The Spatial Consequences of Financial Frictions: Evidence From Brazil*

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Abstract

What are the regional and distributional consequences of government subsidies in credit markets? We provide theory and evidence to answer this question using detailed administrative data from Brazil. We build a dynamic spatial general equilibrium model with working capital constraints in which a government can subsidize credit across sectors and regions. We show that spatial linkages through trade, migration, and input-output relationships are crucial to understand the long-run consequences of such policies. Guided by the model, we evaluate the long-run sectoral and skill composition effects of a credit place-based policy in Brazil. We exploit the fact that treatment intensity varied discontinuously across a geological border. Using a dynamic regression discontinuity design, we find that, after the credit shock, treated municipalities become more agricultural-oriented and less skill-intensive. We estimate the model by matching the reduced-form moments and perform counterfactual simulations to evaluate the regional and distributional effects of credit subsidies. These simulations indicate that credit subsidies differentially increase welfare in richer regions with smaller effects on poorer ones. An alternative policy that improves bankruptcy procedures through court reform, decreasing the cost of credit in local labor markets, differentially improves welfare in poorer regions.

The views expressed herein are those of the author and do not necessarily reflect those of the Banco Central do Brasil nor the Bank of International Settlements.

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1 Introduction

What are the regional and distributional consequences of government subsidies in credit markets? Governments around the world spend large amounts of resources subsidizing credit in specific regions and sectors.[1,2] A common argument made by policymakers is that such policies foster regional growth and industrialization by increasing local investment and capital accumulation.[3,4] Yet, despite their pervasiveness, we know little about the regional and aggregate effects of such policies.

Studying the aggregate effects of these interventions is challenging as they are region- and sector-specific, and, given their magnitude, they may have important general equilibrium effects across space. Moreover, since, by design, these policies try to promote physical capital accumulation, their short and long-run consequences might be very different. In this paper, we provide theory and evidence on the regional and aggregate consequences of government subsidies in credit markets.

In the theoretical part of the paper, we build a dynamic spatial general equilibrium model with working capital constraints. The model accounts for frictional labor mobility of workers of different skills, intra-regional trade, input-output linkages, and regional capital accumulation. Firms in different sectors hire high- and low-skilled workers, rent capital, and buy materials from other sectors. They produce using CES production functions that allow for different degrees of complementarity between capital and high- or low-skilled workers. Firms face a location-sector-specific working capital constraint and a government can reduce these constraints through credit subsidies that are funded through taxes. Reducing working capital constraints decreases prices of investment goods, which increases local capital accumulation. Such increase differentially affects high- and low-skilled workers depending on whether the predominant sector in the local economy exhibits capital high- or low-skill complementarity in the production function.

The model generates rich interactions between financial frictions, capital accumulation, and the spatial distribution of skill, all mediated by spatial linkages through input-output relationships, trade, and migration. Comparative statics in the steady state of the model

[1]National development banks are one of the main players in these subsidies. The outstanding loans as a share of GDP of the national development banks of Brazil, China, and Germany in 2012 were, respectively, 11.3%, 15.5% and 12.4% (Lazzarini et al., 2015).

[2]Rodrik (2004) finds that among other countries, Argentina, Brazil, Chile, Colombia, India, China, Malaysia, and Nigeria currently implement these sorts of policies.

[3]See, for example, Chandrasekhar (2016) and Griffith-Jones and Ocampo (2018).

[4]Economic historians have argued that these policies played an important role in the industrialization of some countries. For example, Cameron (1953) and Gerschenkron (1962) argue that government credit subsidies financed investments that led to the rapid industrialization of Europe. Amsden (1992) argues that the Korean Development Bank infused long-term capital in Korea which helped in its industrialization.

indicate that three main forces drive the effects of region-sector-specific subsidies on local capital accumulation: the tradability of goods across regions, how intensely the targeted sector is used for investment production, and finally, general equilibrium forces through migration and input-output linkages.[5]

Guided by the model, in the empirical part of the paper we study the local labor market effects of firm credit subsidies exploiting a place-based policy that subsidized credit for firms operating in a region of Brazil. Starting in 1989, the Brazilian government implemented a series of credit policies intended to promote regional development in the Brazilian semiarid region (the "Semiarido"). This region is characterized by its harsh climatological conditions, and it has been historically one of the poorest in Brazil.

We exploit the fact that the Semiarido boundary is not related to any administrative unit, as it was defined based on climatological conditions. Specifically, municipalities within the Northeastern region of Brazil with average yearly rainfall below 800 millimeters were defined as being part of the Semiarido. This feature generates variation in treatment intensity across municipalities within the same state, allowing us to compare outcomes for municipalities within the same state, just across the border, over time.

Using a dynamic regression discontinuity design, we show that the policy had a large effect on credit in treated municipalities: credit increased by approximately 30% relative to control municipalities. While the policy does not explicitly mention which sectors were targeted, we use administrative data from the credit registry to measure implied location-sector specific subsidies. Using such measures, we find that interest rate subsidies were targeted toward agriculture and not toward manufacturing nor services.

We next study the real local labor market effects of the policy. We find that, 20 years after the credit shock, treated labor markets experience an increase in the share of workers in agriculture and a decrease in the ratio of high- to low-skilled workers. We also find that, despite the relative increase in the quantity of low-skilled workers, wage inequality does not increase. These results might seem surprising, as previous literature has suggested that credit differentially benefits manufacturing industries (Rajan and Zingales, 1995) and that it is high skill-biased (Fonseca and Van Doornik, 2022). We explore the channels behind these effects through the lens of the model.

Two aspects of the model help us understand the direction and magnitude of the responses observed in the reduced-form evidence: the tradability of manufactured goods

[5] A growing literature studies the role of distortions on the spatial distribution of economic activity within (Tombe and Zhu, 2019; Sotelo, 2018) and across countries (Caliendo et al., 2022; Farrokhi et al., 2022). We build on this literature studying the effects of one specific friction: credit market frictions. As we argue in Section 4, we use detailed credit registry data to inform the magnitude of these frictions across space and sectors in Brazil.

across regions and heterogeneity in capital-skill complementarity in the production function across sectors. The effects of reducing agriculture-specific credit constraints on local sectoral composition depend on whether or not manufactured goods can be imported from other regions. In a closed economy, such a shock could generate an increase in manufacturing employment as the expansion of agriculture requires complementary inputs from manufacturing which have to be locally produced (Rostow, 1959). In an open economy, on the other hand, the shock will generate further specialization in agriculture, as the complementary inputs can be imported from other regions (Matsuyama, 1992).

In terms of capital-skill complementarity, the local labor market effects suggest that there was an increase in the relative quantity of low-skilled workers, without a decrease in their relative wage. This implies that there must have been an increase in the relative demand for these workers. Such increase could be due to the fact that capital and low-skilled workers are complements in agricultural production, that is, if there is capital-low skill complementarity in this sector.

We then estimate the model parameters that underlie the main reduced-form results of the empirical section. In terms of the degree of sectoral tradability, we use information on the road network in Brazil to compute estimates of transport costs for any origin and destination.[6] Using these estimates as well as intra-regional trade flows, we estimate a sectoral gravity equation to recover sectoral trade elasticities in the model. Consistent with the intuition above, we find that manufactured goods are just as tradable across regions as agricultural goods. In terms of the degree of complementarity between capital and low-skilled workers in agriculture, we use the reduced-form analysis to estimate these parameters by matching the observed skill ratio and wage inequality effects in the model as in the data through a method of simulated moments. We find that capital tends to differentially complement low-skilled workers in agriculture.

Having estimated the model, we use administrative data on the universe of firm loans in Brazil, as well as a host of other datasets, to quantify the model. The loan data is obtained from the Brazilian credit registry, a confidential dataset maintained by the Central Bank of Brazil. This dataset allows us to recover average credit spreads within each location-sector. Importantly, the dataset contains information on whether or not each loan is subsidized, allowing us to measure implied subsidies across space and sectors.[7] We combine these

[6] Gollin and Rogerson (2014), Sotelo (2018), and Pellegrina (2022) study how costly intra-regional trade affect subsistence agriculture, productivity, and the propagation of productivity shocks across regions within a country, respectively. We build on this literature exploring the consequences of intra-regional goods trade, particularly in manufactured goods, on long-run local labor market capital accumulation and responses to shocks.

[7] Government interventions in credit markets have been studied by a large literature, see La Porta et al. (2002) for a summary. Several papers have focused on Brazil specifically such as Coleman and Feler

data with other datasets necessary to conduct counterfactual simulations: census data with information on wages and migration by skill level, intra-regional trade data, as well as regional accounts data for agriculture, services, and manufacturing at the municipality level.

Turning to counterfactuals, we explore the effects of policies related to the two main drivers of spatial heterogeneity in the cost of credit in our model: subsidies and frictions. The first counterfactual focuses on the effect of credit subsidies in Brazil where, above and beyond the particular place-based policy we study in the empirical section, 50% of all credit is subsidized.[8] We ask: what would be the effects of removing the credit subsidies observed in the data? Using the credit registry, we document that subsidies tend to be biased towards agriculture and that, when accounting for all subsidies, they tend to be biased towards richer regions at baseline. Counterfactual exercises indicate that, given the observed urban bias in the subsidies, richer regions differentially benefit from the subsidies with smaller effects on poorer ones, increasing welfare inequality across space. Within local labor markets, on the other hand, they tend to reduce welfare inequality as they are differentially targeted towards agriculture.

In terms of frictions, the second counterfactual explores one source of spatial dispersion in the cost of credit: differences in productivity in local bankruptcy courts.[9] For this second counterfactual, we use data on local court productivity, and show that it exhibits large spatial heterogeneity, with poorer municipalities having less efficient courts. Using our model, we explore the effects of equalizing local court productivity across space. To do so, we estimate the passthrough of court productivity to local interest rates exploiting a credit reform that improved the court system in 2005 following Ponticelli and Alencar (2016). Using this estimate, we simulate the effects of equalizing local court productivity across space. Different from the subsidy policy studied in the first counterfactual, results suggest that such policy would reduce spatial inequality in welfare, since it would generate larger capital inflows to poorer regions at baseline.

(2015), Cavalcanti and Vaz (2017), and Garber et al. (2020). We build on this literature exploring the spatial consequences of these interventions.

[8]The credit subsidies we study are a form of place-based policy. We build on papers such as Glaeser and Gottlieb (2008), Kline and Moretti (2014), Fajgelbaum and Gaubert (2020), Austin et al. (2018), and Reed (2020), which have studied the efficiency and distributional consequences of different place-based policies.

[9]In our model, the cost of credit is heterogeneous across space and depends on local frictions, one of which is the productivity of local bankruptcy courts. These frictions, or wedges, can generate misallocation in the spirit of Hsieh and Klenow (2009). Recent papers have studied the role of other frictions in generating spatial misallocation such as housing constraints (Saiz, 2010; Hsieh and Moretti, 2019), taxes (Fajgelbaum et al., 2015), transportation costs (Zárate, 2022), and migration costs (Bryan et al., 2014; Porcher, 2019). Empirically, Bau and Matray (2020) find that reducing financial frictions decreases misallocation in India, similar to what our model would predict.

This paper contributes to three streams of literature. First, it contributes to the literature on finance and development. On the theoretical front, we build on a literature that has modeled the relationship between financial frictions and aggregate outcomes to study the spatial consequences of financial frictions (Buera et al., 2011; Moll, 2014; Itskhoki and Moll, 2019). Recent contributions explicitly model financial frictions across space such as Aguirregabiria et al. (2019) and Ji et al. (2021), but typically abstract away from migration and trade, margins which have been thought to be relevant drivers of the transmission of financial frictions across regions and workers (Banerjee and Duflo, 2005; Buera et al., 2021).[10] Our model complements these papers by building a quantitative model with frictional labor mobility and trade, factors that we show to be important channels through which financial frictions affect regional capital accumulation.

On the empirical front, the paper also contributes to a literature that provides empirical evidence on the local labor market long-run effects of credit policies (Burgess and Pande, 2005; Fonseca and Matray, 2022) and on the equilibrium effects of credit shocks more broadly (Breza and Kinnan, 2021). Consistent with previous literature (Foster and Rosenzweig, 2004; Hornbeck and Keskin, 2014; Asher et al., 2022), we find that positive agricultural shocks did not encourage long-run local non-agricultural activity.

Second, it contributes to the literature that explores the link between financial frictions and structural transformation (Kaboski, 2021).[11] We build on work by Bustos et al. (2016, 2019, 2020) which has explored the implications of productivity improvements in agriculture in Brazil on regional outcomes. Different from them, we explore the consequences of government-led credit policies, and on frictions that generate dispersion in the cost of credit more generally, on local labor market sectoral composition and propose a quantitative model to study long-run sectoral effects of credit shocks.

Finally, this paper contributes to a growing literature on dynamic spatial general equilibrium models (Caliendo et al., 2019; Bilal and Rossi-Hansberg, 2021; Allen and Donaldson, 2020; Kleinman et al., 2022).[12] We build on recent advances in this literature by embedding financial frictions and capital-skill complementarity into a spatial quantitative model with regional capital accumulation.[13] We argue that financial frictions have relevant

[10]These margins, and particularly migration, have also been found important in other contexts such as Morten and Oliveira (2016), Khanna et al. (2021), and Imbert et al. (2022).

[11]More broadly, we build on a literature studying structural transformation across space (Caselli and Coleman II, 2001; Eckert and Peters, 2022), as well as on the literature studying the relationship between trade and structural transformation (Fajgelbaum and Redding, 2014; Cravino and Sotelo, 2019).

[12]We also build on a literature that has studied dynamic capital accumulation in international trade models such as Anderson et al. (2015); Eaton et al. (2016); Ravikumar et al. (2019); Reyes-Heroles et al. (2020); Ding (2021).

[13]Empirically, Dix-Carneiro and Kovak (2017) argue that dynamic capital accumulation is important to understand the long-run effects of negative shocks on local labor markets. Huber (2018) shows that

implications for the spatial distribution of high-skilled and low-skilled workers due to their effects on local capital accumulation through capital high/low skill complementarity in the production function.[14]

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 describes the empirical findings. Section 4 describes how we quantify and estimate the model. Section 5 performs different counterfactuals to understand the regional and distributional consequences of financial frictions and the policies that try to tackle them. Finally, Section 6 concludes.

2 Model

This section introduces a dynamic spatial model with working capital constraints in which a government can subsidize credit across sectors and regions. The model highlights the fact that the effects of credit frictions on capital accumulation and hence sectoral and skill composition depend on spatial linkages through trade, migration, and input-output linkages.

Time is discrete and indexed by subscript t. There are three types of infinitely lived agents: high-skilled workers (H), low-skilled workers (U), and capitalists. There are J sectors indexed by $j, m \in \{1, ..., J\}$, and I locations indexed by $i, n \in \{1, ..., I\}$.[15,16]

At the beginning of each period, each location n inherits a mass of workers of each type $\{U_{nt}, H_{nt}\}$, as well as a capital stock K_{nt}. The state variables of the economy are given by workers by skill level across space and regional capital stocks.

negative financial shocks can lead to long-run regional decline. In our model, local labor market shocks, and particularly credit shocks, have long-term regional effects in part due to physical capital accumulation.

[14]There is a growing literature in macroeconomics and trade that study capital-skill complementarity. Krusell et al. (2000) and Berlingieri et al. (2022) study its effects on the aggregate wage premium in the US and France respectively. Parro (2013) study how trade across countries affects aggregate inequality through capital-skill complementarity. Baum-Snow et al. (2018) study its role in the increase in urban inequality. Dix-Carneiro and Traiberman (2022) study the distributional consequences of trade deficits in a quantitative model with capital-skill complementarity. In this paper, we build on this literature by exploring the spatial implications of this feature of production through a quantitative model.

[15]We use the convention that subscripts refer to locations and superscripts to sectors. When referring to pairwise quantities, such as trade between regions, we use the convention that the first subscript denotes the destination, while the second denotes the origin.

[16]We normalize the total population across locations within each type to one so that U_{nt} is interpreted as the population share of location n at time t of low-skilled workers, and H_{nt} is interpreted as the population share of location n of high-skilled workers. With a slight abuse of notation, we also sometimes refer to skill-type specific measures with superscript $\ell \in \{u, h\}$.

2.1 Production

A non-tradable sectoral good is produced by aggregating a continuum of tradable sector-specific varieties. Non-tradable sectoral goods can be used for the production of a consumption good, production of investment goods, or as intermediate inputs in the production of other varieties.

Non-Tradable Sectoral Goods. The representative firm in sector j location n combines sectoral varieties ω^j through the following production function:

$$Q_{nt}^{j} = \left[\int q_{nt}^{j}(\omega^{j})^{\frac{\eta}{\eta-1}} d\omega^{j} \right]^{\frac{\eta}{\eta-1}}.$$

Underlying varieties ω^j are traded across regions. Firms producing Q_{nt}^{j} search across all regions for the lowest-cost supplier of these varieties.

Variety Producers. There is free entry into the production of each variety ω^j in every location i. Production within sectors is assumed to occur under conditions of perfect competition with the following constant returns to scale CES production function:

$$q_{it}^{j}(\omega^{j}) = a_{it}^{j}(\omega^{j}) \left[V_{it}^{j}(\omega^{j}) \right]^{\gamma^{j}} \left[M_{it}^{j}(\omega^{j}) \right]^{1-\gamma^{j}}, \tag{1}$$

where $V_{it}^{j}(\omega^{j})$ is the amount of value added in the production of good ω^j, and $M_{it}^{j}(\omega^{j})$ denotes the amount of intermediates used in production. The parameter γ^j measures the share of gross output net of frictions in value added, and $a_{it}^{j}\left(\omega^{j}\right)$ is a variety-specific productivity term.

The value-added production function combines low-skilled workers $u_{it}^{j}(\omega^{j})$ and a high-skill capital composite factor $Z_{it}^{j}(\omega^{j})$:

$$V_{it}^{j}(\omega^{j}) = \left[(\vartheta^{j})^{1/\sigma^{j}} u_{it}^{j}(\omega^{j})^{\frac{\sigma^{j}-1}{\sigma^{j}}} + (1-\vartheta^{j})^{1/\sigma^{j}} Z_{it}^{j}(\omega^{j})^{\frac{\sigma^{j}-1}{\sigma^{j}}} \right]^{\frac{\sigma^{j}}{\sigma^{j}-1}}.$$

The high-skill capital composite factor $Z_{it}^{j}(\omega^{j})$, in turn, is produced through the following

CES aggregator:

$$Z_{it}^{j}(\omega^{j}) = \left[(\xi^{j})^{1/\rho^{j}} h_{it}^{j}(\omega^{j})^{\frac{\rho^{j}-1}{\rho^{j}}} + (1-\xi^{j})^{1/\rho^{j}} k_{it}^{j}(\omega^{j})^{\frac{\rho^{j}-1}{\rho^{j}}} \right]^{\frac{\rho^{j}}{\rho^{j}-1}},$$

where $h_{it}^{j}(\omega^{j})$ represents high-skilled workers, and $k_{it}^{j}(\omega^{j})$ represents capital.

The elasticity of substitution between high skill and capital in sector j is given by ρ^{j}, while the elasticity of substitution between low-skill and the high skill-capital composite is given by σ^{j}. This general CES production function allows for differences in factor complementarity across sectors. For example, $\sigma^{j} > \rho^{j}$ represents a case in which high-skilled workers are more complementary to capital relative to low-skilled workers in sector j. This is known as "capital-high skill complementarity" in the literature (Krusell et al., 2000; Parro, 2013). On the other hand, $\sigma^{j} < \rho^{j}$ represents a case in which low-skilled workers are more complementary to capital relative to high-skilled workers ("capital-low skill complementarity"). Cobb Douglas is a special case of this production function, which occurs when $\sigma^{j} = \rho^{j} = 1$.[17]

Intermediates enter the production function through a Cobb Douglas aggregator:

$$M_{it}^{j}(\omega^{j}) = \prod_{m} D_{it}^{jm}(\omega^{j})^{\psi^{jm}},$$

where D_{it}^{jm} denotes the demand for intermediates by sector j from sector m and $\sum_{m} \psi^{jm} = 1$ for all $j = 1, ..., J$. The parameters ψ^{jm} represent input-output coefficients.

We follow Eaton and Kortum (2002) assuming that the productivities of varieties $a_{it}^{j}\left(\omega^{j}\right)$ are random variables drawn from Frechet distributions independently across sectors and regions.

$$F_{it}^{j}(a) = \exp\left\{-x^{-\theta^{j}}\right\}.$$

The parameter θ^{j} captures the dispersion of draws in sector j. A lower value implies there is more dispersion in the draws and hence larger scope for gains from specialization.[18]

[17]In this case ϑ^{j} becomes the low-skill share in gross output, while ζ^{j} regulates the share of high-skilled in gross output.

[18]We normalize the mean level of productivity of the draws to one. As we argue in Section 2.9, we could add a region-sector specific productivity term to the model and our counterfactual simulations would remain the same under the assumption that productivity remains constant over time. Similarly, we abstract away from human capital and agglomeration spillovers. Previous literature such as Chauvin et al. (2017), Ahlfeldt et al. (2015) has found these agglomeration spillovers to be important. They can be added to the model using a functional form similar to Diamond (2016) and Tsivanidis (2021).

