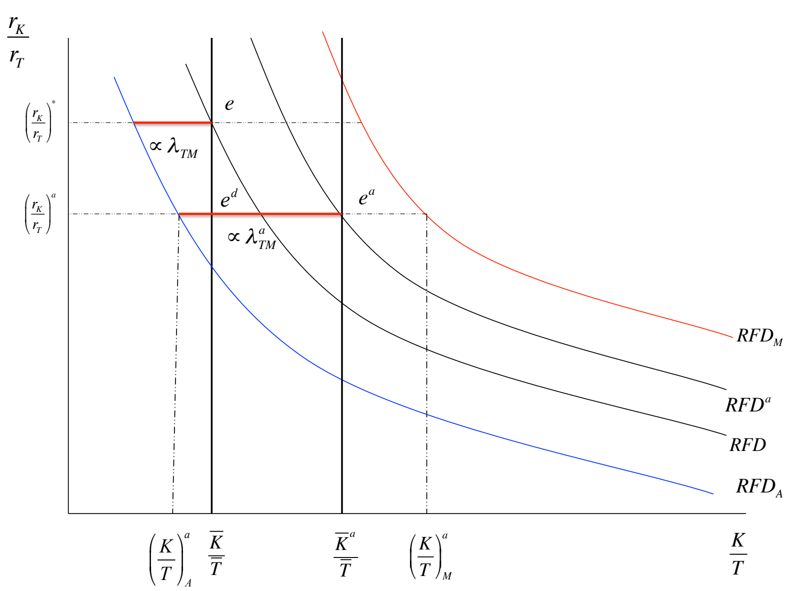
Figure A1.b illustrates the effects of agricultural technical change in the origin region, as described in section II.C above. First, larger agricultural productivity implies that the economy can continue producing both goods at zero profits only if land rents increase and the rental price of capital 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 condition 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.

FIGURE A1: FINANCIAL AUTARKY

(a) Benchmark Equilibrium in Factor Markets



(b) Effect of Agricultural Technical Change in Origin Region



A.D.2 Financial Integration

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

Origin region

Result 5: *Under financial integration, agricultural technical change in the origin region generates an increase in the return to land. However, the rental rate of capital stays above the autarky equilibrium level due to capital mobility. The consequences of these factor price movements depend on whether the economy produced both goods in the benchmark equilibrium.*
a) If the origin region produced both goods in the benchmark equilibrium, the industrial sector becomes unprofitable and it closes. In addition, there are capital outflows.
b) If the origin region is already fully specialized in agriculture in the benchmark equilibrium, agricultural technical change generates capital outflows only 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.

Proof:
We first show that under financial integration, agricultural technical change in the origin region generates local deindustrialization and capital outflows using graphical analysis. Next, we formally prove result 5.

We start by considering the equilibrium depicted in Figure A2.a where the origin region produces both goods in the benchmark equilibrium. When the origin region faces agricultural technical change the return to land increases, as in the financial autarky equilibrium. However, the rental rate of capital stays above the autarky equilibrium level due to capital mobility ($r_K^* > r_K^a$). 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 A2.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. To prove this formally, we need to compare the effect of agricultural technical change on capital supply and demand in the integrated and the autarky equilibrium. For this purpose, we solve for each of the variables of interest as a function of technical change.

Land rents

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:

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

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:

$$\left(\hat{r_{T,t}}\right)_o^i = \frac{(1-\gamma_t)}{\theta_{TA}} \hat{A}_o. \tag{A17}$$

Then, by comparing equations (A7), (A8) and equation (A17) we obtain that $\left(\hat{r_{T,1}}\right)^a > \left(\hat{r_{T,1}}\right)_o^i$ iff $\theta_{TM} > \theta_{TA}\theta_{TM}$ which is true because $\theta_{TA}\epsilon(0,1)$.