2.1.1 Financial Frictions and Unit Costs.

Variety producers face a working capital constraint. They need to finance all of their input purchases with a within-period loan at a gross interest rate $\varkappa_{it}^{j} \geq 1$. That is, given a unit cost of production net of financial frictions c_{it}^{j}, the total cost of producing one unit of variety ω^{j} in location i is given by $\varkappa_{it}^{j} c_{it}^{j}$.[19]

Constant returns to scale in the production function implies that the before trade costs and working capital cost of production is given by $\frac{c_{it}^{j}}{a_{it}^{j}(\omega^{j})}$, where:

$$c_{it}^{j} = \zeta_{i}^{j} \left[\left(P_{it}^{V} \right)^{\gamma^{j}} \left(\prod_{m=1}^{J} \left(P_{it}^{m} \right)^{\psi^{jm}} \right)^{1-\gamma^{j}} \right]. \tag{2}$$

In this expression, P_{it}^{m} is the price paid for inputs from sector m, and P_{it}^{V} is the unit price of value added, which is given by:[20]

$$P_{it}^{V,j} = \left[\vartheta^{j} \left(w_{it}^{u} \right)^{1-\sigma^{j}} + \left(1 - \vartheta^{j} \right) \left(P_{it}^{Z,j} \right)^{1-\sigma^{j}} \right]^{\frac{1}{1-\sigma^{j}}}.$$

This, in turn, is a combination of the wages of low-skilled workers, w_{it}^{u}, and the unit price of the high-skill capital composite, $P_{it}^{Z,j}$, which is given by:

$$P_{it}^{Z,j} = \left[\xi^{j} \left(w_{it}^{h} \right)^{1-\rho^{j}} + \left(1 - \xi^{j} \right) \left(r_{it} \right)^{1-\rho^{j}} \right]^{\frac{1}{1-\rho^{j}}}.$$

The unit price of the high-skill capital composite depends on w_{it}^{h}, r_{it}, which are the high-skill wage and the rental rate of capital in location i in time period t.

Factor Shares. Within each sector-region, denoting Y_{it}^{j} as gross output in sector j location i in time t, we define the share of gross output net of frictions that goes to payment of low-skilled, high-skilled, capital, and intermediates, respectively, as: $\varphi_{it}^{u,j} \equiv \frac{w_{it}^{u} u_{it}^{j}}{Y_{it}^{j} / \varkappa_{it}^{j}}$, $\varphi_{it}^{h,j} \equiv$

[19] An important thing to note is that the working capital constraint affects all factors of production (high- and low-skilled workers, intermediates, and capital) equally. That is, the payment of all of the factors need to be financed before production takes place. We make this assumption for two reasons: first, we can't observe the exact use of each loan in our dataset making it hard to discipline factor-specific constraints. Second, our specification implies that credit market frictions act as negative Hicks-neutral productivity shocks. Moll (2014) shows that this is consistent with a microfoundation in which heterogeneous producers face collateral constraints.

[20] ζ_{i}^{j} is a constant given by $\zeta_{i}^{j} \equiv \left(\gamma^{j} \right)^{-\gamma^{j}} \left[\left(1 - \gamma^{j} \right) \prod_{m=1}^{M} \left(\psi^{jm} \right)^{\psi^{jm}} \right]^{-\left(1-\gamma^{j}\right)}$

$\frac{w^h_{it}h^j_{it}}{Y^j_{it}/\varkappa^j_{it}}$, $\varphi^{k,j}_{it} \equiv \frac{r_{it}k^j_{it}}{Y^j_{it}/\varkappa^j_{it}}$, $\varphi^{m,j}_{it} \equiv \frac{P^j_{it}D^{jm}_{it}}{Y^j_{it}/\varkappa^j_{it}}$. Using the firm's FOCs, we can write these shares as:

$$\varphi^{h,j}_{it} = \gamma^j(1-\vartheta^j)\xi^j \left(\frac{P^{Z,j}_{it}}{P^{V,j}_{it}}\right)^{1-\sigma^j} \left(\frac{w^h_{it}}{P^{Z,j}_{it}}\right)^{1-\rho^j} \tag{3}$$

$$\varphi^{k,j}_{it} = \gamma^j(1-\vartheta^j)(1-\xi^j) \left(\frac{P^{Z,j}_{it}}{P^{V,j}_{it}}\right)^{1-\sigma} \left(\frac{r_{it}}{P^{Z,j}_{it}}\right)^{1-\rho} \tag{4}$$

$$\varphi^{u,j}_{it} = \gamma^j\vartheta^j \left(\frac{w^u_{it}}{P^{V,j}_{it}}\right)^{1-\sigma} \tag{5}$$

$$\varphi^{m,j}_{it} = (1-\gamma^j)\psi^{jm}. \tag{6}$$

2.2 Trade Costs and Prices.

Trade is costly subject to iceberg trade costs: $\tau^j_{nit} \geq 1$ units need to be shipped from i to n, in sector j, in time period t, for one unit to arrive. Given that firms price at marginal cost, the price to import variety ω^j to location n from location i is given by:

$$p^j_{nit}(\omega^j) = \frac{\varkappa^j_{it}c^j_{it}\tau^j_{nit}}{a^j_{it}(\omega^j)}.$$

Producers search across regions for the minimum cost. The actual price paid is given by:

$$p^j_{nt}(\omega) = \min_i \left\{ \frac{\varkappa^j_{it}c^j_{it}\tau^j_{nit}}{a^j_{it}(\omega^j)} \right\}.$$

The sectoral price index of sector j in region n is given by:

$$P^j_{nt} = \left[\int p^j_{nt}(\omega^j)^{1-\eta}d\omega\right]^{\frac{1}{1-\eta}}.$$

Using the properties of the Frechet distribution, the sectoral price index is given by:

$$P^j_{nt} = \Gamma^j \left[\sum_i \left(\varkappa^j_{it}c^j_{it}\tau^j_{nit}\right)^{-\theta^j}\right]^{-\frac{1}{\theta^j}}, \tag{7}$$

where $\Gamma^j \equiv \Gamma\left(\frac{\theta^j+1-\eta}{\theta^j}\right)$ is a constant that depends on θ^j.[21]

[21] $\Gamma(\cdot)$ refers to the Gamma function. Since the Gamma function is defined for positive values, this implies

Trade Shares. Following Eaton and Kortum (2002), the Frechet structure implies that the share of goods purchased in location n from location i in sector j is given by:

$$\pi^j_{nit} = \frac{\left(\varkappa^j_{it} c^j_{it} \tau^j_{nit}\right)^{-\theta^j}}{\sum\limits_{i'} \left(\varkappa^j_{i't} c^j_{i'} \tau^j_{ni't}\right)^{-\theta^j}}. \tag{8}$$

Denoting E^j_{nit} the expenditure in region n of sector j goods coming from i, and $E^j_{nt} = \sum\limits_i E^j_{nit}$ total expenditure. Then, π^j_{nt} is also the expenditure share, this is: $\pi^j_{nit} = \frac{E^j_{nit}}{E^j_{nt}}$.

2.3 Credit Markets: Financiers and Government Intervention.

We assume that foreign financiers can borrow at an exogenous rate $\tilde{r}$ and lend in any location-sector. There is free entry of financiers into credit markets, driving the cost of credit to location-sector specific marginal costs.[22] The cost per unit of output of monitoring a project in a location i sector j, denoted $\tilde{m}^j_{it}$, is exogenous and heterogeneous across locations. The total cost per unit lent is, hence, given by

$$m^j_{it} \equiv \tilde{r} + \tilde{m}^j_{it}, \tag{9}$$

making $\tilde{m}^j_{it}$ the credit spread in the model. The monitoring costs capture, for example, inefficiencies in bankruptcy procedures in local courts. The more inefficient bankruptcy procedures are the more costly it will be for financiers to monitor projects in that location sector.

The government observes the cost of credit in each market and can subsidize credit across regions and sectors by s^j_{it} per unit of output. As explained below, such subsidies are funded through taxation. Accounting for subsidies, the effective gross interest rate paid by

a restriction that $\theta^j > \eta - 1$. The parameter η does not play a role in the equilibrium of the model that follows.

[22]While previous literature has shown that bank competition in Brazil is an important factor in explaining changes in credit spreads (Joaquim et al., 2019), we abstract away from bank competition due to the added complexity of having a discrete number of banks. Modeling a discrete number of banks requires oligopolistic competition in the banking sector. This can be incorporated in the model using bank-location-sector specific nested Frechet shocks similar to Herreno (2020). In our context, estimates from the Central Bank of Brazil suggest that approximately 80% of the level of spreads is due to costs (Trafane Oliveira Santos, 2021) which suggests that the level of credit spreads is informative of costs in our context.

firms in location i sector j is given by:

$$\varkappa_{it}^{j} = 1 + m_{it}^{j} - s_{it}^{j}. \tag{10}$$

We assume that monitoring costs leave the economy as deadweight loss, similar to Liu (2019). In this sense, monitoring costs act like location-sector specific wedges that increase the cost of production.

2.4 Capital Accumulation

Capital is accumulated by immobile capitalists in each location i. Capital is freely mobile across sectors within locations.[23] They choose their consumption and investment to maximize their intertemporal utility subject to their budget constraint. Capitalists' intertemporal utility equals the discounted value of their flow utility:

$$\sum_{t=0}^{\infty} \beta^{t} \frac{(C_{it}^{k})^{1-1/\psi}}{1-1/\psi},$$

where the superscript k represents quantities related to the capitalist, ψ represents the elasticity of intertemporal substitution, and β is the discount rate. They have utility over a composite sectoral good:

$$C_{it}^{k} = \prod_{j=1}^{J} \left(C_{it}^{k,j} \right)^{\alpha^{j}}.$$

The intertemporal budget constraint requires that total income from existing stock of capital $r_{it}K_{it}$ equals total value of their consumption $\left(C_{it}^{k}\right)$, plus the total value of net investment, $X_{it} = (K_{it+1} - (1-\delta)K_{it})$. Capitalists pay a lump sum tax T_t to the government, which is used to finance credit subsidies.

$$r_{it}K_{it} = P_{it}C_{it}^{k} + P_{it}^{X} X_{it} + T_{t}. \tag{11}$$

The investment good is a composite of a sectoral bundle of investment goods with shares given by χ^{j}:

$$X_{it} = \prod_{j=1}^{J} \left(X_{it}^{j} \right)^{\chi^{j}}.$$

[23]We make this assumption due to data constraints: we do not observe sectoral capital accumulation.

The ideal investment price index in location i time period t is given by:

$$P_{it}^{X} = \varrho_i^x \prod_j \left(P_{nt}^j\right)^{\chi^j}, \tag{12}$$

while the ideal consumption price index in location i time period t is given by:

$$P_{it} = \varrho_n^c \prod_j \left(P_{nt}^j\right)^{\alpha^j},$$

where ϱ_n^x, ϱ_n^c are constants.[24]

The capitalists' problem can be solved in stages: across periods, they decide how much to save and consume of the bundle investment and consumption goods. Within each period, they decide how much to consume and invest in each sector. The problem is characterized by the following Euler equation:

$$\left(\frac{C_{it+1}^k}{C_{it}^k}\right)^{\frac{1}{\psi}} = \beta \frac{P_{it}}{P_{it+1}} \left\{ \frac{r_{it+1}}{P_{it}^X} + (1-\delta)\frac{P_{it+1}^X}{P_{it}^X} \right\}. \tag{13}$$

As we further argue in Section 2.8, allowing for heterogeneity in the relevance of sectoral goods in the aggregation of the consumption and investment goods —α^j and χ^j, respectively— generates heterogeneity in the degree to which consumption and investment respond to sectoral shocks. This, in turn, generates differences in the static and dynamic responses of regional variables depending on the sector that experienced the shock. For example, agricultural goods account for an important share of consumption (high α^j), but do not play a large role in investment (low χ^j). In this sense, local positive shocks to agricultural goods, such as agricultural credit subsidies, will have a large effect on local consumption prices but will have a smaller effect on local investment prices.

2.5 Worker Consumption and Migration

Workers are determined by their type $\ell \in \{u, h\}$ and their location n. They have log utility over consumption and amenities. Workers from both types spend their wage income and choose their consumption of varieties to maximize utility in each period. They consume

[24] Specifically, $\varrho^x \equiv \prod \left(\chi^j\right)^{-\chi^j}$ and $\varrho^c \equiv \prod \left(\alpha^j\right)^{-\alpha^j}$.

from all sectors through a Cobb Douglas bundle of sectoral goods:

$$C_{nt}^{\ell} = \prod_{j=1}^{J} \left(C_{nt}^{\ell,j}\right)^{\alpha^j}.$$

They supply one unit of labor inelastically in their location and earn wages w_{nt}^{ℓ}. Their maximization problem is given by:

$$\max_{C_{nt}^{\ell}} \quad \log(b_{nt}^{\ell} C_{nt}^{\ell}) \quad \text{s.t} \quad P_{nt} C_{nt}^{\ell} = w_{nt}^{\ell}.$$

There is free mobility across sectors within locations. The amenity only depends on the location in which they live.

Worker Migration Decisions. After supplying labor and spending wage income on consumption in each period t, workers observe location specific idiosyncratic mobility shocks and decide where to move next period. There is free mobility across sectors within locations.

The value function for a worker of type ℓ, in location i, in period t $\left(\mathbb{V}_{it}^{\ell}\right)$ is equal to the current flow of utility in that location plus the expected continuation value from the optimal choice of location:

$$\mathbb{V}_{it}^{\ell} = \log(C_{it}^{\ell}) + \log(b_{it}^{\ell}) + \max_{\{g\}_{g=1}^{I}} \left\{\beta \mathbb{E}\left[\mathbb{V}_{gt+1}^{\ell}\right] - \kappa_{git}^{\ell} + \nu^{\ell} \epsilon_{gt}^{\ell}\right\}.$$

We assume that the mobility shock is drawn from a Gumbel extreme value distribution $F(\epsilon) = e^{-e^{(-\epsilon-\bar{\gamma})}}$, and that migration costs satisfy $\kappa_{iit}^{\ell} = 0$ and $\kappa_{nit}^{\ell} > 0$ for $n \neq i$. These migration costs are measured in terms of utility.

Using the value function together with the indirect utility function and properties of the extreme value distribution, the expected value from living in location n at time t for a worker of type ℓ after taking expectations with respect to the idiosyncratic mobility shock, also referred to as the "lifetime utility" , $v_{it}^{\ell} \equiv \mathbb{E}_{\epsilon}\left[\mathbb{V}_{it}^{\ell}\right]$, can be written as:[25]

$$v_{it}^{\ell} = \log(C_{it}^{\ell}) + \log b_{it}^{\ell} + \nu^{\ell} \log\left(\sum_{g=1}^{N} \exp\left(\beta v_{gt+1}^{\ell} - \kappa_{git}^{\ell}\right)^{1/\nu^{\ell}}\right). \tag{14}$$

[25]See Appendix D.3.1 for detailed derivations.

Moreover, the out-migration shares are given by:

$$\mu_{nit}^{\ell} = \frac{\exp\left(\beta v_{nt+1}^{\ell} - \kappa_{nit}^{\ell}\right)^{1/\nu^{\ell}}}{\sum_{g=1}^{I} \exp\left(\beta v_{gt+1}^{\ell} - \kappa_{git}^{\ell}\right)^{1/\nu^{\ell}}}, \tag{15}$$

where μ_{nit}^{ℓ} is the out-migration probability from location i to n, between t and $t+1$ for individuals of type ℓ.

2.6 Government Budget Constraint

The government can subsidize credit across locations and sectors. It receives income from taxes:

$$\mathcal{I}_t = \sum_n T_t,$$

and spends resources in subsidizing credit. The total value of subsidies are given by:

$$\mathcal{S}_t = \sum_i \sum_j s_{it}^j \frac{Y_{it}^j}{\varkappa_{it}^j}.$$

The government maintains a balanced budget in every period.

$$\sum_n T_t = \sum_n \sum_j s_{nt}^j \frac{Y_{nt}^j}{\varkappa_{nt}^j}.$$

2.7 Market Clearing

Factor Market Clearing. In each period there is a stock of high-skilled and low-skilled workers in every location $\{H_{nt}, U_{nt}\}$. The demand of these factors must be equal to the supply. Market clearing can be written in terms of payments to factors as:

$$w_{it}^{u}U_{it} = \sum_{j} \varphi_{it}^{u,j} \frac{Y_{it}^{j}}{\varkappa_{it}^{j}} \tag{16}$$

$$w_{it}^{h}H_{it} = \sum_{j} \varphi_{it}^{h,j} \frac{Y_{it}^{j}}{\varkappa_{it}^{j}} \tag{17}$$

$$r_{it}K_{it} = \sum_{j} \varphi_{it}^{k,j} \frac{Y_{it}^{j}}{\varkappa_{it}^{j}}. \tag{18}$$

Markets for Non-Tradable Goods. Market clearing for non-tradable goods requires that total non-tradable production is equal to total non-tradable demand. Total non-tradable demand is composed by consumption, investment, and intermediate good consumption. In this sense, market clearing implies that:

$$Q_{nt}^{j} = C_{nt}^{j} + X_{nt}^{j} + \sum_{m} D_{nt}^{mj}.$$

We can also write this in terms of expenditure so that expenditure in region n sector j is given by:

$$E_{nt}^{j} = P_{nt}^{j}C_{nt}^{j} + P_{nt}^{j}X_{nt}^{j} + \sum_{m} P_{nt}^{j}D_{nt}^{mj}, \tag{19}$$

where $C_{nt}^{j} = C_{nt}^{u,j} + C_{nt}^{h,j} + C_{nt}^{k,j}$ is total consumption.

Goods Market Clearing. In order for the goods market to clear, we must have that total demand for location i sector j goods, which is given by the sum of the expenditures by all regions on these goods, is equal to sectoral gross production net of frictions in that location and sector. This is:

$$\frac{Y_{it}^{j}}{\varkappa_{it}^{j}}(\varkappa_{it}^{j} - m_{it}^{j}) = \sum_{n} \pi_{nit}^{j}E_{nt}^{j}. \tag{20}$$

Total Expenditure. We can write the goods market clearing condition 19 using equation 20 as:

$$E_{nt}^{j} = \alpha^{j}\left[w_{nt}^{h}H_{nt} + w_{nt}^{u}U_{nt} + r_{nt}K_{nt} - P_{nt}^{X}X_{nt} - T_{t}\right] + \cdots$$
$$\cdots + \chi^{j}\frac{P_{nt}^{j}X_{nt}^{j}}{r_{nt}K_{nt}}\sum_{m}\varphi_{n}^{k,m}\sum_{i}\pi_{int}^{m}E_{it}^{m} + \sum_{m}\left(1-\gamma_{n}^{m}\right)\psi_{n}^{mj}\sum_{i}\pi_{int}^{m}E_{it}^{m}. \tag{21}$$

Balanced Trade. We assume that trade is balanced across locations. This implies that total expenditure by a region, across all sectors, has to be equal to its total sales, which in turn are equal to gross production net of frictions.

$$\sum_{j}E_{it}^{j} = \sum_{j}\frac{Y_{it}^{j}}{\varkappa_{it}^{j}}(\varkappa_{it}^{j} - m_{it}^{j}). \tag{22}$$

Population Flow Condition. The population flow condition for the evolution of the population distribution over time is given by:

$$U_{nt+1} = \sum_{i=1}^{N}\mu_{nit}^{u}U_{it} \tag{23}$$
$$H_{nt+1} = \sum_{i=1}^{N}\mu_{nit}^{h}H_{it}. \tag{24}$$

2.8 Equilibrium and Steady State.

The endogenous state of the economy is given by the distribution of high-skilled and low-skilled workers across regions, as well as the capital stocks in each location $\{H_{nt}, U_{nt}, K_{nt}\}$. The fundamentals in this economy are given by trade costs, migration costs, and amenities, $\tau_t \equiv \{\tau_{nit}^{j}\}, \kappa_t \equiv \{\kappa_{nit}^{\ell}\}$, $b_t \equiv \{b_{it}^{\ell}\}$, which we jointly denote as $\Omega_t \equiv (\tau_t, \kappa_t, b_t)$. The government policy variable is given by subsidies across locations and sectors $s_t \equiv \{s_{it}^{j}\}$. Monitoring costs across locations and sectors are denoted by $m_t \equiv \{m_{it}^{j}\}$. With these definitions in mind, an equilibrium in this model is defined as follows:

Definition 2.1. *Equilibrium.* Given the state variables $\{U_{n0}, H_{n0}, K_{n0}\}$ in an initial period $t = 0$, and given a path of time varying fundamentals $\{\Omega_t\}_{t=0}^{\infty}$, of policy variables $\{s_t\}_{t=0}^{\infty}$, and of frictions $\{m_t\}_{t=0}^{\infty}$, an equilibrium is a sequence of wages, rental rates, expected value functions, mass of workers by skill type, and stock of capital in each location $\{w_{nt}^{h}, w_{nt}^{u}, r_{nt}, v_{nt}^{h}, v_{nt}^{u}, U_{nt+1}, H_{nt+1}, K_{nt+1}\}_{t=0}^{\infty}$ such that in each time period: factor shares are given by equations 3, 4, and 5; sectoral prices are given by equation 7; trade shares are given by equation 8; factor markets clear by equations 16, 17, and 18; goods market clear for each sector 20; sectoral expenditures are given by equation 21; and trade is balanced in equation 22. Moreover, dynamic decisions are determined as follows: investment and consumption decisions satisfy the capitalist budget constraint 11 and the Euler equation 13, migration decisions are given by equations 15, and population flows are given by equations 23 and 24.

Steady State. We define a steady state in the model as an equilibrium in which all regional endogenous variables do not change over time. Formally:

Definition 2.2. *Steady State Equilibrium.* A steady state in this economy is an equilibrium in which all endogenous variables $\{w_n^{h*}, w_n^{u*}, r_n^*, v_n^{h*}, v_n^{u*}, U_n^*, H_n^*, K_n^*\}$, as well as exogenous fundamentals, frictions, and policy variables $\{\Omega^*, m^*, s^*\}$ are constant across time.