Capital Supply

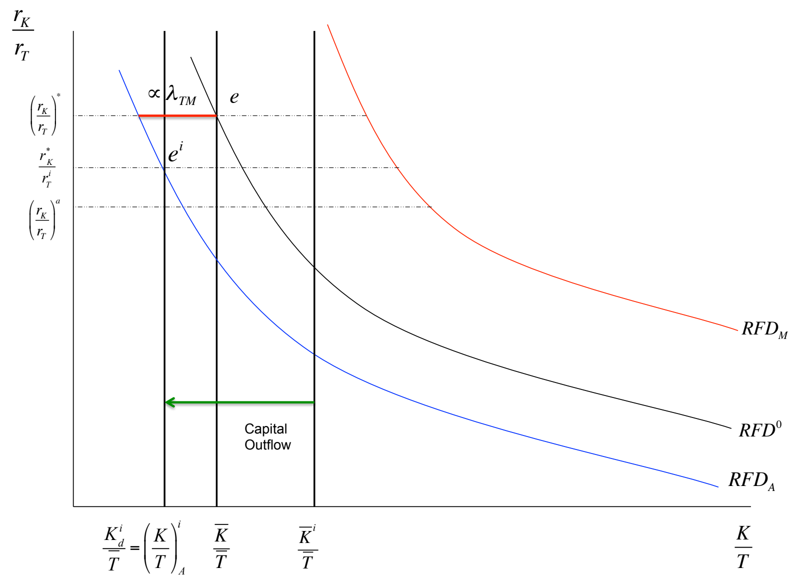
At the same time, because the increase in land-rents is partly temporary, and there is no change in the interest rate, savings and the relative supply of capital increase. In addition, it increases more than in the autarky equilibrium. To see this evaluate the capital accumulation condition (A6) at the financial integration equilibrium values of the rental rate of capital ($r_{K,1} = r_{K,2} = r_K^* = 1/\beta$) to obtain:

$$K_2^s = \frac{1}{1+\beta} K_1^s + \frac{\beta}{1+\beta} \left[r_{T,1} - r_{T,2} \right] T.$$

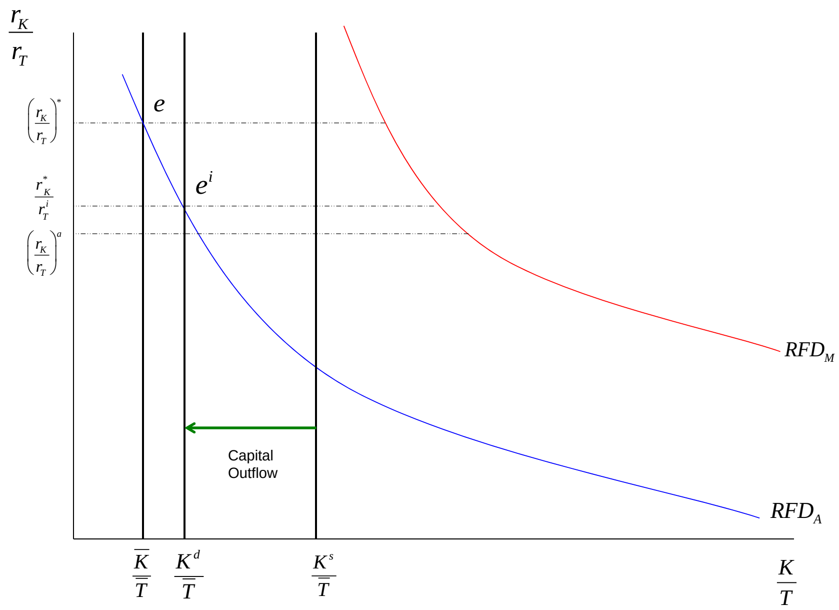
where K_t^s denotes capital supply at period t. Now, differentiate this condition with respect to land rents which are the only r.h.s. variables which change in response to agricultural

Figure A2: Financial Integration: Origin Region

(a) Incomplete Specialization in the Benchmark Equilibrium



(b) Complete Specialization in the Benchmark Equilibrium



technical change in the financial integration equilibrium:

$$dK_2^s = \frac{\beta}{1+\beta}\left[dr_{T,1} - dr_{T,2}\right] T.$$

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:

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

Finally, use equation (A17) to substitute for the change in land prices with respect to the benchmark steady state equilibrium in response to technical change to obtain:

$$\left(\hat{K_2^s}\right)_o^i = \frac{\gamma_2}{\theta_{TA}} \frac{\alpha_{T,1}}{1-\alpha_{T,1}} \hat{A}_o. \tag{A18}$$

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 (A9). 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.

Capital Demand and Capital Flows

Finally, we analyse the effect of agricultural technical change on capital demand and capital flows. First, we consider the equilibrium depicted in Figure A2.a where the origin region produces both goods in the benchmark equilibrium but agricultural technical change generates full specialization in agriculture. Second, we consider the alternative case where the origin region is already fully specialized in agriculture in the benchmark equilibrium.

a) Incomplete specialization in the benchmark equilibrium

We just showed that the return to capital is larger in the integrated equilibrium than in autarky, while land rents are lower: $(r_k/r_T)_o^a < (r_k/r_T)_o^i$. As a result, capital intensity in agriculture is lower in the integrated equilibrium. This implies that capital demand is lower in the integrated equilibrium than in the autarky equilibrium:

$$\left(\frac{K^d}{\overline{T}}\right)_o^i = \left(\frac{K_A}{T_A}\right)_o^i < \left(\frac{K_A}{T_A}\right)_o^a < \left(\frac{K^d}{\overline{T}}\right)_o^a = \left(\frac{\overline{K}}{\overline{T}}\right)_o^a,$$

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, local aggregate capital demand is lower in the integrated equilibrium than in autarky. Then, there are capital outflows as long as capital supply does not fall. But we have just shown that capital supply increases even more in the financial integration equilibrium than in autarky. This is because in autarky the return to capital falls, reducing savings. In sum, we showed that in integrated equilibrium the growth in capital supply is larger than in autarky and the growth in capital demand is lower than in autarky, thus there must be capital outflows.

b) Complete specialization in the benchmark equilibrium

In this case we can 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 A2.b, where the relative factor supply in the benchmark equilibrium $\frac{\overline{K}}{\overline{T}}$ 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 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. As discussed just above, qualitative results are similar in that case. In particular, agricultural technical change induces the origin economy to fully specialize in agriculture and there are capital outflows.

To obtain an analytical expression for 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:

$$\hat{K^d} = \hat{a_{KA}} - \hat{a_{TA}} = \theta_{TA}\sigma_A\left(\hat{r_T}\right) + \theta_{KA}\sigma_A\left(\hat{r_T}\right) = \sigma_A\left(\hat{r_T}\right),$$

where the second equality uses the solutions for $\hat{a_{ij}}$ obtained in equations (A12) and (A13). Finally, we substitute for the change in land prices and get the equilibrium change in capital demand:

$$\left(\hat{K^d}\right)_o^i = \frac{(1-\gamma_2)}{\theta_{TA}}\sigma_A \hat{A}_o. \tag{A19}$$

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:

$$\left(\hat{K^s}\right)_o^i - \left(\hat{K^d}\right)_o^i = \left[\frac{\alpha_{T,1}}{1-\alpha_{T,1}}\gamma_2 - \sigma_A\left(1-\gamma_2\right)\right]\frac{\hat{A}_o}{\theta_{TA}}. \tag{A20}$$

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

$$\frac{\alpha_{T,1}}{1-\alpha_{T,1}}\frac{\gamma_2}{(1-\gamma_2)} > \sigma_A, \tag{A21}$$

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.

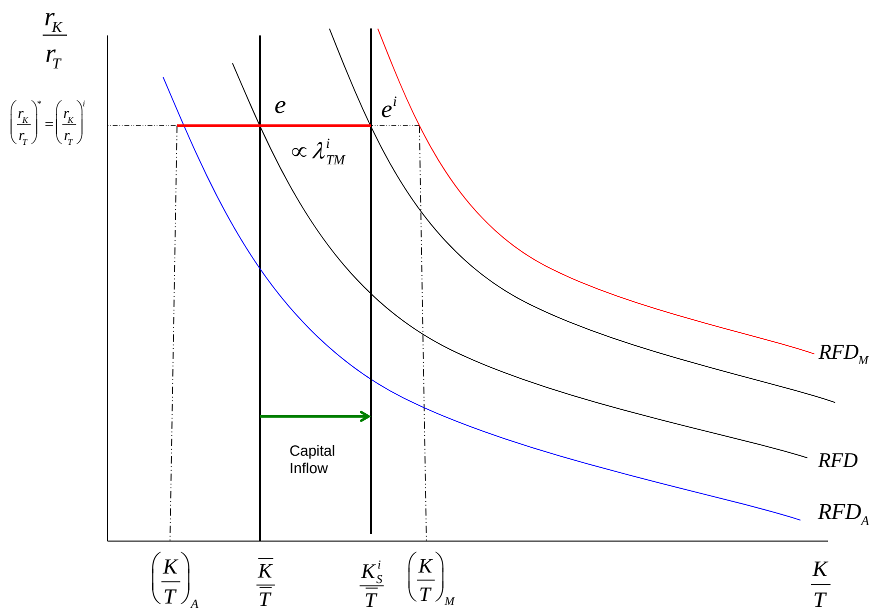
Destination Region

Result 6: *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, the destination region experiences structural transformation as capital reallocates towards the manufacturing sector.*

Proof: 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 A3. 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. 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 Rybczynski effect with no changes in technology.