Financial Frictions, Trade, and Steady State Capital. To gain some intuition of the forces underlying the model, we do comparative statics on the steady state capital stock. The steady state capital stock in location n is determined by the Euler equation:

$$r_n^* = P_n^{X^*}\left[\frac{1}{\beta} - (1-\delta)\right]. \tag{25}$$

Plugging in the expression of the price of investment in equation 12 into the steady state expression of the rental rate of capital in equation 25, we can show that the rental rate of capital in steady state is proportional to the price of investment, which in turn is determined by trade costs, unit costs, and working capital costs across space:

$$r_n^* \propto \prod_j \left(\left[\sum_i \left(\varkappa_i^{j*} c_i^{j*} \tau_{ni}^{j*} \right)^{-\theta^j} \right]^{-\frac{1}{\theta_j}} \right)^{\chi^j}.$$

Suppose that the there is a change in the friction of location i sector j due to, for example, government subsidies. Taking comparative statics, we show that the change of the rental rate of capital in steady state in location n is given by:

$$d\log\left(r_n^*\right) = \underbrace{\chi^j \pi_{ni}^{j*} d\log\left(\varkappa_i^j\right)}_{\text{Direct Effect}} + \underbrace{\sum_{j'}\sum_{i'} \chi^{j'} \pi_{ni'}^{j'*} d\log\left(c_{i'}^{j'}\right)}_{\text{GE Effect/IO/Migration}}. \tag{26}$$

A change in the working capital constraint of a location n sector j will have a direct effect and an indirect effect through general equilibrium forces. Focusing on the direct effect, a reduction in frictions on location i sector j will have a larger effect on the steady state capital stock in location n (r_n^*) if the good is used intensively for investment (large χ^j), and if the treated region is an important trading partner of location n (large π_{ni}^{j*}). Crucially, the endogenous responses through migration and input-output linkages will also matter as, in general equilibrium, they will change the underlying costs of different regions and sectors ($c_{i'}^{j'}$), which are captured by the second effect on the right.

This equation highlights the main forces that mediate how reducing financial frictions affect the steady state capital stock of different locations: the tradability of goods (π_{ni}^{j*}), the sectors targeted and how important they are for investment (χ^j), and general equilibrium forces through input-output linkages and migration.

2.9 Dynamic Exact Hat Algebra

Solving the equilibrium in our dynamic spatial general equilibrium model requires having data on the future path of the time varying fundamentals $\{\Omega_t\}_{t=0}^{\infty}$, which is typically not available for a researcher.

To overcome this challenge, we extend dynamic hat algebra results from Caliendo et al. (2019) and Kleinman et al. (2022) to our setting with financial frictions, skill types, and CES production functions. We assume that we observe the spatial distribution of economic activity somewhere in the transition path towards an unobserved steady state. Denoting variables in time differences as ($\dot{x}_{t+1} = x_{t+1}/x_t$), we define a convergent sequence of fundamentals, of policy variables, and frictions as a sequence of changes $\dot{\Omega}_t \equiv \left(\{\dot{\tau}_{nit}^j\}_i, \{\dot{\kappa}_{nit}^\ell\}_i, \{\dot{b}_{it}^\ell\}_{i,\ell}\right)$, and $\dot{m}_t \equiv \left(\{\dot{m}_{it}^j\}_j,\right)$, $\dot{s}_t \equiv \left(\{\dot{s}_{it}^j\}_j\right)$, such that, in the limit, these variables do not change over time:

$$\lim_{t\to\infty} \dot{\Omega}_t = 1, \lim_{t\to\infty} \dot{m}_t = 1, \lim_{t\to\infty} \dot{s}_t = 1.$$

With these definitions in mind, we now turn to the main proposition related to dynamic exact hat algebra. Given the initial observed endogenous variables, one can solve for the economy's transition path in time differences for any anticipated convergent sequence of changes of fundamentals, policy variables, or frictions, without having to observe the initial level of fundamentals. Formally:

Proposition 2.1. *Dynamic Exact Hat Algebra*. Given an initial allocation of the economy $\left(\{U_{n0}\}_n, \{H_{n0}\}_n, \{K_{n0}\}_n, \{K_{n1}\}_n, \{\varphi_{n0}^{j\ell}\}_{n,j,\ell}, \{\pi_{ni0}^j\}_{n,i,j}, \{\mu_{ni-1}^\ell\}_{n,i,j,\ell}\right)$, and initial levels of the monitoring costs and subsidies $\left(\{m^j_{n0}\}_{n,j}, \{s^j_{n0}\}_{n,j}\right)$, then, given a convergent sequence of changes in fundamentals $\left(\{\dot{\tau}^j_{nit}\}_i, \{\dot{\kappa}^\ell_{nit}\}_i, \{\dot{b}^\ell_{it}\}_{i,\ell}\right)$, as well as a convergent sequence of changes in subsidies and frictions $\left(\{\dot{m}^j_{it}\}_j, \{\dot{s}^j_{it}\}_j\right)$, one can solve for the model in changes without information on the initial value of the fundamentals.

Proof. See Appendix D.1. □

2.10 Computing Counterfactuals

From Proposition 2.1, we can solve for a baseline economy without explicitly estimating the initial levels of fundamentals. We can use a similar strategy to study counterfactuals in which fundamentals, subsidies, or frictions change. When solving for counterfactuals in our dynamic model, we assume that agents at $t = 0$ do not anticipate the change in the path of either the fundamentals, the frictions, or the subsidies, and that at time $t = 1$, they learn about the entire future counterfactual sequence of fundamentals, frictions, or subsidies. Under this assumption, we can solve for the dynamic responses of agents' in a counterfactual, comparing the effects of a particular policy relative to what would have happened had there have been no change at all.

We use these results to numerically solve the model in Section 5, where we explore counterfactuals related to the two main drivers of heterogeneity in the cost of credit across space in our model, $\{\varkappa^j_{it}\}$: subsidies, $\{s^j_{it}\}$, and frictions $\{m^j_{it}\}$. Before that, we describe empirical results on the effect of place-based firm credit subsidies on local labor markets.

3 Empirical Findings: Local Labor Market Effects of Firm Credit Subsidies

Guided by the model, this section documents empirical results on the effects of credit subsidies on local labor markets in Brazil. We estimate the causal impact of credit subsidies exploiting a place-based policy that differentially subsidized credit for firms operating within a particular region in Brazil.

3.1 Context: Credit Place-Based Policies in Brazil

Brazil is divided into five regions—South, Southeast, Midwest, Northeast, and North—containing 26 states and a Federal District, Brasilia. Historically, the Southeast and the Northeast have been the most populated regions with 45% and 30% of the population respectively, followed by the South with 15% (Figure A1a). The Midwest and the North are the least populated with less than 10% each.

In terms of GDP per capita, the story is quite different: the Southeast, and, more recently, the Midwest and the South, have been the main poles of economic activity in the country. On the other hand, the Northeast and the North have lagged behind in terms of growth (Figure A1b). There has been little sign of convergence from these two regions since 1920: in fact, the GDP per capita of the Northeast was 40% that of the Southeast in 1920, and the gap has widened 90 years later, being 38% in 2010 (Figure 1).[26]

Worried about such spatial inequality, the Brazilian government instituted several place-based policies related to credit after the promulgation of the 1988 Constitution. The main tool to implement these policies were the National Constitutional Funds (CFs), also known as the Regional Funds. These funds receive permanent resources each year coming from 3% of the sum of total income taxes (*Imposto de Renda*) as well as taxes on manufacturing goods (*Imposto sobre Produtos Industrializados*), which are used to subsidize credit for firms operating in the North, Northeast, and Midwest.[27]

The objectives of this policy, as written in the 1988 Constitution, were to: "(...) contribute to the economic and social development of the North, Northeast and Midwest (...) by executing financing programs for productive sectors (...)." Additionally, CFs must give "(...) preferential treatment to the productive activities of small and mini-scale rural producers (...)," and should support the "(...) creation of new, dynamic centers, activities, and hubs, notably in inland areas, to reduce intra-regional income disparities (...)" (Pereira et al., 2019).[28]

There is one fund per lagging macro-region, and each fund is operated by particular banks: *Banco do Nordeste* operates the fund for the Northeast, *Banco da Amazonia* operates the fund for the North, and the *Banco do Brasil* operates the fund for the Midwest region. The operator banks of the regional development funds are responsible for analyzing and deciding whether to award the subsidized loans to applicants. Applicants can be individuals, small businesses, enterprises, or cooperatives/associations that want to finance a new business or an existing one located in these regions.

[26] Previous literature has explored the reasons behind the observed spatial inequality in Brazil. Naritomi et al. (2012) argue that local institutional quality across Brazil was in part inherited from the colonial era. Fujiwara et al. (2022) argue that municipalities with more slavery during the colonial era have lower state capacity and higher income inequality today. Bird and Straub (2017) study the role of transportation infrastructure investments between 1960 and 2000s on the spatial allocation of population and economic activity.

[27] These three regions were defined by the government as the three "lagging" macroregions.

[28] See Resende (2013) for a summary of the literature that has studied regional policies in Brazil.

Semiarido Policy and Discontinuity. Even within regions, the government has differentially targeted particular subregions. For example, by law, 50% of the loans from the Northeast fund have to be allocated to the "Semiarido" region (Figure 2a). This area is known for its semiarid climate. It is one of the poorest regions in Brazil, yet it is also highly populated with more than 12% of the population living in it.

Its boundary was defined by the Northeast Development Superintendency (*SUDENE*) based on average rainfall: municipalities within the Northeast that had less than 800mm of rainfall per year were defined as being part of Semiarido. This geological region crosses eight different states with Semiarido status varying across municipalities, within a given state, across the boundary.

3.2 Data

To study the local labor market effects of firm credit subsidies, we combine different data sources: administrative data from the credit registry, four waves of the population census, publicly available data on credit at the municipality year level, as well as other relevant datasets such as agricultural yields and rainfall measures.[29]

Population Census. We use microdata from four waves of the population census in Brazil: 1980, 1990, 2000, and 2010. This data contains detailed information on the sector, wage, education, and location of individuals in Brazil. We restrict the sample to workers between the ages of 25 and 64 so as to abstract from human capital accumulation considerations given that these forces are not considered in the model.[30] We define high-skilled workers as having more than or equal to high school following the definition that has been used in previous literature for Brazil (Fonseca and Van Doornik, 2022).

Universe of Bank Loans from the Credit Registry (SCR). The Central Bank of Brazil collects information on all loans made to firms in Brazil through its credit registry, known as SCR (*Sistema de Informações de Crédito*). This is an administrative dataset with detailed information on the interest rate charged, the volume of the credit, the zip code of the firm, as well as bank and firm identifiers. It is available starting in 2003. Each loan contains information on the origin of the resources used for such loan, distinguishing on whether the loan is subsidized by the government or not. We aggregate the dataset at the municipality-year-loan type level (subsidized or not) for the empirical analysis.

[29] We use AMCs as our geographical unit ("*Area Mínima Comparável*"). These units of aggregation take into account the fact that municipality borders change over time, and can be consistently compared across time. Throughout the text, we use "municipality" interchangeably with "AMCs".

[30] A benefit of using the population census is that it includes information on all individuals regardless of their formality status. This is important in our context since informality accounts for 50% of employment in Brazil (Ulyssea, 2018; Dix-Carneiro et al., 2021).

Local Bank Balance Sheets (ESTBAN). The Central Bank of Brazil also maintains a publicly available dataset aggregated at the bank branch-month level with information on outstanding credit called ESTBAN (*Estatística Bancária Mensal*). The data has a long panel structure starting from 1988. It distinguishes between agricultural credit and non-agricultural credit. We aggregate the data to the municipality-year level.

Other Sources of Data. We also obtain information on time-invariant relevant characteristics at the municipality level. Specifically, we obtain potential crop yield data for different crops from FAO GAEZ, as well as rainfall data from PERSIANN-Cloud Classification System (PERSIANN-CCS).

3.3 Empirical Strategy: Dynamic Regression Discontinuity

Studying the effects of local firm credit subsidies through the regional funds on municipality outcomes is challenging, among other reasons, because treatment is defined at the region level, and hence, it does not vary within states. Any time-varying state policy will confound treatment as we will not be able to disentangle the effect of the credit subsidies with other time-varying state policies.

We overcome this challenge by exploiting the differential treatment across the Semiarido boundary, which, as discussed above, was defined based on geological features at the municipality level: municipalities with less than 800mm of rainfall were defined as being part of Semiarido. The subsidy allocation rule by the government indicates that 50% of all subsidies in the Northeast have to go to firms within the Semiarido boundary, generating plausibly exogenous variation in the supply of credit, and of credit subsidies, across space. We use that variation to study the effects of the credit subsidies on municipality outcomes.

We use a Dynamic Regression Discontinuity design that compares municipalities just outside the border of the Semiarido region versus municipalities just inside the border, over time. The regression specification we use is the following:

$$y_{ms(m)t} = \alpha_m + \alpha_{s(m)t} + \sum_{\tau} 1\{\tau\} \left[\beta_{1\tau} Semi_m + \gamma_\tau g(Lat, Lon)_m + \boldsymbol{\beta_\tau} \boldsymbol{X}'_{ms(m)\tau}\right] + u_{ms(m)t} \tag{27}$$

In this regression, $y_{ms(m)t}$ is an outcome for municipality m, located in state $s(m)$, in year t, $Semi_m$ is a dummy for whether the municipality m, is within the Semiarido region, $g(Lat, Lon)_m$ is a polynomial in latitude-longitude so as to compare municipalities across the border within similar geographic regions in latitude-longitude space (Dell, 2010; Dell and Olken, 2020; Méndez-Chacón and Van Patten, 2021), and $\boldsymbol{X}_{ms(m)t}$ is a vector of time-varying controls. We use a linear polynomial on latitude and longitude space based on Gelman and Imbens (2019).[31] We include municipality and state-year fixed effects in the regression. The latter allows us to control for any policy that varies at the state level across time. We include as controls distance to the coast interacted with time dummies. We use a 50km bandwidth across the border for the main specification. The sample of treatment and control municipalities is shown in Figure 2b.

One requirement for the empirical strategy is that relevant factors besides treatment vary smoothly at the boundary before the policy so that municipalities just outside the boundary are an appropriate counterfactual for those inside the boundary. To test for whether the regions are similar in time-invariant and pre-reform characteristics, we use 1980 census outcomes, average potential yields across all crops from FAO GAEZ, as well as average rainfall information. We run the follow specification, normalizing all outcomes to standard deviation units.

$$y_{ms(m)1980} = \alpha_{s(m)} + \beta_1 Semi_m + \gamma g(Lat, Lon)_m + \boldsymbol{\beta}' \boldsymbol{X}_{ms(m)} + u_{ms(m)} \tag{28}$$

Results of this specification are shown in Table 1. Reassuringly, we find that all outcomes are balanced in the pre-period. Consistent with the definition of the boundary, we find that rainfall has a negative coefficient, but it is not statistically significant.

3.3.1 Main Results: Effect of Semiarido Policy on Credit and on Real Outcomes

In this section, we explore the main empirical results. We find that the policy generated an increase of 30% on agricultural credit for treated municipalities. Moreover, credit registry data indicates that credit subsidies were differentially larger for agriculture, but not for manufacturing. We find a positive but insignificant effect on subsidies for the service sector. In terms of real effects we find that 20 years after the policy, treated municipalities become more agricultural-oriented and less skill-intensive.

Effects on Credit. We begin by exploring the effects of the policy on credit outcomes. Figure 3a shows the results of running specification 27 with the outcome being the log of agricultural credit.[32] The figure shows that treatment and control municipalities behave similarly in terms of total credit until the mid-1990s after which agricultural credit starts to

[31]The Semiarido boundary was updated in 2005 to include 100 more municipalities. We exclude them from the main analysis to avoid issues related to treatment timing. Results are robust to their inclusion as well.

[32]Due to data availability, we only have one pre-period year in the credit data. Nonetheless, for the real outcomes we use the population census in which we can compare municipality level outcomes 10 years before the policy and find no evidence of pre-trends as well.

differentially increase in Semiarido municipalities relative to those outside the boundary.[33] In Figure 3b, we also find that other sources of credit increase in Semiarido region starting in the mid 1990s.[34] This is consistent with the intent of the policy, which was supposed to differentially target credit and credit subsidies to municipalities within Semiarido.

In Table 2, we show the coefficients on a regression in which we categorize all years after 1990 as being in the post period through the following specification:

$$y_{ms(m)t} = \alpha_m + \alpha_{s(m)t} + \beta_1 SemiA_m + \beta_2 SemiA_m \times Post_t + \gamma_1 g(Lat, Lon) + \gamma_2 g(Lat, Lon) \times Post_t + \boldsymbol{\beta X}'_{ms(m)t} + u_{ms(m)t} \tag{29}$$

The difference in difference coefficient indicates that overall credit increased in treated municipalities by around 24% while agricultural credit increased by 28%. In general, these results suggest that, as intended by the policy, municipalities in Semiarido experienced a credit supply shock relative to municipalities just outside it.

Effects on Credit Subsidies. The previous section showed that overall credit as well as agricultural credit increased in Semiarido. In this section we further explore the sectoral allocation of subsidies using the credit registry. Specifically, while the policy does not explicitly mention which sectors are targeted, we can use the credit registry to back out measures of subsidies by sector directly. In order to do this, we compute subsidies at the location m sector j level as:

$$s^j_{mt} = \left(\frac{\text{Subsidized Credit}^j_{mt}}{\text{Total Credit}^j_{mt}} \right) \left[R^{j,n}_{mt} - R^{j,d}_{mt} \right],$$

where $R^{j,n}_{it}$ is the loan-weighted average credit spread in location i sector j for non-directed loans (non-subsidized), and $R^{j,d}_{it}$ is the loan-weighted average credit spread for directed loans (subsidized).[35] We compute subsidies for three broad sectors: agriculture, manufacturing, and services.

The Credit Registry data is available starting in 2003, so we run the static version of the regression discontinuity separately by sector j taking the average subsidy from 2003 to

[33]While the policy started in 1988, we find that there is a lag between implementation and the effects. As discussed in Appendix A, and particularly as shown in Figure A3, Brazil underwent a hyperinflation period between 1988 and 1995, making it hard to implement such policy during this period.

[34]Other sources of credit include credit for housing, consumer credit, and firm credit to non-agricultural sectors.

[35]We further explain the computation of subsidies in Appendix C.1.

2010. We run the following specification:

$$s_m^j = \alpha_{s(m)} + \beta_1^j Semi_m + \gamma g(Lat, Lon)_m + \boldsymbol{\beta}' \mathbf{X}_{ms(m)} + u_{ms(m)}^j \tag{30}$$

The results of this specification are shown in Table 3. The implied subsidies for agriculture are found to be 1.24 percentage points larger within Semiarido relative to municipalities outside Semiarido, representing an increase of 34% of the mean agricultural subsidy. We find a positive but insignificant effect for services. On the other hand, the coefficient on the manufacturing subsidies is close to zero and not statistically significant.

Taken together results suggest that, as intended by the policy, there was a large increase in credit in municipalities within Semiarido. Moreover, we find that implied subsidies were larger for agriculture within Semiarido. We next turn to study whether this credit shock had long-run real effects on treated labor markets.

Effects on Real Outcomes: Sectoral Composition and Skill Intensity. After characterizing the effect of regional funds on credit outcomes, we explore the effects on sectoral composition and skill composition, as they speak directly to the model. To do so, we exploit the four waves of population census from 1980 to 2010 and build measures of sectoral employment shares, as well as skill composition and wage premium.[36]

We first explore the effects of the policy on sectoral composition running specification 27 with the dependent variable being the share of employment within a local labor market in different sectors. Focusing on the share of workers in agriculture (Figure 4a), we find no evidence of pre-trends with the difference in sectoral composition before the policy being similar across the border before the policy. Yet, over time, municipalities in Semiarido become more agricultural with the share of workers in agriculture increasing by 2 percentage points 20 years after the policy. In contrast, the share of workers in manufacturing decreases over time (Figure 4b), with treated municipalities experiencing a decrease of 2 percentage points in the share of workers in manufacturing during the same time frame.

To understand the overall effects, the first two columns of Table 4 show the results from running specification 29 with sectoral composition as outcomes. We find that the point coefficients of agricultural employment and manufacturing employment shares are of the same magnitude but with the opposing signs: results suggest that workers moved from manufacturing towards agriculture, with the share of workers in manufacturing seeing

[36]We measure skilled workers as those having a high school education or above. In terms of wage premium, we measure it as the relative average hourly wage for high- and low-skilled workers.

a decline of 6% relative to the mean, and the share of primary workers experiencing an increase of 3% relative to the mean.

Finally, we study the effects on skill composition and wage inequality. Figure 5a shows the results when using the skill ratio as a dependent variable in equation 27. Similar to what we found with sectoral composition, we find no evidence of pre-trends, and over time treated municipalities become less skill intensive. An important thing to note is that these results are driven by migration and not by human capital accumulation decisions, since we restricted the sample throughout to working age population.

In terms of the wage premium, Figure 5b studies the dynamic coefficients of specification 27 with the dependent variable being the wage premium. As shown in the graph, we find that, despite the fact that there was a large decrease in the share of high to low-skilled workers, the wage premium remains relatively constant with a point coefficient close to zero. In fact, columns 3 and 4 of Table 4 suggest that treated labor markets become more low-skill intensive but the point coefficient of the wage premium is actually negative.

3.3.2 Taking Stock: Effect of Agricultural Credit Subsidies on Sectoral Employment and Skill Composition

Overall, these results show that, as intended, the policy increased the supply of credit in treated municipalities. Using the credit registry, we find that subsidies were differentially targeted towards agriculture in treated municipalities. In the long-run, these municipalities became more agricultural, less skill-intensive, and wage inequality did not increase. How can one rationalize these results through the lens of the model?

In order to develop intuition, we simulate the effects of an agricultural subsidy in a simplified version of the model with 2 regions and 3 sectors in Appendix B. We highlight that two forces —the tradability of manufactured goods and the degree of capital-skill complementarity in agriculture— affect the magnitude and direction of the observed sectoral, skill composition, wage inequality responses.