We next obtain the allocation of capital across sectors in the destination region. For this purpose, log-differentiate the factor market clearing conditions (A4) and (A5) in the

Figure A3: Financial Integration: Destination Region



destination region to find that the expansion in manufacturing output in the destination region is proportional to the growth in capital supply:

$$\left(\hat{X_M} - \hat{X_A}\right)^i_d = \frac{1}{\lambda_{KM} - \lambda_{TM}} \left(\hat{K}^s\right)^i_d, \tag{A22}$$

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 ($\Delta K^s_d = \Delta K^s_o - \Delta K^d_o$) the growth in capital supply in the destination region in the integrated equilibrium is

$$\left(\hat{K}\right)^i_d = \omega_{od} \left(\hat{K^s_o} - \hat{K^d_o}\right)^i_o \tag{A23}$$

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

$$\left(\hat{X_M} - \hat{X_A}\right)^i_d = \frac{1}{\lambda_{KM} - \lambda_{TM}} \omega_{od} \left(\hat{K^s_o} - \hat{K^d_o}\right)^i_o, \tag{A24}$$

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

$$\left(\hat{\lambda}_{KM}\right)_d^i = \frac{1-(\lambda_{KM}-\lambda_{TM})}{\lambda_{KM}-\lambda_{TM}}\left(\hat{K}\right)_d^i. \tag{A25}$$

Additional References

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B From Model to Data

This Appendix connects the model to the empirical strategy. First, section B.A extends the two-region model presented in Appendix A to the case of many regions financially integrated through banks. Second, section B.B presents the derivations necessary to obtain all the empirical specifications presented in section III in the paper.

B.A Multi-region model with banks

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 (A23)]. 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. 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 factor endowments located in a given municipality in the benchmark equilibrium are owned by residents who deposit their savings in bank branches located within the municipality. 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 (A18) we obtain:

$$\hat{deposits}_{bo} = \left(\hat{K^s}\right)_o^i = \phi_o \hat{A}_o. \tag{A26}$$

where $deposits_{bo}$ are deposits at bank b in origin municipality o and $\phi_o = \left[\frac{\gamma_2}{\theta_{TA}} \frac{\alpha_{T,1}}{1-\alpha_{T,1}}\right]$ 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 equalisation in the benchmark equilibrium. The expression above indicates that deposits grow faster in municipalities with faster agricultural productivity growth, specially if they have a large land income share.

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:

$$Deposits_b = \sum_{o \in O_b} deposits_{bo} \tag{A27}$$

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. Note that 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}) because $deposits_{bo} = \psi_{bo} K_o^s$. Next, we can substitute for equation (A26) to obtain:

$$\hat{Deposits}_b = \sum_{o \in O_b} \omega_{bo} \phi_o \hat{A}_o. \tag{A28}$$

The equation above describes the growth rate of deposits in the integrated equilibrium with respect to the benchmark equilibrium. This expression 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.[5] 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 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:

$$\hat{loans}_{bd} = \hat{Loans}_b = \sum_{o \in O_b} \omega_{bo} \varphi_o \hat{A}_o. \tag{A29}$$

where we used equation (A20) to substitute for the excess capital supply in each origin municipality and $\varphi_o = \frac{1}{\theta_{TA}} \left[\frac{\alpha_{T,1,o}}{1-\alpha_{T,1,o}} \gamma_2 - \sigma_A (1-\gamma_2) \right]$ is the elasticity of capital outflows from origin municipality o with respect to local agricultural productivity growth. Note that this elasticity is increasing in the land income share in municipality o ($\alpha_{T,1,o}$), as all remaining variables are constant across municipalities in the benchmark equilibrium 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:

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

[5] In 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 we need to assume that banks can only reallocate savings to municipalities where they have branches. Note that if some deposits where 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.