Starting with sectoral composition, the simulations show that the magnitude of the shift towards agricultural employment given a local agricultural subsidy depends on the degree to which manufacturing goods can be imported from other regions. When manufactured goods are non-tradable, the expansion of agriculture brought forth by the subsidy will require the production of manufactured inputs that have to be locally produced. This means that some employment will have to go into manufacturing, reducing the magnitude of the local employment shift towards agriculture and increasing, at least in part, manufacturing employment.[37] On the other hand, when manufactured goods are highly tradable across regions the shift towards agriculture will be magnified, as forces related to comparative advantage will come into play, allowing the subsidized region to specialize in the sector that was subsidized (Matsuyama, 1992).

Focusing on the skill composition and wage inequality effects, the simulations shows that the effects of a local agricultural subsidy on these two variables depends on whether capital differentially complements high-skilled or low-skilled workers in agriculture. This is governed by the factor elasticities of substitution of the sectoral production function $\{\sigma^{Agro}, \rho^{Agro}\}$.[38] An agricultural subsidy will generate an expansion in agriculture, which in turn will require capital accumulation. If such capital differentially complements high-skilled workers ($\sigma^{Agro} > \rho^{Agro}$) (capital-high skill complementarity), the expansion of agriculture will generate a relative increase in the demand for high-skilled workers. If, on the other hand, capital differentially complements low-skilled workers in agriculture ($\sigma^{Agro} < \rho^{Agro}$) (capital-low skill complementarity) the expansion in agriculture will lead to an increase in relative demand for low-skilled workers. Hence, the response in relative quantities (skill ratio) and relative prices (wage inequality) depend on these parameters of the model.

In the next section, we quantify the model emphasizing these two forces: tradability of goods across sectors and complementarity between factors in agriculture. To do so, we estimate the intra-regional trade elasticity by sectors by building estimates of transport costs across Brazil. In terms of the degree of complementarity between factors in agriculture, we use the reduced-form evidence to discipline the model through a method of simulated moments. In what follows, we describe the data that we use for model quantification, and the estimation and calibration of the main parameters of the model.

4 Model Quantification and Estimation

This section describes how we take the model to the data, how we estimate relevant parameters for the model, and how we calibrate the rest. We first describe the data used to perform dynamic exact hat algebra. We then turn to the estimation and, finally, to the calibration of the rest of the parameters of the model.

[37] In fact, a similar argument was made by Rostow (1959) in explaining the sudden increase in manufacturing employment during the Industrial Revolution brought forth by improvements in productivity in agriculture.

[38] As a reminder, σ^{Agro} measures the elasticity of substitution between low-skilled workers and capital, and ρ^{Agro} measures the elasticity of substitution between high-skilled workers and capital. Capital will be neutral in the production function in the Cobb Douglas case, when $\rho^{Agro} = \sigma^{Agro} = 1$.

4.1 Taking the Model to the Data

Implementing the dynamic exact hat algebra procedure requires data on the distribution of high- and low-skilled workers across space $\{U_{n0}\}_n$, $\{H_{n0}\}_n$, initial capital stocks by region $\{K_{n0}\}_n$, $\{K_{n1}\}_n$, the initial share of output going to factors $\{\varphi^{j\ell}_{n0}\}_{n,j,\ell}$, bilateral trade flows by sector $\{\pi^j_{ni0}\}_{n,i,j}$, initial migration flows by skill type $\{\mu^\ell_{ni-1}\}_{n,i,j,\ell}$, as well as initial subsidies and monitoring costs $\{m^j_{n0}\}_{n,j}$, $\{s^j_{n0}\}_{n,j}$. We describe the data sources used to obtain them.

Regions and Sectors. For the quantitative implementation of our model, we aggregate the data at the mesoregion level and focus on three main sectors: agriculture, manufacturing, and services.[39] We choose the mesoregion aggregation for computational feasibility and also because it is a market definition that has been extensively used before in the literature (Dix-Carneiro and Kovak, 2015, 2017; Porcher, 2019).[40] In terms of the sectoral aggregation, we choose these three sectors due to data constraints particularly related to obtaining factor value-added shares by sector as mentioned below.

Distribution of Workers, Migration, and Capital. We use the 2000 population census aggregated at the mesoregion level to measure the distribution of workers by skill type across space as well as to obtain a measure of the initial migration matrix using retrospective questions related to migration.

Measuring the capital stock at disaggregated units is challenging in our context because no publicly available regional capital stock measures exists.[41] To overcome this challenge, we proxy for the capital stock using a regionally disaggregated housing stock series obtained from the regional accounts in IPEA.

Factor Value-Added Shares by Sector. We obtain initial factor value-added shares by matching regional-sectoral GDP estimates from IPEA. Given information on the wage bill by skill and sector obtained from the population census, we obtain the value-added share by sector and skill type dividing the wage bill over sectoral GDP. We obtain the capital

[39] The 27 states in Brazil are grouped into 3,830 AMCs, in turn divided into 136 mesoregions.

[40] Solving a dynamic spatial general equilibrium model with 3,830 regions and three sectors would imply that, within each time period, the trade flow matrix would have more than 14 million entries. Solving the model for 100 years would require information on 14 billion entries just for the trade matrix, making it computationally challenging to solve.

[41] Previous literature has used confidential data on site to measure capital stock at the state level (Fally et al., 2010) but these sources have not been available due to the pandemic.

share as a residual.[42]

Trade Data. Cross-region trade information is obtained from the intra-regional trade matrix compiled by NEREUS (*Núcleo de Economia Regional e Urbana da Universidade de São Paulo*) for 2008 (Guilhoto et al., 2010). The original data is available at the state-sector level for 26 different sectors. We aggregate the data to the three broad sectors used in the model and impute trade flows at the mesoregion level using a gravity procedure as in Adao et al. (2019).

Intermediate, Consumption, and Investment Shares. We obtain the input-output coefficients ψ^{jm}, as well as the consumption α^j, and investment shares χ^j from intra-regional input-output matrix (Guilhoto et al., 2010).

Monitoring Costs and Subsidies. We use credit registry data to measure location-sector monitoring costs and subsidies. To do so, we exploit the fact that the credit registry distinguishes subsidized versus non-subsidized loans. As explained in Appendix C.1, we measure the implicit subsidy for a location-sector as a share-weighted difference between the non-subsidized interest rate minus the subsidized interest rate. On the other hand, we measure monitoring costs directly as loan-weighted average non-subsidized interest rates based on equation 9.[43]

4.2 Estimation of Elasticities

In this section, we describe how we estimate the main elasticities of the model. We first describe how we estimate the sectoral trade elasticities. We then describe how we use the reduced-form evidence to discipline the elasticity of substitution between capital and high/low-skilled workers in agriculture through a method of simulated moments. Finally, we describe the values we use for the other parameters of the model.

4.2.1 Trade Elasticity Estimation

To measure transport costs, we parametrize $\tau^j_{ni} = Minutes^{\delta}_{ni}$ as Pellegrina (2022), where $Minutes_{ni}$ measures the amount of time it takes to go from origin i to destination n through

[42] Reassuringly, we find that such method delivers an aggregate labor share of 0.51, close to aggregate estimates of 0.54 for Brazil (Reinbold et al., 2018).

[43] As a reminder, given the assumption of marginal cost pricing, the observed gross interest rates across locations are directly informative of the marginal costs of lending. This is why we can obtain monitoring costs as average interest rates for non-subsidized loans.

the road network. We use data on the Brazilian road network obtained from the National Road System (*SNV –Sistema Nacional de Viação*) to compute this variable solving the shortest route through the network for all origins and destinations using ArcGIS network analyst package (Figure A7).[44]

Using these transport costs estimates together with intra-regional trade data, we run a sectoral gravity equation to recover sectoral trade elasticities:

$$\log(\pi^j_{ni}) = \delta^j_i + \delta^j_n - \theta^j \delta \log(Minutes_{ni}) + u^j_{nit} \tag{31}$$

The results from this specification are shown in Table 5.[45] Results indicate that agriculture and manufacturing have a similar degree of tradability across regions in Brazil, with the trade elasticity of agriculture being 5.3 and that of manufactured goods being 6.4. On the other hand, services have a higher trade elasticity of 10.1, which implies that they are relatively non-tradable.

The fact that agriculture and manufacturing are similarly tradable in Brazil indicates that agricultural credit subsidies are likely to reinforce sectoral composition rather than generate manufacturing employment given that regions can import manufactured goods from other regions. To see this more clearly, we plot the own trade share by sector in the baseline period —that is, the share of all expenditures within a location-sector that is produced by that particular location (Figure 6). As shown in that plot, the Northeast of the country, which was the main target of the policy we studied in Section 3, tends to produce very little manufacturing goods, while the Southeast is the main hub of production for this sector. In this sense, the data suggests that local subsidies in the Northeast will have a hard time generating a large sectoral shift to manufacturing as most of the manufacturing production can be imported from other regions such as the Southeast.

4.2.2 Capital High/Low-Skill Complementarity in Agriculture

The reduced-form results show that, after an agriculture-specific regional subsidy, the relative supply of skilled workers decreased with no significant increase in the wage premium decreased. Such relative quantity and price movements are informative of the degree of complementarity between factors in agriculture $\Theta \equiv \{\sigma^{agro}, \rho^{agro}\}$. In the model, a reduction of agricultural credit constraints generates an increase in the local capital stock.

[44]We describe this procedure in Appendix E.1.

[45]As is clear from equation 31, δ is not separately identified from θ^j. We use the estimate of δ from Pellegrina (2022), who uses price gaps across space in Brazil to estimate this parameter. Reassuringly, we find trade elasticities that are very close to those in that paper despite the fact that we use a different data source.

As we argued above, the effect of such increase on skill composition and wage inequality depends on the degree of complementarity between capital and high- and low-skilled workers in the predominant local sector.[46] If there is capital-low skill complementarity, then the increase in the capital stock should differentially increase the demand for low-skilled workers. On the other hand, without capital-low skill complementarity, the increase in the capital stock should be either neutral or even decrease the demand for low-skilled workers locally.

Using such intuition, we calibrate these parameters using a method of simulated moments. Specifically, we perform the same experiment in the model as in the reduced-form, using the subsidy shocks across the boundary observed in the data (Table 3). Starting from a baseline equilibrium, we solve the model assuming that the government subsidizes sectors differentially across the boundary as observed in the data. We then do a difference in difference calculation in the model as in the reduced-form, and obtain the parameters Θ that minimize the distance between the observed response in terms of skill composition and wage premium, the empirical moments M^E, and their model counterparts, $M(\Theta)$.[47] We calibrate these parameters as:

$$\Theta^* = \arg\min_{\Theta} \left\| \mathcal{M}\left(\Theta\right) - \mathcal{M}^E \right\|^2 .$$

This procedure suggests a moderate degree of capital low-skill complementarity in agriculture $\rho^{Ag} = 1.12, \sigma^{Ag} = 0.8$: this is, capital tends to differentially complement low-skilled workers in agriculture. We can compare these estimates to recent estimates for elasticities of substitution in manufacturing in Brazil. Fonseca and Van Doornik (2022) estimate these elasticities for manufacturing industries in Brazil during our sample period. The average value of these parameters for manufacturing industries are $\rho^{Manuf} = 0.7, \sigma^{Manuf} = 2.2$. Their estimates imply that, on average, capital is relatively more complementary to high-skilled workers relative to low-skilled workers in manufacturing.

The fit of this procedure is shown in Table 6. The method has a good fit for the level of targeted moments: the difference in difference coefficient is relatively similar in the model as in the data, both for the skill ratio as well as for the wage premium. In terms of non-targeted moments, we explore whether the model matches the observed response in

[46] See Appendix B for simulations in a simple two region version of the model showing why the skill ratio and wage premium responses inform the production function parameters in agriculture.

[47] Given the noisy coefficient in the wage premium in Table 4, we target a 0 effect on the wage premium in this calibration. If we were to target a negative effect on the wage premium, the degree of capital low-skill complementarity would be even larger. We perform robustness to these estimates in the counterfactual estimates.

the changes of sectoral employment for agriculture and manufacturing. As shown in the Table, the model does a good job matching the level of the increase in the share of workers in agriculture: the model predicts that this increase would have been 0.015, while the point estimate in the reduced form results indicate that it was 0.016. On the other hand, while the model predicts the manufacturing employment decreases, it under-predicts the level of the observed response in the reduced form. According to the model, some of the sectoral reallocation also arises through a decline in services employment.

In what follows, we use $\rho^{Ag} = 1.12, \sigma^{Ag} = 0.8$ for the main results, but, given the noisiness in the wage premium response observed in the data, we perform robustness using different elasticities of substitution for agriculture in the counterfactuals.

4.2.3 Other Parameters

We obtain the elasticities of substitution of the production function in manufacturing $\{\sigma^{manuf}, \rho^{manuf}\}$ as the average elasticity in Fonseca and Van Doornik (2022).[48] We assume that the service sector is Cobb Douglas $\sigma^{services} = 1, \rho^{services} = 1$.[49] For migration elasticities, we use the estimates from Porcher (2019).[50,51]

For the rest of the parameters, we use standard values in the literature: we use a yearly discount factor of $\beta = 0.95$ for both workers and capitalists. For the baseline results, we use an intertemporal elasticity of substitution of $\psi = 0.5$ following Ravikumar et al. (2019). Finally, we use a depreciation rate of 0.3. The values of all parameters can be found in Table 7.

[48]They estimate CES production functions for all manufacturing sectors in two-digit industries in Brazil during our sample period. They follow De Loecker and Warzynski (2012) using production function estimation through Olley and Pakes (1992) using data from 2000-2010.

[49]Note that assuming that there is high skill-capital complementarity in services would further increase the degree of capital-low skill complementarity needed to match the reduced-form evidence.

[50]Porcher (2019) builds and estimates a model in which migration is subject to information frictions. The model is estimated using Brazilian data. Importantly, such paper reports migration elasticities with and without information frictions and the frictionless migration elasticity is the same as in this model. We use those estimates for the baseline results. Without a good estimate for differential migration elasticity by skill type in our context, we set the same value for low and high-skilled workers. This ensures that the observed responses in the model are not driven by differences in migration elasticities.

[51]A natural way to estimate the migration elasticity would be to use the method proposed by Caliendo et al. (2019). In our context, implementing this method requires data on local prices, which are not available.

5 Counterfactuals: Spatial Consequences of Subsidies and Frictions

What are the spatial effects of the credit subsidies currently implemented by the government? How do frictions that generate dispersion in the cost of credit across space affect welfare? This section explores these questions through the lens of our structural model. As we have argued, the model allows us to understand the spatial consequences of credit frictions accounting for rich general equilibrium interactions such as migration, capital accumulation, and input-output linkages.

Specifically, we run counterfactuals related to the drivers of heterogeneity in the cost of credit across space in our model. Recall that, in the model (Equation 10), the cost of credit in a location i, sector j, is given by:

$$\underbrace{\varkappa_{it}^{j}}_{\text{Cost of Credit}} = 1 + \underbrace{m_{it}^{j}}_{\text{Frictions}} - \underbrace{s_{it}^{j}}_{\text{Subsidies}},$$

that is, heterogeneity in the cost of credit across locations and sectors is driven by differences in monitoring costs, which we call "frictions", and differences in the degree to which the government subsidizes credit across locations and sectors.

The first counterfactual focuses on the credit subsidies $\{s_{it}^{j}\}$. We ask: what would be the effects of removing the credit subsidies observed in the data? An important thing to note is that, above and beyond the place-based policy studied in Section 3, approximately 50% of all credit is subsidized in Brazil.[52] This is a wide-ranging policy both spatially and across sectors. Given its magnitude, this policy might have important general equilibrium effects across locations and sectors. We account for these in our counterfactuals using our structural model.

The second counterfactual focuses on the frictions $\{m_{it}^{j}\}$ and on factors that might decrease them. We follow the literature that argues that the efficiency of local bankruptcy courts matters for the local cost of credit. For example, Ponticelli and Alencar (2016) show that improvements in nation-wide bankruptcy law in Brazil differentially increased the credit supply in municipalities where bankruptcy courts were less backlogged. Moreover, they show that the increase in credit supply generated an increase in local investment as our model would predict.

Intuitively, given that bankruptcy procedures are handled by local bankruptcy courts,

[52] Figure 8a shows the spatial heterogeneity in credit subsidies. As shown in the Figure, while the Northeast, and particularly Semiarido, appear as regions with large average subsidies, the overall policy is much more wide-ranging with mesoregions across all regions receiving large subsidies.

the cost of monitoring a project from the perspective of a financiers depends on the degree to which these courts operate efficiently. In a municipality with very inefficient bankruptcy courts, the financier knows that the cost of recovering their assets in the face of default will be larger since they will have to go through long procedures to recover them. Effectively, the cost of monitoring the project by a financier for a firm located in a municipality with inefficient bankruptcy courts will be larger.

Based on such idea, for the second counterfactual we use data on local court productivity from *Justica Aberta* to estimate the passthrough from local court productivity to the cost of credit. In order to do so, we exploit the same nationwide bankruptcy reform as Ponticelli and Alencar (2016) to study whether the improvement of bankruptcy procedures differentially decreased the cost of providing credit in municipalities with higher court productivity. We find that increases in local court productivity lead to decreases in the cost of credit faced by firms. Using such pass-through, we then simulate the effects of equalizing local court productivity across space within Brazil.

5.1 Subsidy Counterfactual: Spatial and Distributional Consequences of Observed Credit Subsidies

This section studies the spatial consequences of credit subsidies in our model. To do so, we first lay out a few facts observed in the data. Then, we simulate the convergence towards steady state starting from the observed equilibrium in two scenarios. In the first scenario, we assume that subsidies remain fixed at their 2003 level forever. In the second scenario, we assume that subsidies are removed starting from 2004 onwards. Using dynamic exact hat algebra, we study the effects of the subsidies, comparing the economy with subsidies relative to the one without them. By comparing the economy with subsidies versus a counterfactual economy in which they are removed, we measure the overall spatial and distributional consequences of this policy.

5.1.1 Facts: Heterogeneity in the Cost of Credit and Subsidies Across Locations & Sectors

Credit spreads in Brazil are large compared to other countries. For example, the average interest rate spread is 0.7% in Japan, 3% in the U.S., 10% in Uruguay, and 40% in Brazil (Cavalcanti et al., 2021).[53] This is shown in Table 8. The average yearly non-subsidized interest rate charged for loans in Brazil is 34.8%. Within any given local labor market,

[53] Banerjee (2003) documents that credit spreads are similarly large in other developing countries such as India.

on average 10% of all loans are subsidized, with the gap between subsidized rates and non-subsidized rates being, on average, of 21 percentage points.

There are two relevant dimensions in terms of where the subsidies are targeted: sectors and regions. We start by exploring heterogeneity in sectoral allocation of subsidies (Figure 7). As shown in Figure 7a, on average, non-subsidized rates are larger in manufacturing. In contrast to this, Figure 7b shows that subsidies tend to be larger in agriculture. This heterogeneity in the sectoral allocation of subsidies is relevant for the distributional consequences of the subsidies. Due to heterogeneity in capital-high/low skill complementarity across sectors, low-skilled workers will typically benefit from agricultural subsidies, while high-skilled workers will benefit from manufacturing subsidies.

The data also exhibits large spatial heterogeneity in average subsidies (Figure 8). As mentioned above, something to keep in mind is that the credit place-based policy studied in Section 3 is only part of all of the subsidies in Brazil. In fact, while Semiarido does appear as a region with large subsidies, the subsidy policy also affects many other local labor markets (Figure 8a). Given the magnitude of the policy, it is important to consider general equilibrium effects, which is one advantage of using our structural model to evaluate this policy. In terms of the specific locations that the policy targets, Figure 8b shows that, when one measures all of the subsidies in the credit registry, the policy is not progressive: the correlation between local GDP per capita and subsidies relative to private rates is positive, albeit small.

5.1.2 Counterfactual: Spatial and Distributional Consequences of Subsidies

We compare the results of an economy in which subsidies remain at their 2003 level forever, versus an economy in which the subsidies are removed starting in 2004. First, we study the effects of the subsidies on local capital accumulation. As explained in Section 2.8, in the model local credit subsidies decrease the price of investment goods, which, in turn, increase local capital accumulation. The effects of the subsidies depend on the size of the subsidies, the sectors targeted and how important they are for investment, the tradability of goods across regions, and general equilibrium forces through migration and input-output linkages.

As shown in Section 5.1.1, the subsidies are differentially targeted towards richer regions at baseline. In this sense, as one would expect, this generates larger capital inflows into these regions (Figure 9a). Despite the differential targeting towards richer regions at baseline, the subsidies have an important effect on the steady state capital stock across all regions. We find that, on average, the steady state stock of capital of any region increases by 30% due to the subsidies.

Such capital flows have different effects on the welfare of high- and low-skilled workers due to the heterogeneity in capital-skill complementarity in the production function across sectors. Richer regions at baseline also tend to be more manufacturing intensive, while poorer regions tend to be more agricultural. Given the fact that capital tends to be differentially complement high-skilled workers in manufacturing, while it tends to differentially complement low-skilled workers in agriculture, one would expect manufacturing subsidies to disproportionately benefit high-skilled workers, while agricultural subsidies should disproportionately benefit low-skilled workers.

To measure welfare, we use a compensating variation equivalent measure derived from the model following Caliendo et al. (2019). Letting $\hat{W}_n^\ell$ be the change in welfare for workers of type ℓ, in location n, given a counterfactual change in fundamentals, subsidies, or frictions, then we show in Appendix D.3.2 that this can be expressed as:

$$\hat{W}_n^\ell = \sum_{t=1}^{\infty} \beta^t \log\left(\frac{\hat{C}_{nt}^\ell}{\left(\hat{\mu}_{nnt}^\ell\right)^{\nu_\ell}}\right),$$

which is measured in terms of consumption equivalent variation. Due to the fact that there is frictional labor mobility, welfare is not equalized across space for workers of a given type and the effects of different subsidy policies will depend on where the workers are located. Specifically, the welfare effects of a shock depend on two (dynamic) components: changes in consumption, $\hat{C}_{nt}^\ell$, and changes in the option value of a location $\hat{\mu}_{nnt}^\ell$.

Starting with consumption, $\hat{C}_{nt}^\ell$ is the change in consumption for workers in location n, of type ℓ, at time t, brought forth by a change in either fundamentals, subsidies, or frictions. The larger this change is, the more workers will need to receive as compensating variation if there had been no such change. On the other hand, $\hat{\mu}_{nnt}^\ell$ measures the change in the share of workers that remain in local labor market n across time.[54] If this term becomes lower, then the location n has a larger option value in the counterfactual, also increasing the compensating variation under the counterfactual.

Using these measures, we explore the spatial distribution of welfare changes for workers of different types. We plot the change in welfare for a worker of type ℓ conditional on the initial GDP per capita of her local-labor market (Figure 9b). Given the observed urban bias in the subsidies, we find that welfare measures are upward sloped with respect to initial GDP per capita for both high- and low-skilled workers. This means that subsidies

[54]Such variable measures a location-specific option value. If workers are located in a region in which there is a lot of mobility (low μ_{nnt}^ℓ), then this location has a large option value given workers can move to more attractive locations in the face of shocks. On the other hand, if, for example, mobility costs are infinite, workers can not move across space and the location-specific option value becomes zero with $\mu_{nnt}^\ell = 1$.

tend to differentially increase welfare for richer regions at baseline. On the other hand, we also find that low-skilled workers typically benefit more from the subsidies. This is due to the agricultural bias in the subsidies observed in the data. In summary, we find that the subsidies tend to decrease welfare inequality *within* regions, but they tend to increase welfare inequality *across* regions.

As a robustness, we show the welfare effects for different levels of capital-skill complementarity in agriculture in Table 9. Intuitively, given the large subsidies observed towards agriculture in Brazil, low-skilled workers will benefit more when capital tends to complement low-skill in this sector. This is what we find: as we move from capital-low skill complementarity, to Cobb Douglas, to capital-high skill complementarity in agriculture, the average low-skilled worker tends to benefit less from the subsidies. In the baseline calibration, we find that, on average, there is an increase of 6.029% on the welfare of low-skilled workers. In contrast to this, if there was capital-high skill complementarity in agriculture as in manufacturing, the average low-skilled worker would experience an increase of 4.6% in her welfare. On the other hand, as one would expect, high-skilled workers tend to benefit more from the subsidies as we move from capital-low skill complementarity in agriculture, towards capital-high skill complementarity in this sector.[55]

Finally, we also explore the effects of this policy on a measure of spatial inequality *across* regions typically used by the government: the Gini coefficient of GDP per capita. Comparing the Gini coefficient in GDP per capita before and after the subsidies, we find that the subsidies increase spatial inequality *across regions*: the Gini increases from 0.20 to 0.22 with the subsidies.

5.2 Frictions Counterfactual: Spatial Consequences of Equalizing Local Court Productivity through Court Reform

In the model, the overall cost of credit depends on subsidies and on frictions. As shown in the previous section, subsidies, at least how they are currently implemented in Brazil, tend to increase spatial inequality. We now focus on the frictions. This counterfactual is motivated by Figure 10, which shows that private credits spreads, which in our model inform monitoring costs, tend to be larger in poorer municipalities. One important component in the cost of monitoring projects depends on the functioning of the local court system. In well-functioning court systems, financiers will have little trouble recovering their assets in the face of default, regardless of how likely default is. On the other hand, in

[55]In order to aggregate welfare across regions, we use a utilitarian welfare measure that averages welfare across locations with equal weights.

badly functioning local court systems, they will have to spend lots of time going through bankruptcy procedures, increasing monitoring costs, and forcing banks to charge higher spreads for credit in order to break even.

Based on this idea, this section studies the spatial consequences of differences in productivity in local bankruptcy and business courts as a driver of heterogeneity in the cost of credit across space. We first explain the data we use to measure court productivity and show some facts related to this data. We then exploit a national reform passed in 2005 which improved bankruptcy procedures in the country to estimate the passthrough from court productivity to cost of credit (Ponticelli and Alencar, 2016). Using this passthrough, we explore a counterfactual in which we equalize court productivity across space.

5.2.1 Local Bankruptcy Court Productivity Measures: Data and Facts

To measure court productivity, we use data from *Justica Aberta*, a dataset covering all Brazilian courts, which is maintained by the National Justice Counsel. Administrative staff within each court have to fill out a mandatory survey each month detailing information on the cases received by a judge, the cases resolved, as well as other data related to the activity of the courts. A useful feature for our purpose is that the data distinguishes by type of court. We use data on local bankruptcy and business courts, both of which handle bankruptcy procedures.[56] Using this data, we measure court productivity as the ratio of cases that are resolved relative to the cases received in each court within a given year.[57,58]

Figure 11a shows a map of this measure of productivity, and Figure 11b shows the correlation between local court productivity and GDP per capita. These figures show that mesoregions in the Southeastern part of the country tend to have larger court productivity, while mesoregions in the Northern part of the country tend to have lower court productivity. This leads to a positive correlation between GDP per capita at baseline and court productivity.

While such correlation suggests that poorer municipalities might have institutional features that make it more costly to provide credit, we do not know whether this correlation

[56] All processes related to bankruptcy happen in the closest court to where the main business establishment from the debtor is located, making these local courts relevant in our context.

[57] The data is available from 2015 onwards. We show in Table A2 that court productivity is highly auto-correlated. Based on this, we use the average value from 2015-2019 as our proxy for time-invariant productivity.

[58] Not all municipalities in Brazil have bankruptcy courts given that the judicial system is based on a territorial definition called *Comarcas*. *Comarcas* typically cover multiple municipalities. Judges within a particular *Comarca* are responsible for the cases in their jurisdiction. Unfortunately, there is no available data regarding the delimitation of *Comarcas*. As a proxy, we impute court productivity in municipalities without a bankruptcy court based on the closest bankruptcy court.

is causal. That is, we do not know whether increasing court productivity would decrease the cost of providing credit. To try to measure the passthrough of court productivity to the cost of credit, we exploit changes in bankruptcy rules introduced in Brazil with a reform in 2005. This law eased bankruptcy procedures such that it increased the value recovered by banks from insolvent firms that went into bankruptcy. It also increased the recovery rate for banks that provide loans guaranteed by collateral. This reform has been previously studied in Ponticelli and Alencar (2016), who find that less backlogged court systems saw an increase in credit supply after the reform, which increased investment in these municipalities.

We follow a similar strategy to Ponticelli and Alencar (2016) hypothesizing that more productive local courts should benefit the most from the passing of the bankruptcy law. To test whether this is the case, we run the following specification:

$$\log(CreditSpread)^j_{it} = \alpha^j_t + \alpha_i + \sum_\tau \mathbb{1}\{\tau\} \times \beta_\tau \log\left(CourtProductivity\right)_i + \boldsymbol{\beta}'_t \boldsymbol{X}_{it} + u^j_{it} \tag{32}$$

where $\log(CreditSpread)^j_{it}$ measures the log of the average credit spread in region i sector j at time t, α^j_t is a sector-time fixed effect, α_i is a region fixed effect, and the coefficients of interest are β_τ which measure the passthrough of court productivity to the cost of credit across time. We control for baseline GDP per capita interacted with time dummies so as to ensure that the effects are not driven by the cost of credit going down in richer municipalities at baseline.

The results from this specification are shown in Figure 12. As hypothesized, we find that more productive local courts see a decline in the cost of credit over time. This is consistent with the notion that more productive courts benefit from improvements in institutional quality after the reform. Table 10 shows the results of the difference-in-difference version:

$$\log(CreditSpread)^j_{it} = \alpha^j_t + \alpha_i + \beta \log\left(CourtProductivity\right)_i \times Post_t + \boldsymbol{\beta}'_t \boldsymbol{X}_{it} + u^j_{it} \tag{33}$$

As shown in the table, results indicate that a 1% increase in court productivity, decreases the cost of credit by 0.01%.

Using such coefficient, we then ask: what would be the effect of equalizing court productivity across space? That is, what would happen to the cost of credit, and hence to economic activity, if we were to increase court productivity to the level of Brasilia, the most productive local court in our data? We show the resulting change in court productivity and the effects that it would have on the cost of credit in Figure 13. Results show that equalizing court productivity would decrease the cost of credit in the poorest municipalities, as they also tend to have lower court productivity.

5.2.2 Counterfactual: Spatial and Distributional Consequences of Equalizing Local Bankruptcy Court Productivity

To understand the effects of this changes on spatial inequality, we now solve the model comparing an economy in which the cost of credit remains fixed in its 2003 level versus an economy in which court productivity is equalized across space and hence the cost of credit decreases starting in 2004 as shown in Figure 13.

We first explore the effects on local capital accumulation. Equalizing court productivity across space would generate capital inflows into the poorest regions (Figure 14a). On average, the steady state capital stock of all regions would increase as there are fewer frictions in the economy, but such policy would differentially benefit poorer regions at baseline.

In terms of welfare, we use the same compensating variation measure as before to understand who benefits the most from such a policy. As shown in Figure 14b, equalizing court productivity across space would reduce spatial inequality in welfare, again benefiting poorer regions the most. We do not find large differences in terms of welfare effects within regions across skill types given that all sectors are equally affected within a given local labor market.

Finally, in terms of spatial inequality in income across regions, we find that the Gini coefficient in GDP per capita would decrease from 0.22 to 0.19 by equalizing court productivity.

6 Conclusion

Financial underdevelopment is thought of as an important barrier to growth in developing countries. Credit subsidies are a common tool used by governments to try to promote local investment. A common objective of these subsidies is to promote local industrialization and reduce spatial inequality. Whether or not these subsidies achieve their objectives is unclear. This paper provides theory and evidence on the aggregate and regional effects of these interventions.

On the theoretical front, we build a dynamic spatial general equilibrium with working capital constraints that can be used to evaluate the long-run consequences of credit policies. We show that credit frictions interact in important ways with capital accumulation and hence with the spatial distribution of high- and low-skilled workers due to the presence of capital-skill complementarity in the production function. The model indicates that spatial linkages through trade and migration are crucial to understand the long-run consequences of these interventions.

Guided by the model, we turn to the empirics, where we show that a particular subsidy policy generated more agricultural employment and decreased the skill intensity of treated labor markets. Through the lens of the model, we argue that such effects arise from spatial equilibrium in which regions are integrated through intra-regional trade and migration, and the production function exhibits capital low-skill complementarity.

Finally, we use the model to understand the aggregate consequences of both credit subsidies as well as policies that try to tackle spatial dispersion in the cost of credit through court reform. Our results indicate that, at least as currently implemented, credit subsidies in Brazil increase welfare inequality across space. Tackling underlying frictions by increasing court productivity in lagging regions, on the other hand, decreases spatial inequality in welfare.

We think there are several interesting avenues for future research. One margin we abstracted away from was endogenous human capital accumulation decisions. In principle, financial frictions could depress the wage premium in the presence of capital-high skill complementarity. This, in turn, might endogenously affect human capital accumulation decisions, generating a novel channel through which financial frictions affect the spatial distribution of skill and regional outcomes more generally. Adding dynamic human capital accumulation decisions in a spatial model with financial frictions to quantify this interaction could be an interesting avenue for future work. In a similar vein, we abstracted away from human capital and agglomeration externalities, factors that have been found to be important quantitatively in the literature. Adding them to this model might help quantify the relevance of different channels in explaining the long-run consequences of financial shocks that have been documented empirically in other contexts such as by Huber (2018). Finally, while numerically studying the dynamic welfare effects of different policies is feasible in this model, characterizing the optimal dynamic policy is quite challenging. In this sense, Itskhoki and Moll (2019) study optimal policy in a growth model and find that optimal policy is stage-dependent: it is initially "pro-capital" and later turns into "pro-worker". Studying this in our spatial framework might also yield interesting insights into whether and how governments should optimally target sectors across space.

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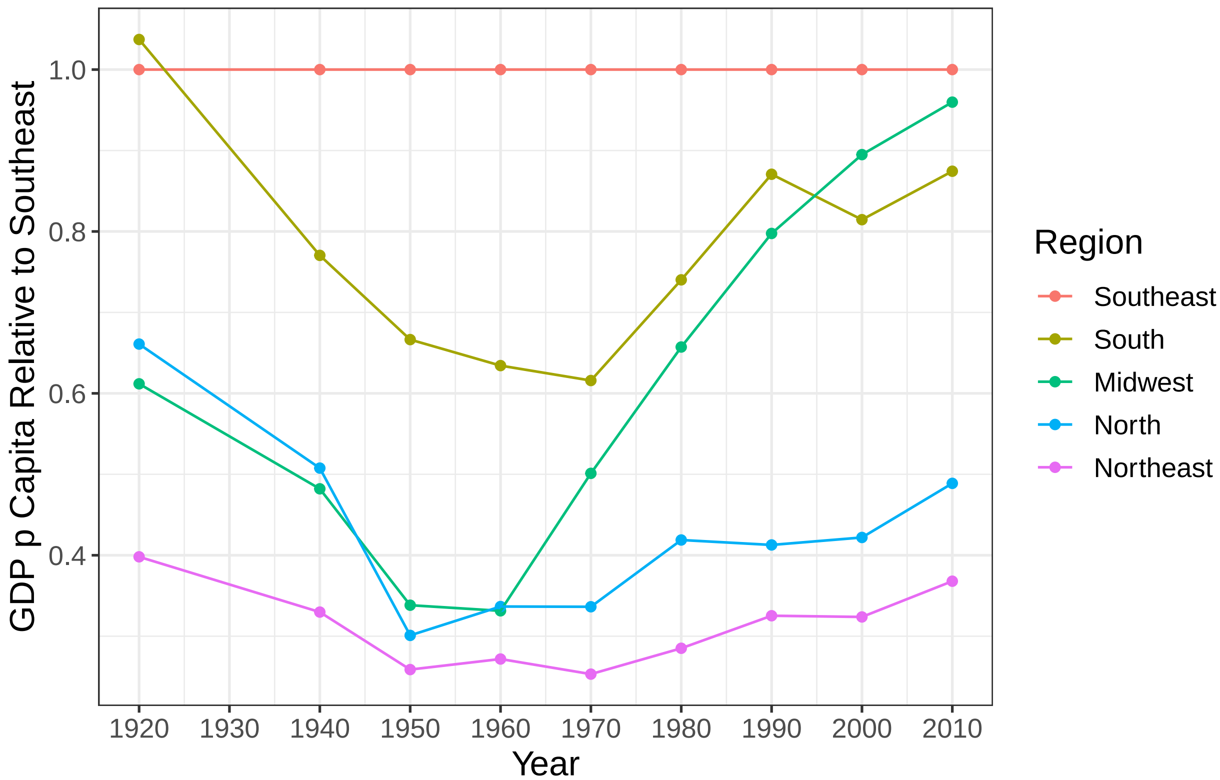
1 Figures

Figure 1: GDP per Capita by Region Relative to Southeast

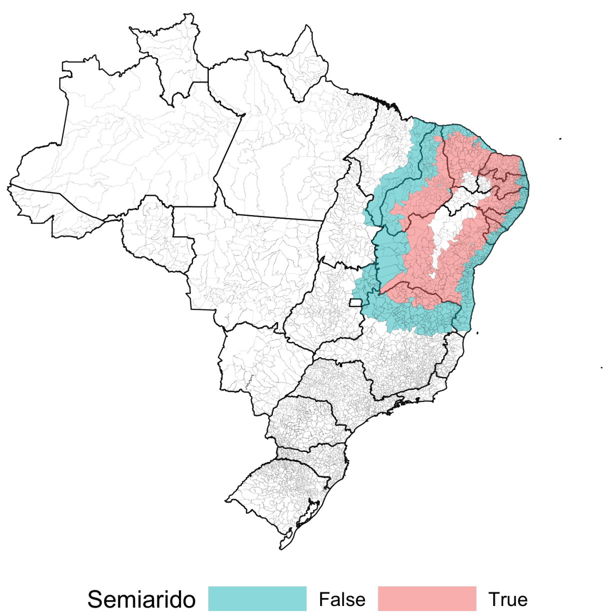


Notes: Brazil is divided into 5 regions: Southeast, South, Midwest, North, Northeast. This figure shows the GDP per capita of each region relative to the Southeast from 1920 to 2010. The data is obtained from IPEA's regional accounts module (back).

Figure 2: Semiarido Region and Sample for Regression Discontinuity

(a) Semiarido Region

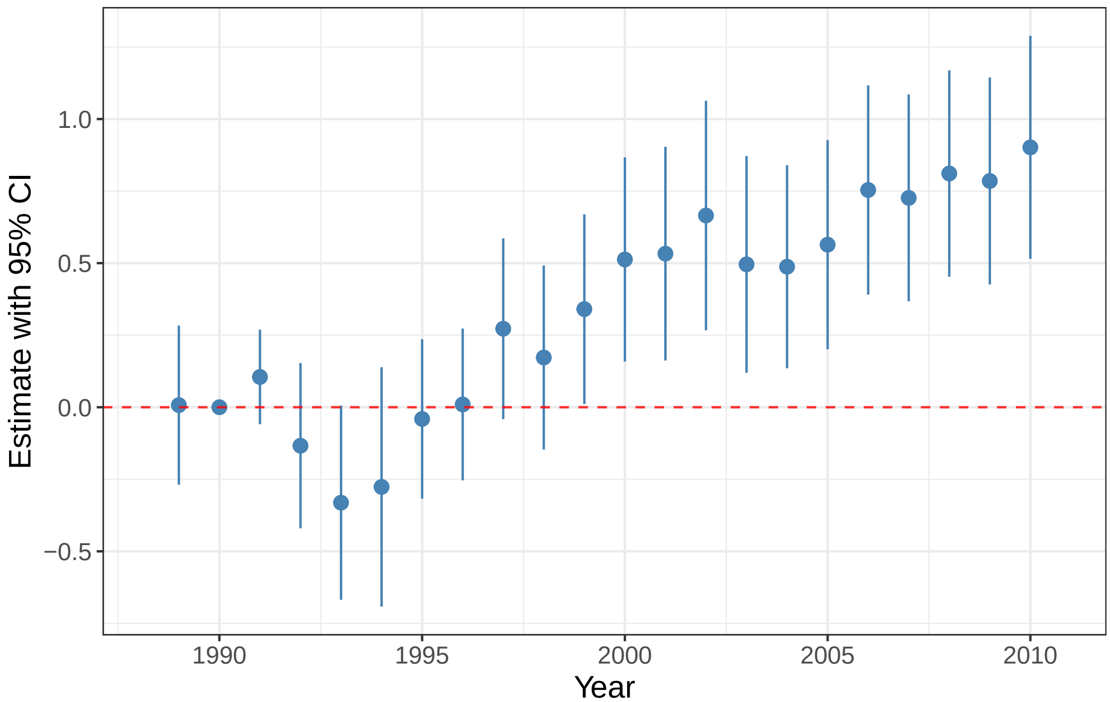
(b) Sample for Regression Discontinuity



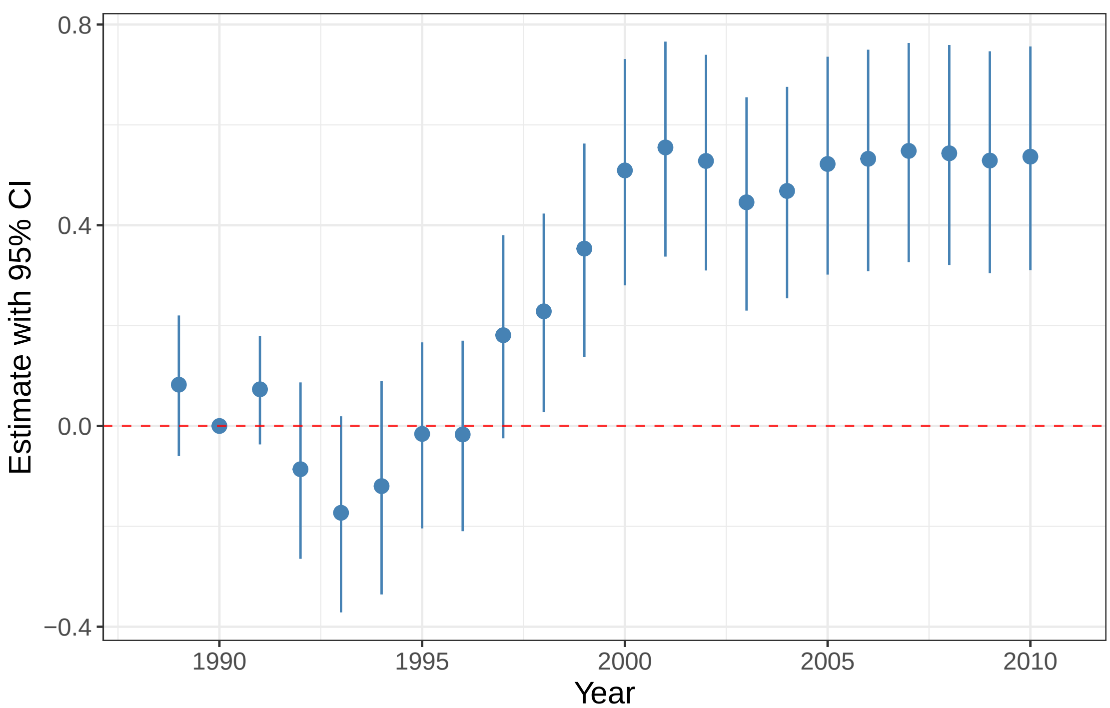
Notes: Panel 2a shows the municipalities that fall within the Semiarido region. The boundary was defined based on average rainfall with municipalities in the Northeast having less than 800mm of yearly rainfall defined as being part of Semiarido. Panel 2b map shows the treatment and control groups used for the regression discontinuity specification 27. We use a 50km bandwith at both sides of the border. We control for distance to the coast in all specifications (back).