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:

$$\hat{Loans}_d = \sum_{b \in B_d} \omega_{bd} \hat{loans}_{bd}$$

where $\omega_{bd} = \frac{loans_{bd}}{loans_d}$ is the loan market share of each bank b in destination d. Finally, we substitute for $\hat{loans}_{bd}$ by using equation (A29) to obtain:

$$\hat{Loans}_d = \sum_{b \in B_d} \omega_{bd} \sum_{o \in O_b} \omega_{bo} \varphi_o \hat{A}_o. \tag{A30}$$

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. For this purpose, we assume that each bank can only lend to a subset of firms already connected to it. This type of relationship lending has been justified in the literature based on asymmetric information.[6] Note that in the context of our model, this type of credit constraint 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. In addition, 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 loans to all connected firms proportionally, which according to equation (A30) implies that the growth rate of loans in a firm i connected to a bank b is the following:

$$\hat{loans}_{ibd} = \hat{loans}_{bd} = \hat{Loans}_b = \sum_{o \in O_b} \omega_{bo} \varphi_o \hat{A}_o. \tag{A31}$$

[6] A 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).

B.B Empirical specifications

B.B.1 Local effects

In this subsection we explain how we derive equation (1) which we use to estimate the local effects of agricultural technical change. In the model, equation (A17) describes the growth rate of land rents in the integrated equilibrium with respect to the benchmark equilibrium as a function of local agricultural technical change. 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 land rents can be written as:

$$\log r_{T,j,t} \approx \log r_{T,j,\tau} + \psi \left(\log A_{o,t} - \log A_{o,\tau}\right) \tag{A32}$$

where $\log r_{T,j,t}$ is land rents in municipality j at any given point in time t and $\psi = \frac{(1-\gamma_2)}{\theta_{TA}}$ is identical for all municipalities due to factor price equalization in the benchmark equilibrium. The expression above indicates that land rents grow faster in municipalities with faster agricultural productivity growth.

To estimate equation (A32) we need to find measures of each of its components. First, we measure total factor productivity in agriculture (A) with the FAO-GAEZ potential yields per hectare of soy ($A^{soy}_{o,t}$).[7] Second, we proxy for land rents using agricultural profits. Finally, we add time and municipality fixed effects to obtain:

$$\log r_{T,j,t} = \alpha_j + \alpha_t + \beta \log(A^{soy}_{jt}) + \varepsilon_{jt} \tag{A33}$$

where $\alpha_j = \log r_{T,j,\tau} - \beta \log A_{o,\tau}$ and the error term represents both classical measurement error and other municipality-level shocks to land rent growth not explicitly included in the model. Notice that the parameter β does not have a structural interpretation in terms of the parameters of the model (ψ). This is because the measure of technical change we use captures potential agricultural productivity for only one crop, while the model refers to realized overall productivity.

B.B.2 Bank Exposure

In this subsection we explain how we derive equation (4) which presents a measure of bank exposure which we we use to link credit supply in destination municipalities to the GE soy driven deposit increase in origin municipalities. In the model, equation (A28) describes the growth rate of deposits of bank b in the integrated equilibrium with respect

[7] Note that this measure has the advantage of being exogenous as it refers to potential, not realized yields. However, the use of this measure will give rise to measurement error to the extent that it captures potential agricultural productivity for only one crop, while the model refers to realized overall productivity.

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:

$$\log Deposits_{b,t} \approx \log Deposits_{b,\tau} + \sum_{o \in O_b} \omega_{bo} \phi_o \left(\log A_{o,t} - \log A_{o,\tau} \right) \tag{A34}$$

where $\log Deposits_{b,t}$ is the national level of deposits of bank b at any given point in time t. We approximate deposits of bank b at time t with their 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 (A34) we need to find measures of each of its components. First, we measure total factor productivity in agriculture (A) with the FAO-GAEZ potential yields per hectare of soy ($A^{soy}_{o,t}$).[8] Second, we need to measure ϕ_o which has only one component varying at the municipality level, namely $\alpha_{T,1,o}$, which is the land income share.[9] We do not have information on factor income shares at the municipality level, thus we proxy for the land income share ($\alpha_{T,1,o}$) with the share of land employed by the agricultural sector (λ_{TAo}).[10] Finally, we add time and bank fixed effects to obtain:

$$\log Deposits_{bt} = \gamma_b + \gamma_t + \beta \underbrace{\left[\sum_{o \in O_b} w_{bo} \, \lambda_{TAo} \, \log A^{soy}_{o,\tau} \right]}_{BankExposure_{bt}} + \eta_{bt} \tag{A35}$$

where:

$$\gamma_b = \log deposits_{b,\tau} - \beta \sum_{o \in O_b} w_{bo} \, \lambda_{TAo} \, \log A^{soy}_{o,\tau}.$$

where the error term captures classical measurement error and other shocks to bank deposit growth not explicitly included in the model. 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, parameters capturing the elasticities of the variables in the model with respect to their empirical counterparts.