Figure 3: Dynamic Effects of Semiarido on Credit

(a) Effect on $log(AgriculturalCredit)$



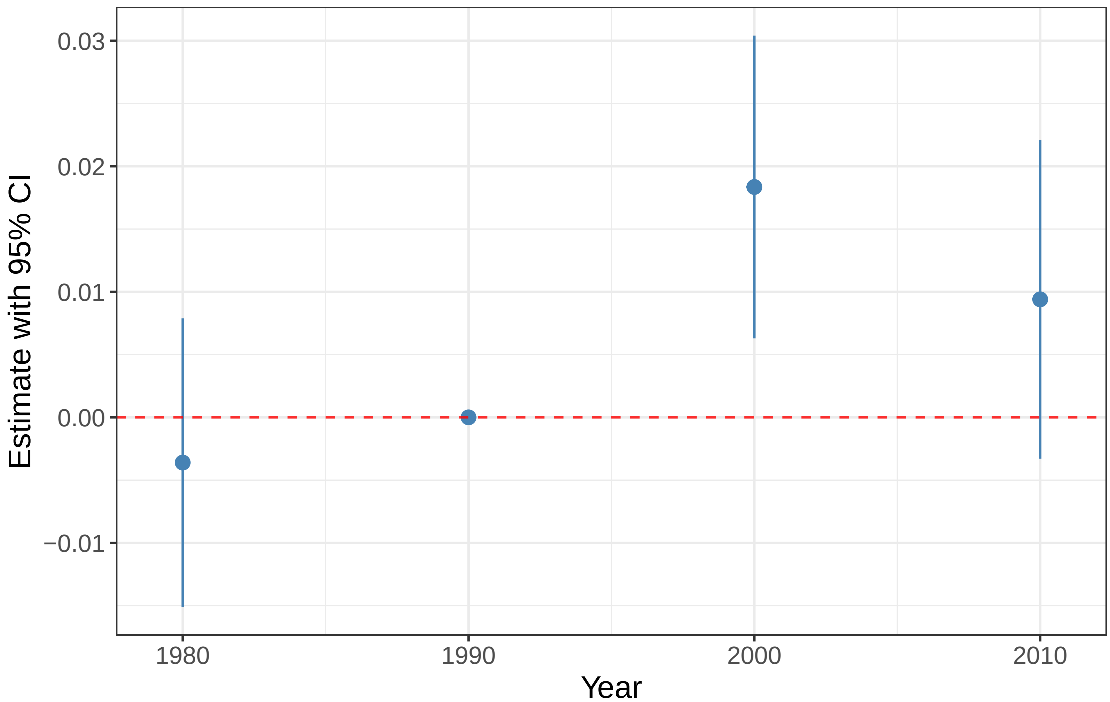
(b) Effect on $log(TotalCredit)$



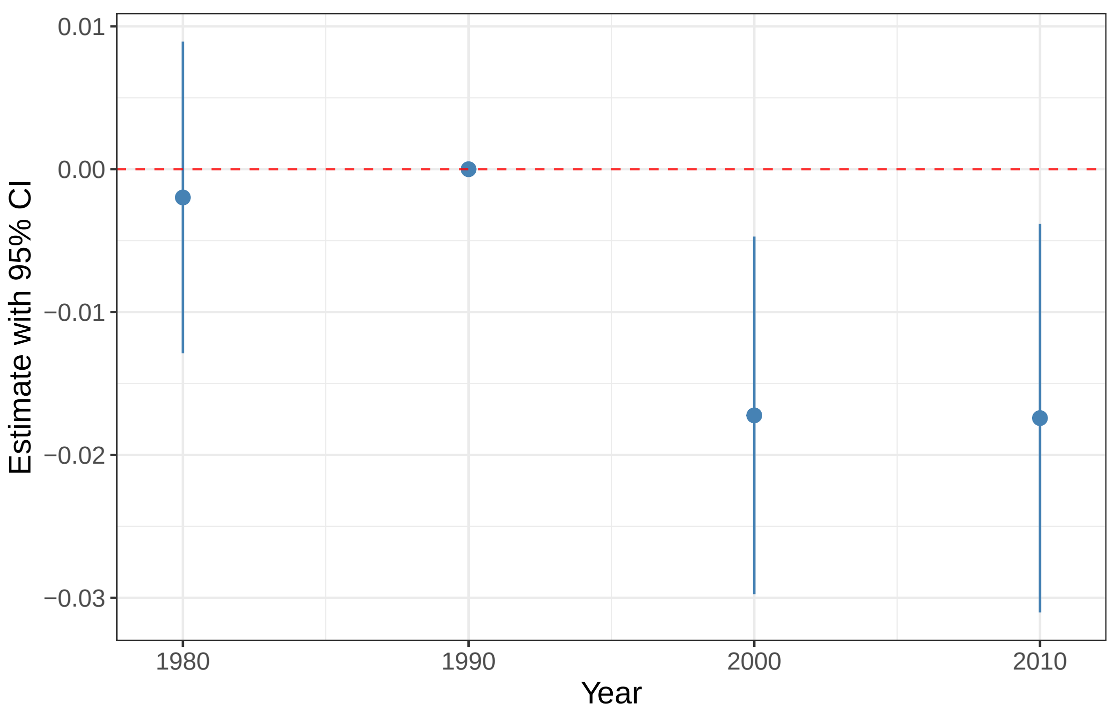
Notes: This figure shows the dynamic coefficients from equation 27. The outcome variable is the log of total agricultural credit in panel 3a and the log of total credit in panel 3b. Controls include a linear polynomial on latitude and longitude, state times year fixed effects, distance to the coast interacted with year dummies. Standard errors are clustered at the municipality level (back).

Figure 4: Dynamic Effects on Share of Workers by Sector

(a) Share of Workers in Primary Sector



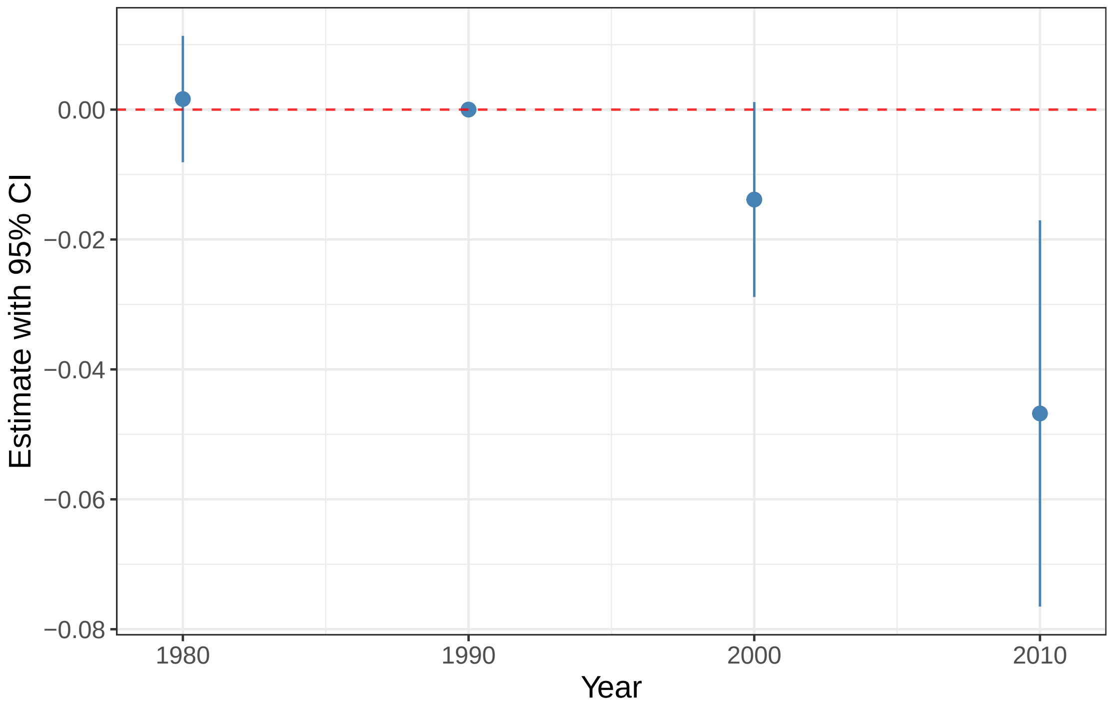
(b) Share of Workers in Manufacturing Sector



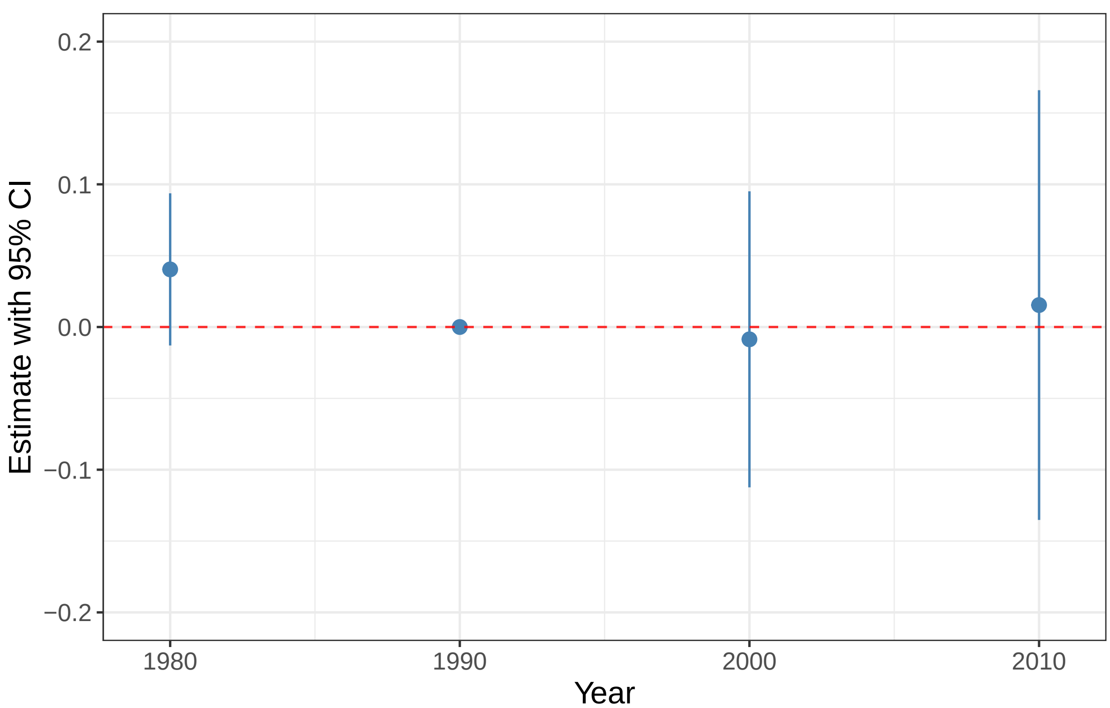
Notes: Panel 4a shows the dynamic coefficients from equation 27 with the outcome being the share of workers in agriculture, while Panel 4b shows the effects with the outcome being the share of workers in manufacturing. Controls include a linear polynomial on latitude and longitude, state times year fixed effects, and distance to the coast interacted with time dummies. Standard errors are clustered at the municipality level (back).

Figure 5: Dynamic Effects on Skill Ratio and Wage Premium

(a) Skill Ratio

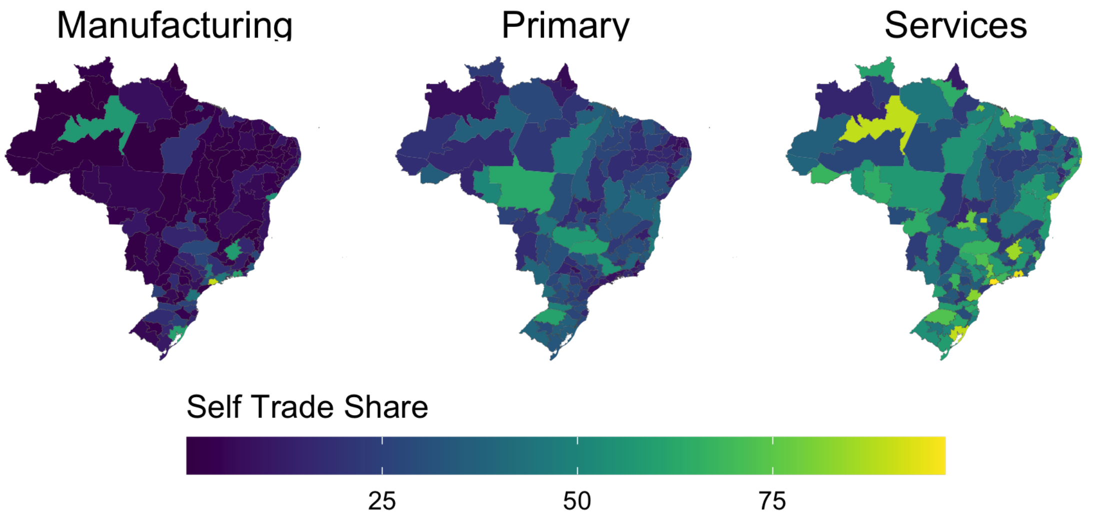


(b) Wage Premium



Notes: Panel 5a shows the dynamic coefficients from equation 27 with the outcome being the ratio of high to low-skilled workers, while Panel 5b has as outcome the wage premium. High skilled workers are defined as having more than or equal to high school. The wage premium is measured as the ratio of average hourly wage of high to low skilled workers. Controls include a linear polynomial on latitude and longitude, state times year fixed effects, and distance to the coast interacted with time dummies. Standard errors are clustered at the municipality level (back).

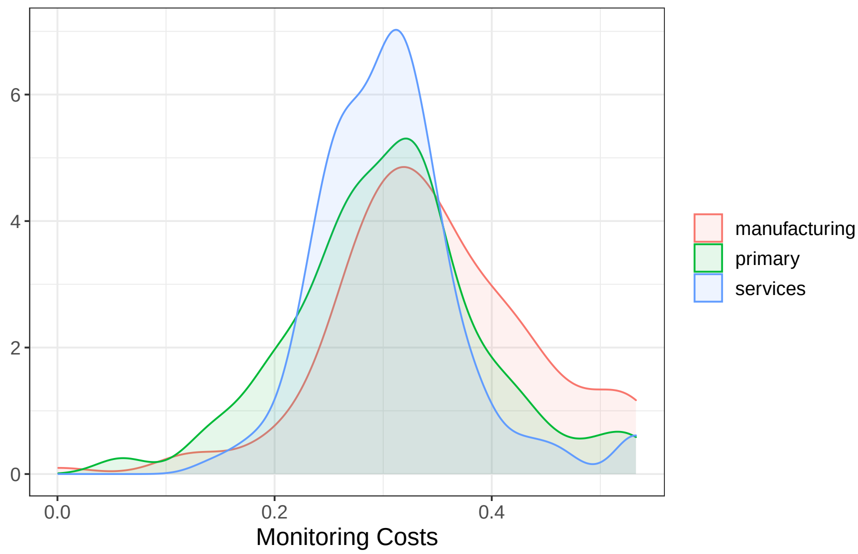
Figure 6: Own Trade Share by Sector



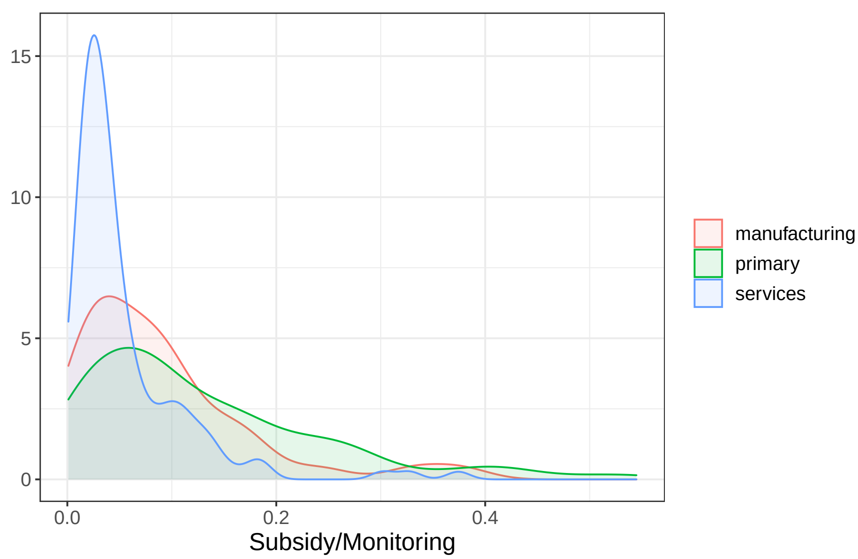
Notes: This figure shows the own trade share of all goods consumed within a sector that are produced in the same location π^j_{nn} in the baseline period. This is, the share of all sectoral expenditure in a location that is produced within that location (back).

Figure 7: Heterogeneity in Cost of Credit and Credit Subsidies Across Sectors

(a) Monitoring Costs



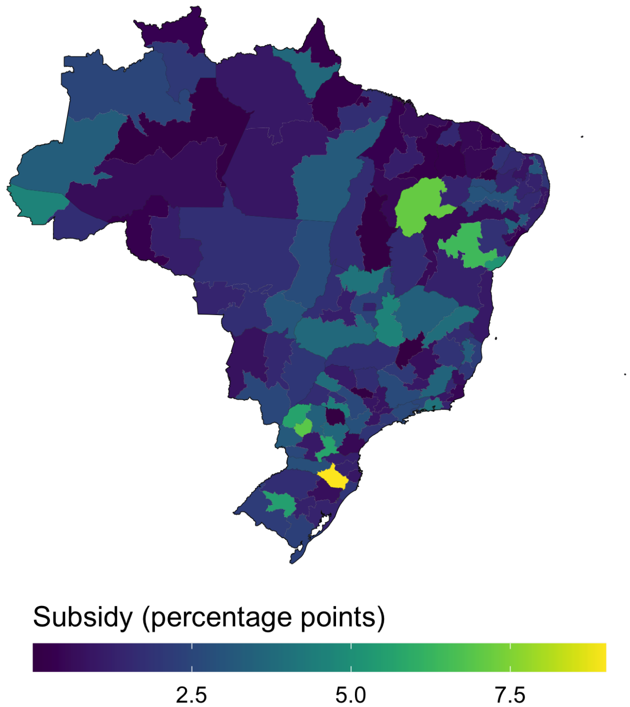
(b) Subsidy/Monitoring



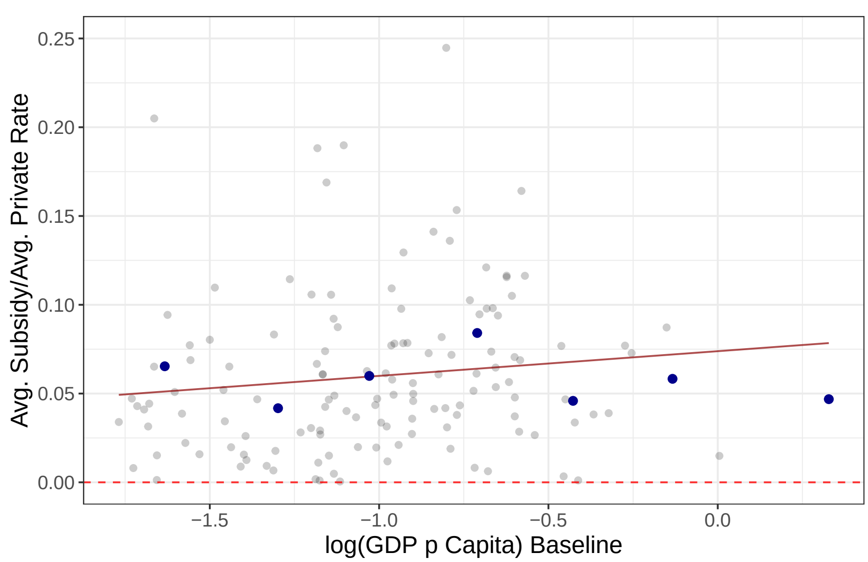
Notes: Panel 7a shows the distribution of monitoring costs (private interest rates) across space within sectors. Panel 7b shows the distribution of credit subsidies relative to monitoring costs across space within sectors. We obtain these measures from the credit registry as described in Appendix C. (back)