[8] Note that this measure has the advantage of being exogenous as it refers to potential, not realized yields. However, the use of this measure will give rise to measurement error to the extent that it captures potential agricultural productivity for only one crop, while the model refers to realized overall productivity.

[9] The 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.

[10] In 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 α_{To} 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 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}).

Equation (A35) 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 (4) in the paper. In the paper we define the summation in brackets inside equation (A35) as our measure of bank exposure to the deposit increase driven by soy technical change.

B.B.3 Municipality Exposure

In this subsection we explain how we derive equation (6) which presents a measures of destination municipality exposure which links credit supply in destination municipalities to the GE soy driven deposit increase in origin municipalities. In the model, equation (A30) describes the growth of credit in each destination municipality. We derive its empirical counterpart by following the same steps as in the previous section:

$$\log Loans_{dt} = \alpha_d + \alpha_t + \mu \sum_{b \in B_d} w_{bd} \underbrace{\left[\sum_{o \in O_b} w_{bo}\, \lambda_{TAo}\, \log A^{soy}_{o,\tau} \right]}_{BankExposure_{bt}} + \varepsilon_{dt} \tag{A36}$$

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

B.B.4 Firm Exposure

In this subsection we explain how we derive equation (7). In the model, equation (A31) 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:

$$\log loans_{ibdt} = \nu_b + \nu_d + \nu_t + \mu \underbrace{\left[\sum_{o \in O_b} w_{bo}\, \lambda_{TAo}\, \log A^{soy}_{o,\tau} \right]}_{BankExposure_{bt}} + \varepsilon_{ibdt} \tag{A37}$$

. 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:

$$\log L_{idt} = \nu_d + \nu_t + \lambda \sum_{b \in B} \pi_{ib} \underbrace{\left[\sum_{o \in O_b} w_{bo} \, \lambda_{TAo} \, \log A^{soy}_{o,\tau} \right]}_{BankExposure_{bt}} + \varepsilon_{idt} \tag{A38}$$

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

Additional References

Williamson, S.D. (1987). "Costly Monitoring, Loan Contracts, and Equilibrium Credit Rationing", *Quarterly Journal of Economics 102*(1), 135–145.

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.[11] Second, the Credit Information system has a reporting threshold above which financial institutions are required to transmit loan information to the Central Bank.[12] 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 C4 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 C6 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.[13] Finally, in Figure C7, 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

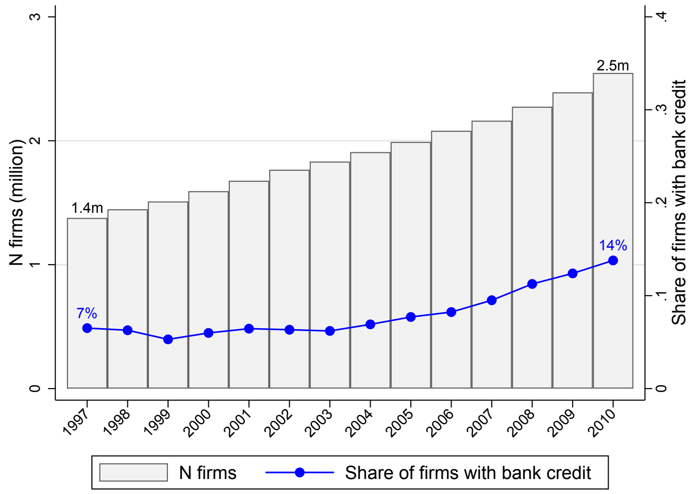
[11] Self-employed are not required to report information to RAIS.

[12] To 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).

[13] It 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.

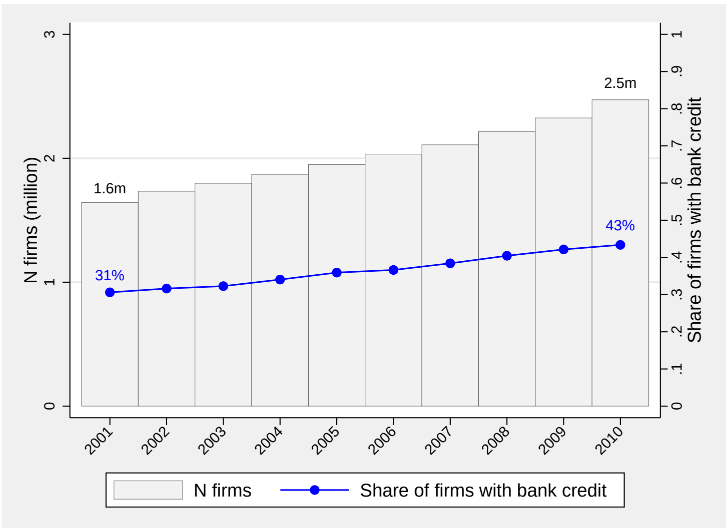
are micro firms (84.1 percent of firms in our data in 1997). For these firms, the 50,000 1997 BRL reporting threshold corresponds to 1.6 times their average wage bill, making the definition of access to bank credit particularly demanding. In the years between 1997 and 2010, however, the share of micro 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 in 2010.

Figure C4: Share of Firms with Bank Credit (50,000 BRL Threshold)
Brazil: 1997-2010



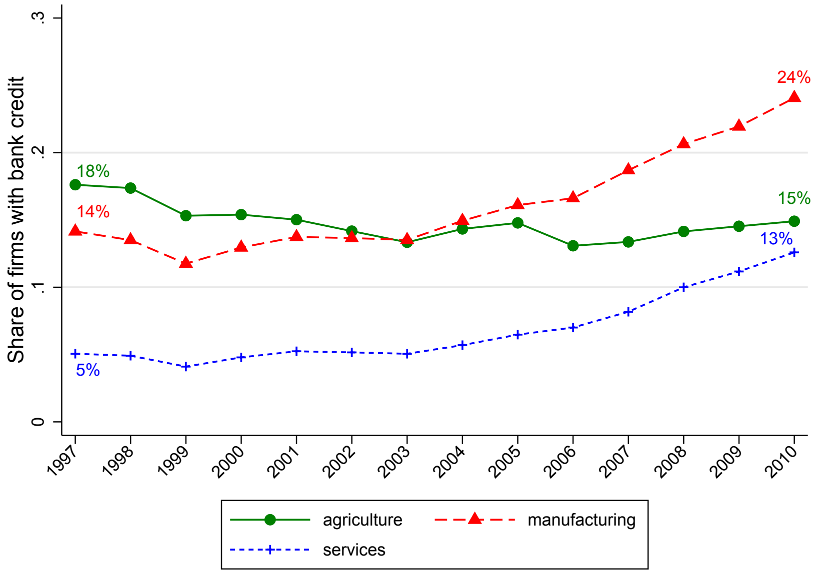
Notes: Sources are the Credit Information System of the Central Bank of Brazil and RAIS. Authors' calculation from micro-data. Access to bank credit is defined as an outstanding credit balance with a financial institution of at least 50,000 1997 BRL.

Figure C5: Share of Firms with Bank Credit (5,000 BRL Threshold) Brazil: 2001-2010



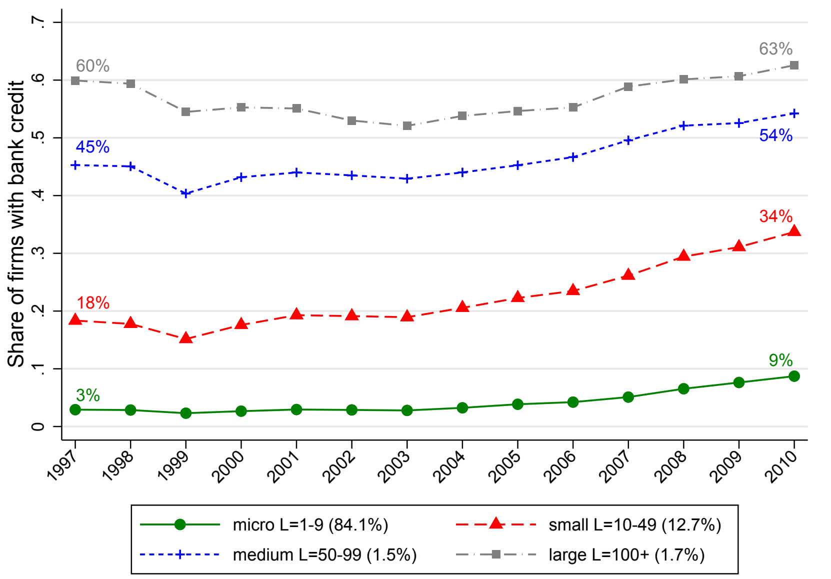
Notes: Sources are the Credit Information System of the Central Bank of Brazil and RAIS, authors' calculation from micro-data. Access to bank credit is defined as an outstanding credit balance with a financial institution of at least 5,000 1997 BRL.