Figure 8: Spatial Heterogeneity in Credit Subsidies

(a) Subsidies Across Space



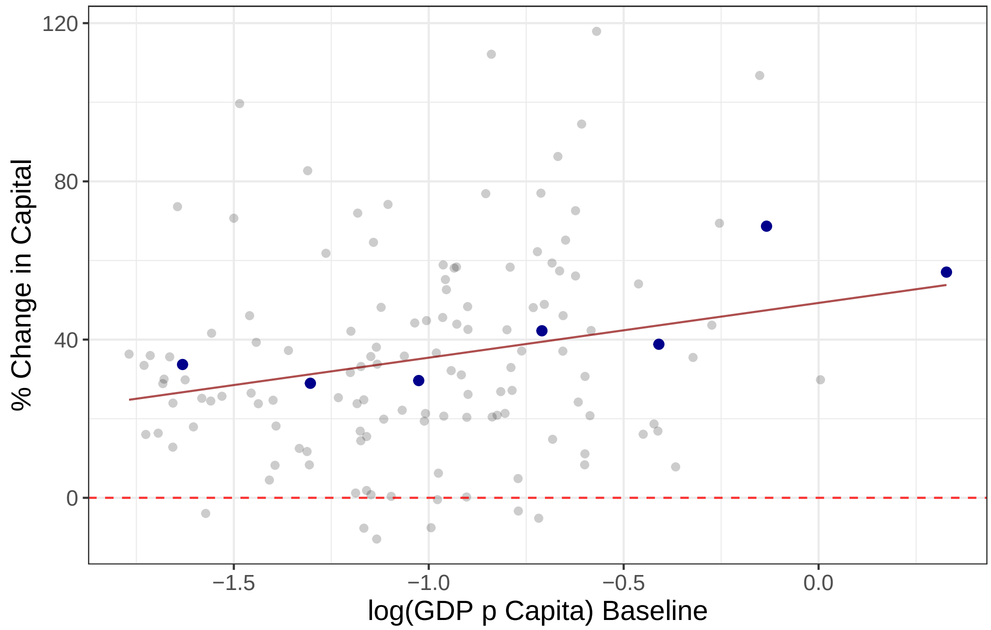
(b) GDP per Capita versus Subsidies



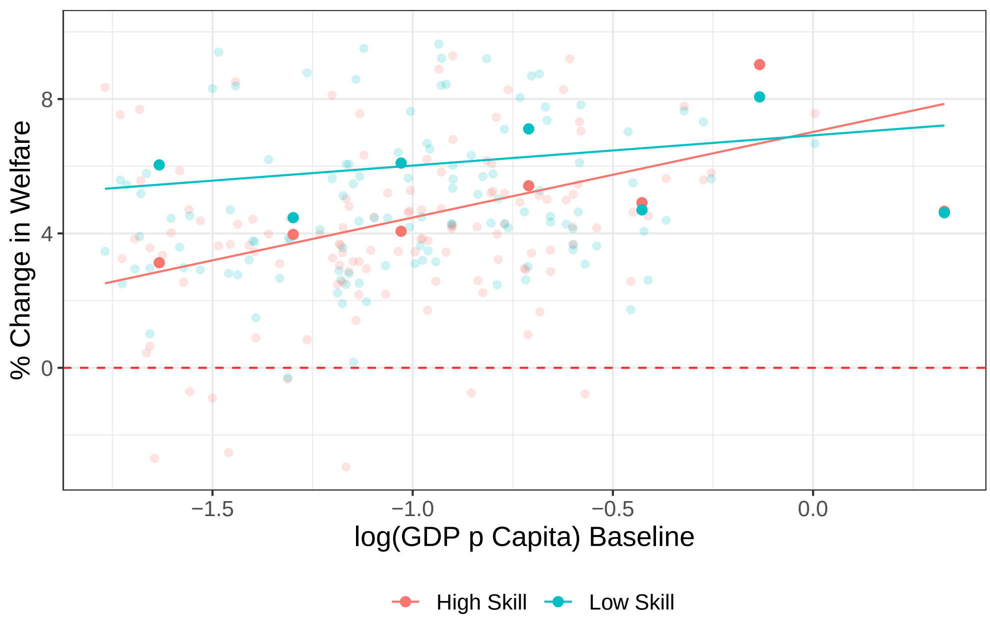
Notes: Panel 8a shows the distribution of average subsidies across local labor markets in Brazil. Subsidies are measured in percentage points. Panel 8b shows a binned scatter plot between log(GDP per capita) in 2000 and the average subsidy relative to the non-subsidized interest rates. We obtain these measures from the credit registry as described in Appendix C (back).

Figure 9: Counterfactual: Comparing Economy w/ vs. w/o Observed Credit Subsidies

(a) Effects of Subsidies on Steady State Capital Stock

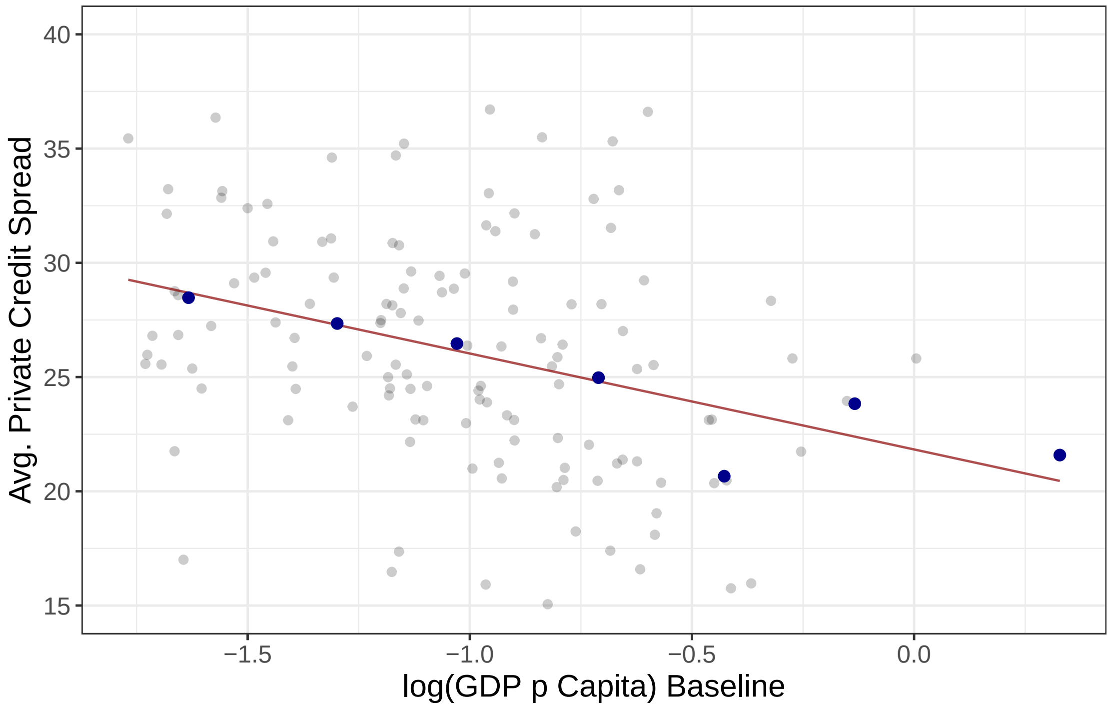


(b) GDP per Capita versus Subsidies



Notes: Panel 9a shows the relationship between GDP per capita at baseline and the percentage change in the steady state capital stock generated by all of the subsidies. Panel 9b shows the welfare effects generated by the subsidies for low- and high-skilled workers conditional on the initial GDP per capita of their location. Welfare effects are measured as describe in Appendix D.3.2. The effects are obtained comparing the economy where credit subsidies remain in their observed level in the initial period forever, versus an economy in which subsidies are eliminated starting in period 1 (back).

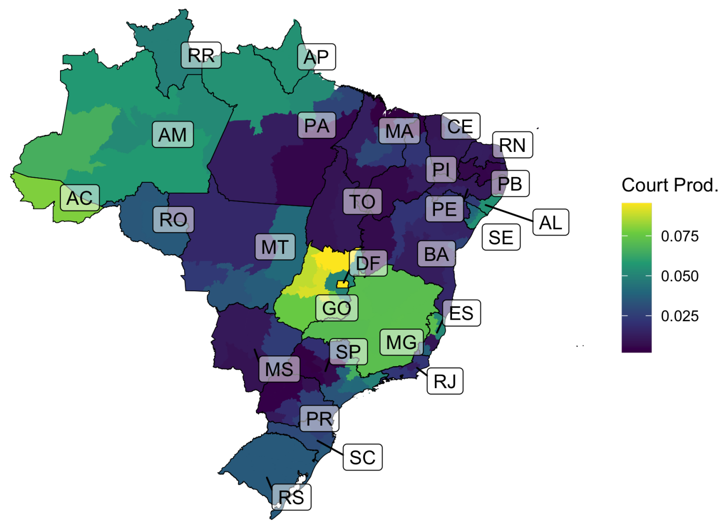
Figure 10: Correlation GDP per Capita and Credit Spreads



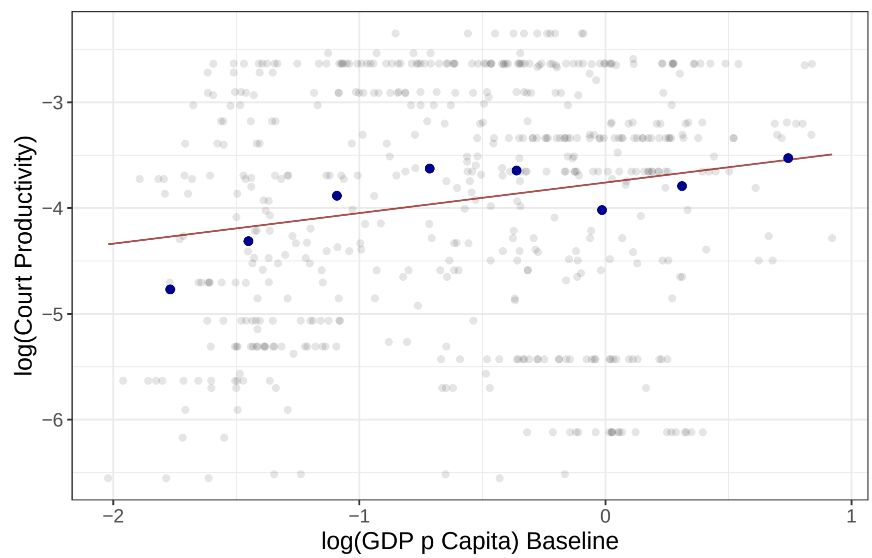
Notes: This figure shows the correlation between average credit spreads at the meso-region level and GDP per capita at baseline. Credit spreads are computed using the Credit Registry as explained in Appendix C. (back).

Figure 11: Spatial Heterogeneity in Local Bankruptcy Court Productivity

(a) Local Bankruptcy Court Productivity Across Space

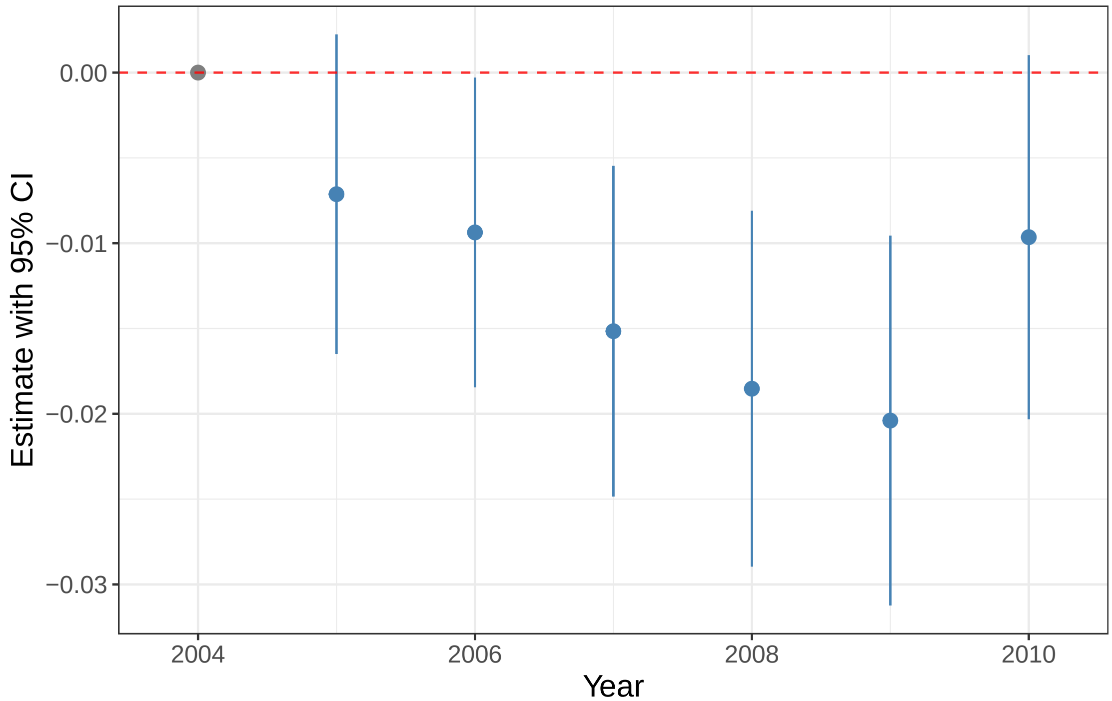


(b) Relationship Between GDP per Capita and Local Bankruptcy Court Productivity



Notes: Panel 11a shows a map of local bankruptcy court productivity at the meso-region level. State codes are shown in the labels. Panel 11b shows a binned scatterplot between the log GDP per capita at baseline and the log of local bankruptcy court productivity. Measures of court productivity are obtained from *Justica Aberta*. They are available from 2015-2019. We average local court productivity across time to obtain a time-invariant proxy of the efficiency of local bankruptcy courts. We compute productivity as $Productivity_i = \frac{\text{Cases Resolved}_i}{\text{Cases Received}_i}$ (back).

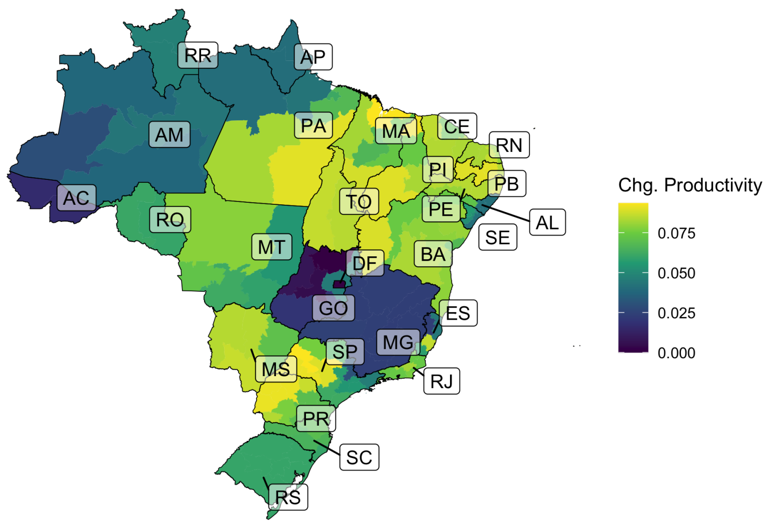
Figure 12: Effect of 2005 Bankruptcy Reform on Cost of Credit



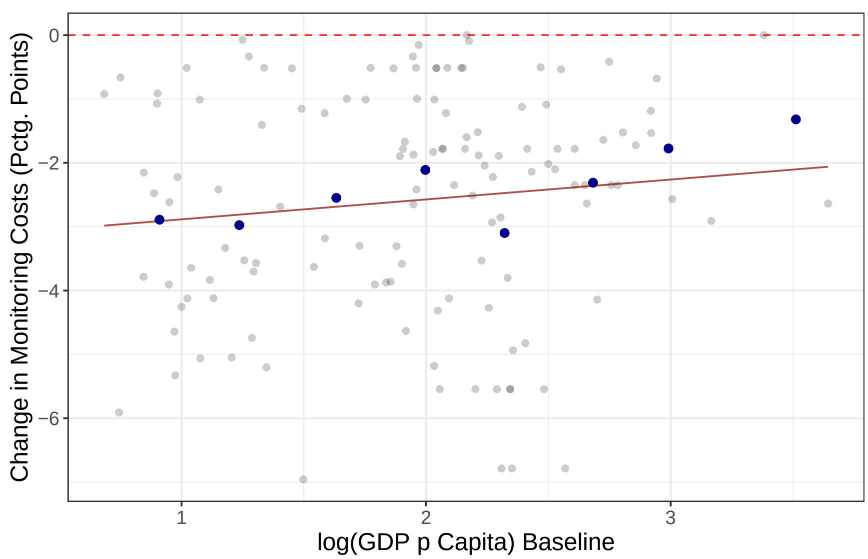
Notes: This figure shows the dynamic difference in differences coefficients from equation 32. Dependent variable is the log of average credit spreads in a location-sector. We measure spreads using the Credit Registry data as explained in Appendix C. Controls include baseline GDP per capita interacted with time dummies (back).

Figure 13: Counterfactual: Effects of Equalizing Local Bankruptcy Court Productivity Across Space

(a) Change in Court Productivity



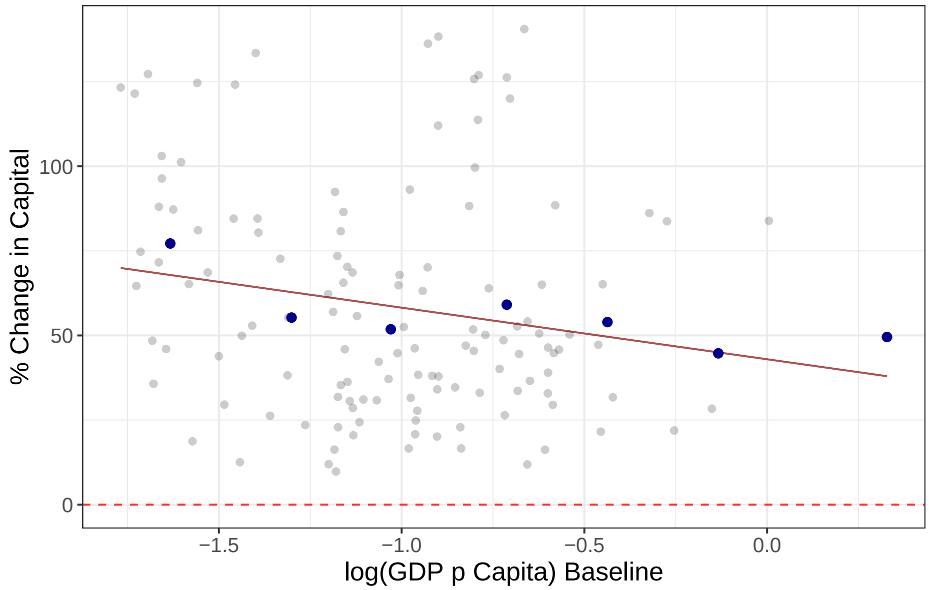
(b) Change in the Cost of Credit (Monitoring Costs)



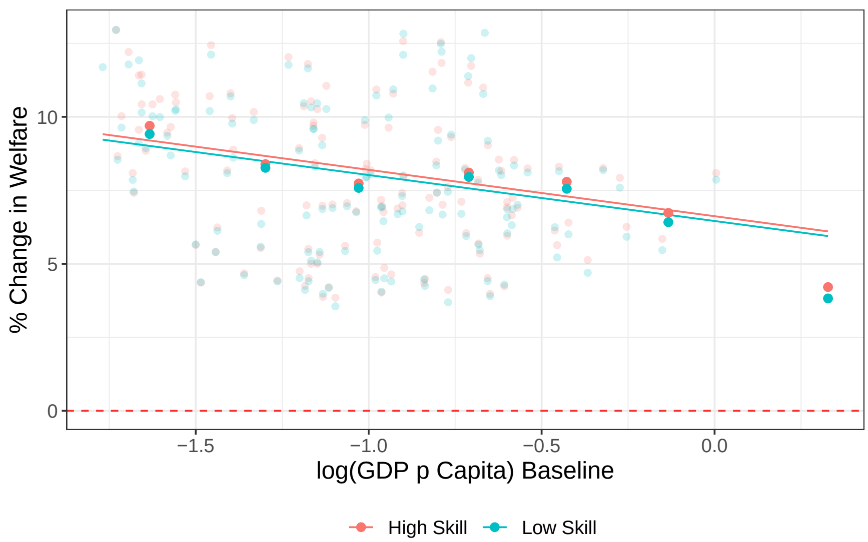
Notes: Panel 13a shows the change in court productivity that would occur if we were to equalize court productivity across space. Panel 13b shows the counterfactual percentage point change in local cost of credit (monitoring costs) if local court productivity was equalized across space. We compute such change using the coefficient in Table 10 (back).

Figure 14: Counterfactual: Effects of Equalizing Local Bankruptcy Court Productivity

(a) Effects on Steady State Capital Stock



(b) Welfare Effects by Skill Type



Notes: Panel 14a shows the relationship between GDP per capita at baseline and the percentage change in the steady state capital stock generated by equalizing court productivity across space. Panel 14b shows the welfare effects by skill type that would occur if local court productivity was equalized across space. The effects are obtained comparing the economy with court productivity equalization relative to the one without it. Welfare effects are measured as described in Appendix D.3.2 (back).

2 Tables

Table 1: Balance Table Semiarido

Dep. Vars.:	Rain (1)	Avg. Yield (2)	Manuf. Emp (3)	Pop. (4)	Agr. Emp. (5)	Total Wage (6)	Total Income (7)	Number LS (8)	Number HS (9)	Wage HS (10)	Wage LS (11)
Variables											
Semiarido	-0.028	0.004	-0.018	0.095	0.147	-0.087	0.046	0.106	-0.024	-0.023	0.060
	(0.032)	(0.104)	(0.104)	(0.103)	(0.098)	(0.106)	(0.105)	(0.102)	(0.109)	(0.111)	(0.104)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed-effects											
State	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fit statistics											
N Observations	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068
Dep. Var. Mean	934.9	591.5	828.6	9,184.4	6,753.1	10,635.7	26,133.9	8,788.3	396.2	5.17	2.60
Dep. Var. Std	656.7	168.9	1,900.2	15,261.6	9,187.5	21,995.3	47,338.8	13,883.6	1,530.6	1.07	0.490

Notes: This table shows the coefficients from equation 28. All variables are standardized relative to their standard deviation. Controls include a linear polynomial in latitude and longitude, state fixed effects, as well as distance to the coast. Rainfall data is obtained from PERSIANN-CCS and is averaged within municipalities across years. Average Yield is measured using FAO GAEZ data. We use the average potential yield for all crops available in GAEZ. The rest of the variables are obtained from the population census in 1980. Conley standard errors in parenthesis. *Signif. Codes: ***: 0.01, **: 0.05, *: 0.1* (back).