Figure C6: Share of Firms with Bank Credit: by Sector
Brazil: 1997-2010



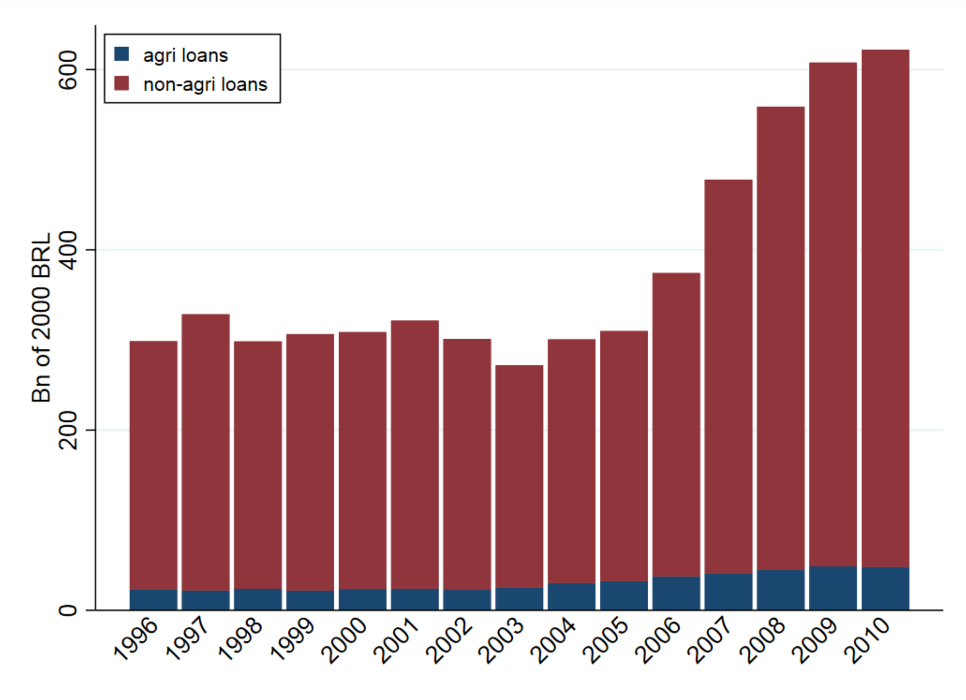
Notes: Sources are the Credit Information System of the Central Bank of Brazil and RAIS, authors' calculation from micro-data. Access to bank credit is defined as an outstanding credit balance with a financial institution of at least 50,000 1997 BRL. Services include: construction, commerce, lodging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

Figure C7: 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 C8: 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***	0.033***	0.119***	0.116***
	[0.003]	[0.003]	[0.028]	[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 (1):

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

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

	log(deposits)	deposit share		
outcome:	total	checking accounts	saving accounts	term deposits
	(1)	(2)	(3)	(4)
log A^{soy}	0.070***	-0.021***	0.018***	0.002
	[0.016]	[0.007]	[0.006]	[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:	$1(Frontier)$	$\frac{deposits-loans}{assets}$	
		Frontier	Non-Frontier
	(1)	(2)	(3)
$\Delta \log A^{soy}$	0.130***		
	[0.020]		
$\log A^{soy}$		0.228**	0.347***
		[0.115]	[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

	Δ Profits per he (%)		$\frac{deposits-loans}{assets}$		$\frac{non-agriculturalloans}{totalloans}$	
	unweighted	weighted	unweighted	weighted	unweighted	weighted
weight:		Agricultural Land 1996		Bank Assets 1996		Total Loans 1996
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \log A^{soy}$	0.229***	0.336**				
	[0.079]	[0.158]				
$\log A^{soy}$			0.297***	0.061**		
			[0.065]	[0.025]		
$MunicipalityExposure_{dt}$					0.090***	0.111**
					[0.016]	[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:	bank credit access				
sample	all	non-soy regions	soy regions	non-soy regions	
				micro and small	medium and large
	(1)	(2)	(3)	(4)	(5)
$MunicipalityExposure_{dt}$	0.005	0.012**	-0.003	0.012**	-0.001
	[0.004]	[0.006]	[0.005]	[0.006]	[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: 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.