Table 2: Effect of Semiarido on Credit Outcomes

Dependent Variables:	log(Total Credit) (1)	log(Agr. Credit) (2)
Variables		
Semiarido $\times$ Post	0.243^{**}	0.286^{*}
	(0.099)	(0.151)
Fixed-effects		
Municipality	Yes	Yes
State-Year	Yes	Yes
Fit statistics		
N Observations	11,742	11,742
Dep. Var. Mean	135.6	67.6

Notes: This table shows the difference in difference coefficients from equation 29. Controls include a linear polynomial in latitude and longitude, state times year fixed effects, as well as distance to the coast interacted with year dummies. Total credit and agricultural credit measure, respectively, the stock of total credit and the stock of agricultural credit in a municipality. They are obtained from ESTBAN and are measured in millions of BRL. Errors are clustered at the municipality level. *Signif. Codes: ***: 0.01, **: 0.05, *: 0.1* (back).

Table 3: Effect of Semiarido on Credit Subsidies by Sector

Dependent Variable:	Subsidy		
	(1)	(2)	(3)
Variables	Agriculture	Manufacturing	Services
Semiarido	1.24*	-0.080	0.986
	(0.703)	(0.314)	(0.797)
Fixed-effects			
State	Yes	Yes	Yes
Fit statistics			
N Observations	1,068	1,068	1,068
Dep. Var. Mean	3.61	0.360	5.97

Notes: This table shows the Semiarido coefficient from equation 30, which is run separately by sector. Controls include a linear polynomial on latitude and longitude, as well as distance to the coast. Subsidies are measured using administrative data from the credit registry as explained in Appendix C. Units are percentage points. Conley standard errors in parenthesis. *Signif. Codes: ***: 0.01, **: 0.05, *: 0.1.* (back).

Table 4: Effect of Semiarido on Sectoral Employment Shares and Skill Composition

Dependent Variables:	Share Primary	Share Manuf.	Skill Ratio	Wage Premium
	(1)	(2)	(3)	(4)
Variables				
Semiarido $\times$ Post	0.016***	-0.016***	-0.037***	-0.013
	(0.005)	(0.005)	(0.010)	(0.030)
Fixed-effects				
Municipality	Yes	Yes	Yes	Yes
State-Year	Yes	Yes	Yes	Yes
Fit statistics				
N Observations	4,272	4,272	4,272	4,272
Dep. Var. Mean	0.557	0.268	0.055	1.60

Notes: This table shows the difference in difference coefficients from equation 29. Controls include a linear polynomial on latitude and longitude, distance to the coast interacted with year dummies. Share Primary and Share Manuf. measure the share of workers in a municipality that participate in agricultural activities and manufacturing respectively. The skill ratio is measured as the ratio of high-skilled to low-skilled workers in a municipality, where high skill is measured as workers with more than or equal to high school. The wage premium is computed as the ratio of the average hourly wage for high-skilled workers relative to low-skilled workers. Errors are clustered at the municipality level. *Signif. Codes: ***: 0.01, **: 0.05, *: 0.1* (back).

Table 5: Trade Elasticity Estimation

Dependent Variables:	log(Trade Flow)		
	(1)	(2)	(3)
Variables	Agriculture	Manufacturing	Services
log(minutes)	-0.424***	-0.512***	-0.808***
	(0.041)	(0.024)	(0.029)
Fixed-effects			
Origin	Yes	Yes	Yes
Destination	Yes	Yes	Yes
Implied θ	**5.3**	**6.4**	**10.1**
Fit statistics			
N Observations	729	729	729

Notes: This table shows the gravity equation estimation 31 using sectoral intra-regional trade data at the State level from *NEREUS*. Errors are clustered at the origin, destination level. *Signif. Codes: ***: 0.01, **: 0.05, *: 0.1* (back).

Table 6: Method of Simulated Moments Fit

	Δ Skill Ratio	Δ Wage Premium	Δ Share Agriculture	Δ Share Manufacturing
Data	-0.037	0	0.016	-0.016
Model	-0.037	-0.004	0.015	-0.001
Targeted	Yes	Yes	No	No

Notes: This table shows the fit of the model for targeted and non-targeted moments in the method of simulated moments. The change in the skill ratio and wage premium are targeted by the calibration, while the change in sectoral composition are not (back).

Table 7: Parameters of the Model

Description	Parameter	Value	Source
Trade elasticities	θ^j	-	Gravity Equation Estimation
Consumption Sectoral Shares	α^j	-	Input-Output Tables
Investment Sectoral Shares	χ^j	-	Input-Output Tables
Prod. Function Estimates	$\rho^{Manuf}, \sigma^{Manuf}$	{0.7,2.2}	Fonseca and Van Doornik (2022)
Prod. Function Estimates	ρ^{Ag}, σ^{Ag}	{1.12,0.8}	MSM
Prod. Function Estimates	$\rho^{Services}, \sigma^{Services}$	{1,1}	
Intertemporal Elasticity of Substitution	ψ	0.5	Ravikumar et al. (2019)
Depreciation Rate	δ	0.3	
Discount Factor	β	0.95	Literature
Migration Elasticities	ν_ℓ	2.92	Porcher (2019)

Notes: This table shows the values and sources of the main parameters of the model (back).

Table 8: Summary Statistics: Cost of Credit and Subsidies

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
Share Subsidized	2,877	0.17	0.19	0	0.03	0.1	0.2	1
$\bar{R}^n - \bar{R}^d$	2,877	18.34	11.88	0	11.50	16.73	23.33	59.09
Credit Subsidies (s)	2,877	2.90	4.08	0	0.3	1.7	3.8	42
Average Private Rate (m)	2,877	27.62	11.90	0	22.51	27.98	33.80	59.09

Notes: This table shows summary statistics for the subsidy and interest rate measures used in the analysis using data from 2004-2010 at the mesoregion-sector level. There are 137 mesoregions and 3 sectors. Share Subsidized refers to the share of all loans that are subsidized within a sector-region-year. $\bar{R}^n - \bar{R}^d$ measures the percentage point difference between subsidized rates and non-subsidized rates. s refers to the aggregate percentage point subsidy within sector-region-years, m refers to the average yearly interest rate charged by non-subsidized loans. We obtain these measures from the credit registry as described in Appendix C (back).

Table 9: %Δ Welfare Subsidies and Degree of Capital-Skill Complementarity in Agr.

%Δ Welfare	Capital-Low Skill Complementarity $\{\sigma^{Agro} = 0.8, \rho^{Agro} = 1.12\}$	Cobb Douglas $\{\sigma^{Agro} = 1, \rho^{Agro} = 1\}$	Capital-High Skill Complementarity $\{\sigma^{Agro} = 2.2, \rho^{Agro} = 0.7\}$
High Skill	4.471%	4.496%	4.608%
Low Skill	6.029%	5.75%	4.832%

Notes: This table shows the average welfare effects of the subsidies by skill type as a function of the degree of capital-skill complementary in agriculture. We aggregate welfare across labor markets using a utilitarian approach to aggregate welfare within skill type across labor markets (back).

Table 10: Effect of Court Productivity on Monitoring Costs

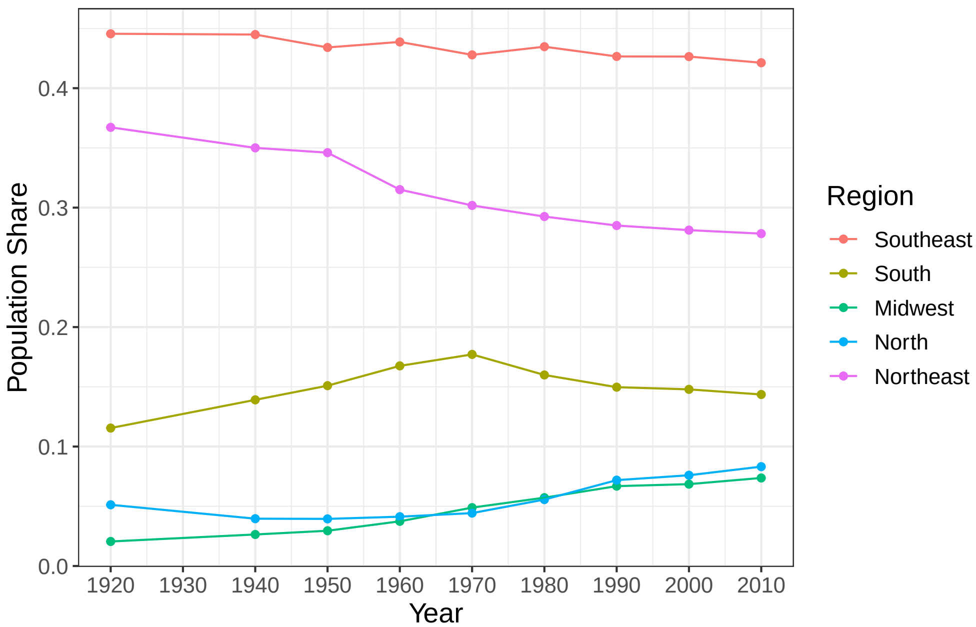
Dependent Variable:	log(Credit Spreads)	
	(1)	(2)
Variables		
log(Productivity)× Post	-0.011***	-0.010***
	(0.004)	(0.004)
Fixed-effects		
Municipality-Industry	Yes	Yes
Year-Industry	Yes	Yes
Controls	No	Yes
Dep. Var. Mean	42.2	42.2
Fit statistics		
Observations	50,100	50,100

Notes: This table shows the coefficients from specification 33. Controls include baseline GDP per capita interacted with time dummies. Errors are clustered at the municipality-industry level. *Signif. Codes: ***: 0.01, **: 0.05, *: 0.1* (back).

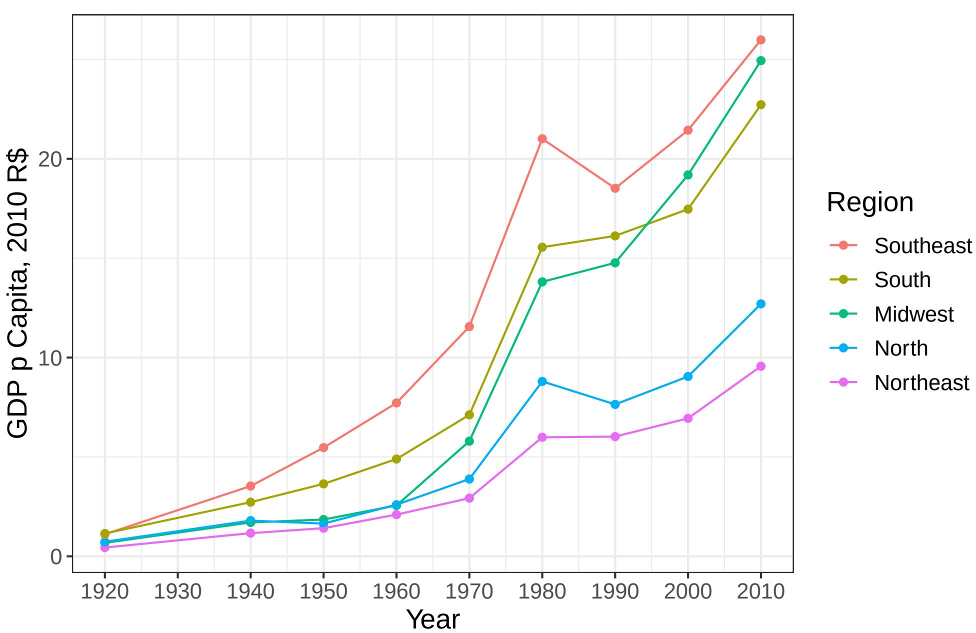
A Additional Tables and Figures

Figure A1: Population and GDP p/ Capita by Region

(a) Population Shares

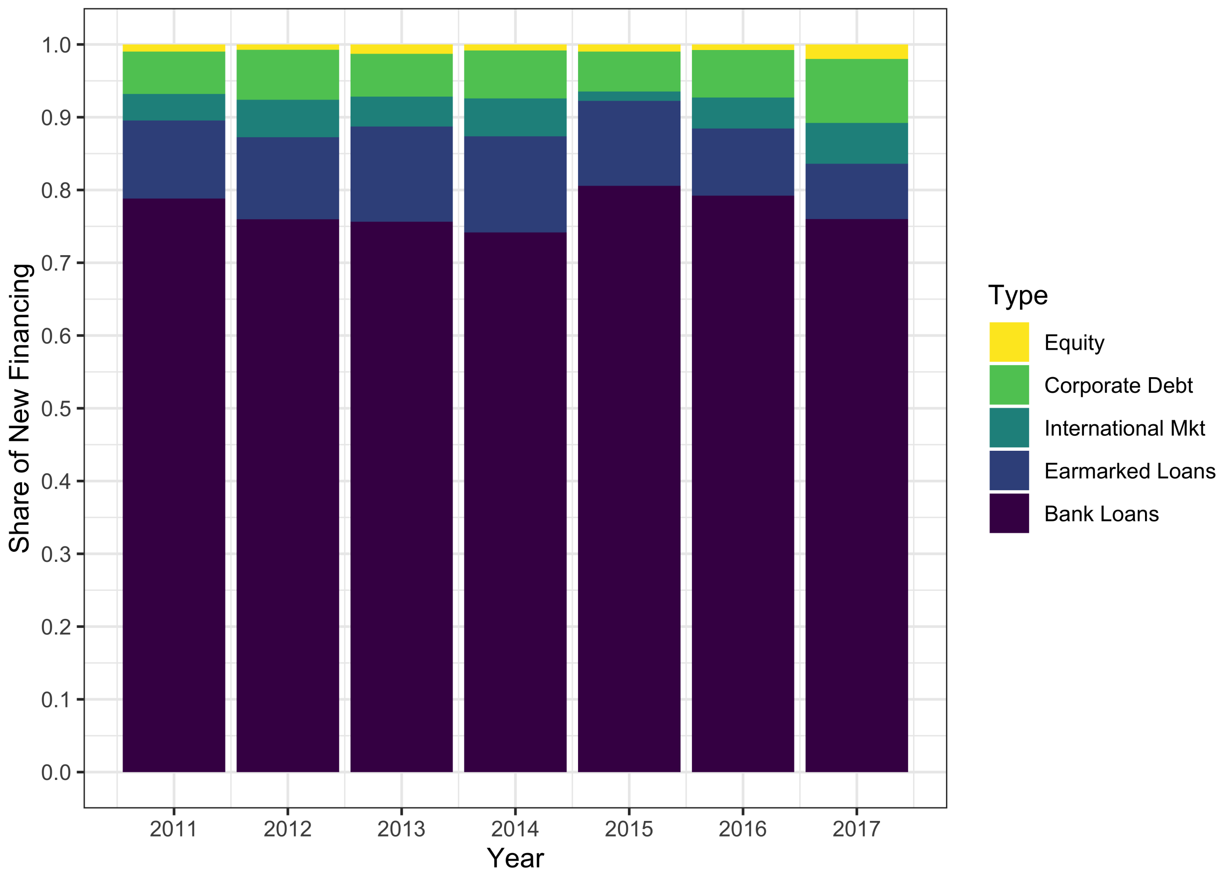


(b) Real GDP per Capita



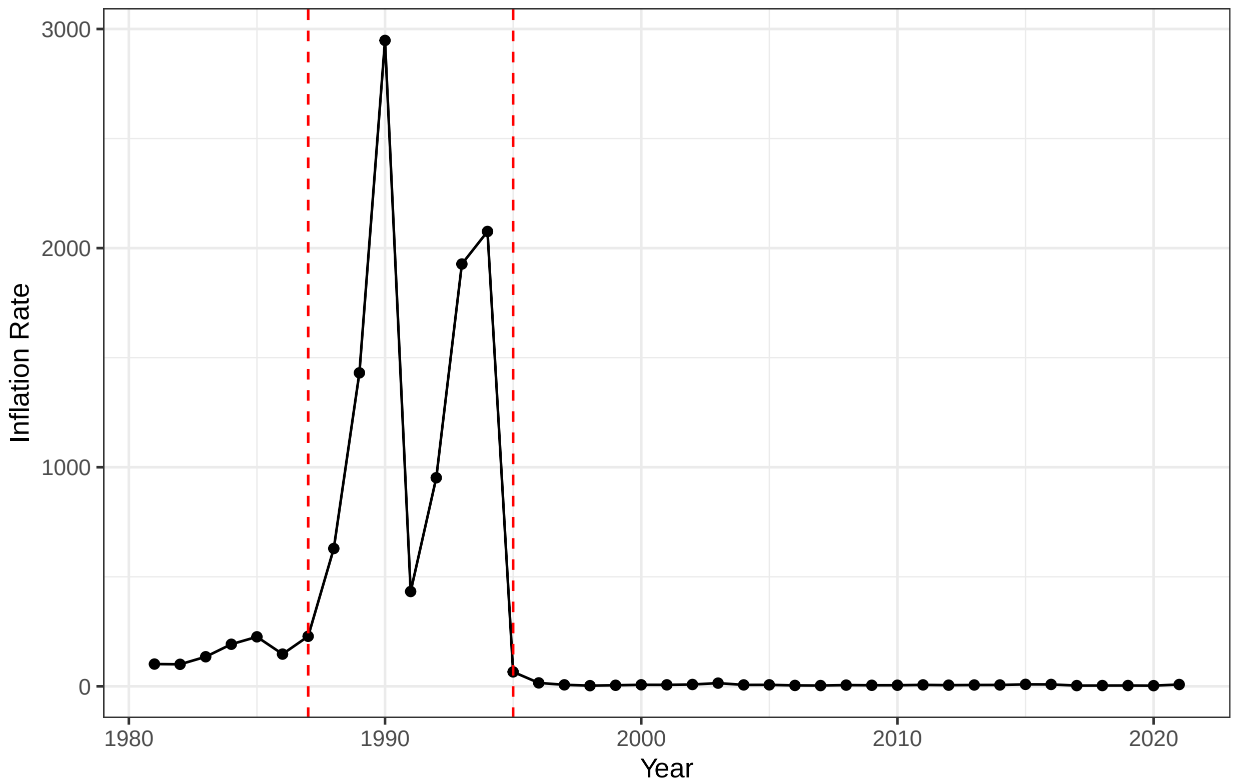
Notes: The figure on the left shows the population share by each region from 1920 to 2010. The figure on the right shows real GDP per capita by region from 1920 to 2010. The data is obtained from IPEA's regional accounts module (back).

Figure A2: Shallow Capital Markets



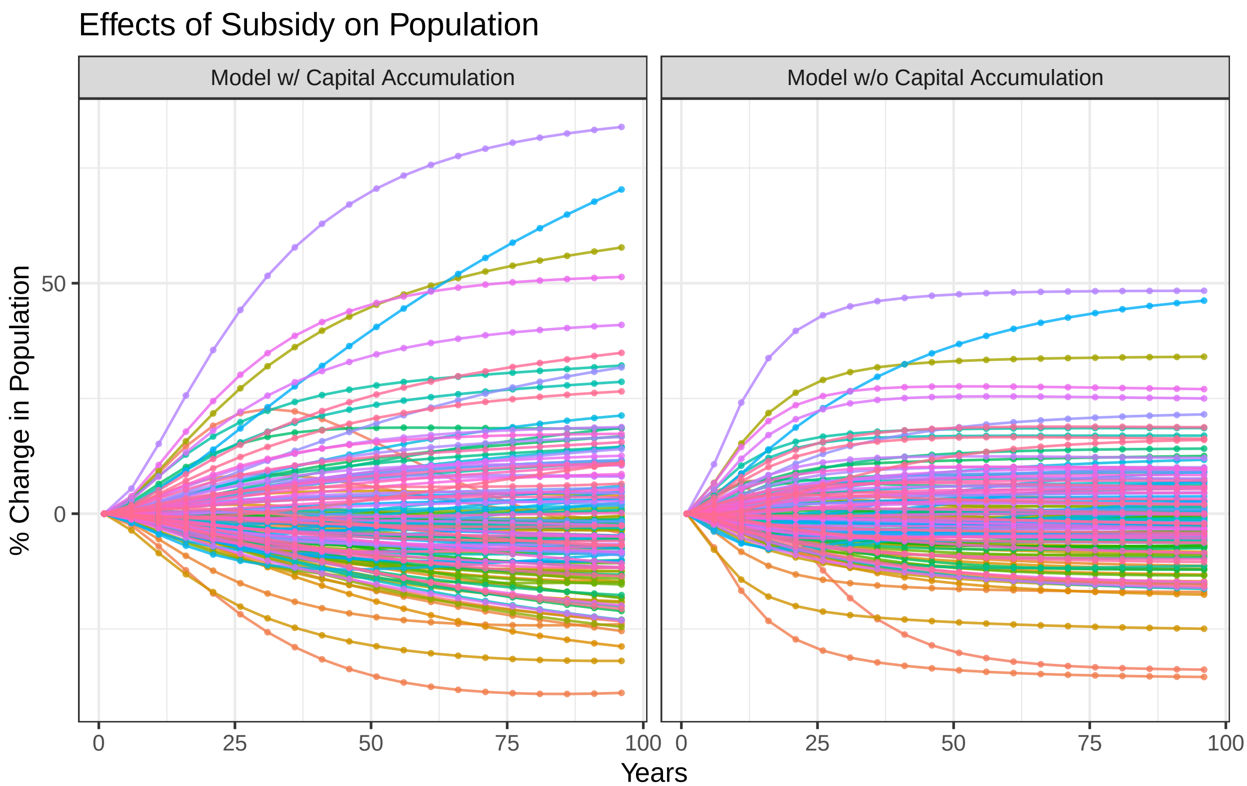
Notes: This figure shows the share of new financing obtained from different sources. The source of the date is the *Comissao de Valores Mobiliarios*, Public Firms.

Figure A3: Inflation Rate Brazil



Notes: This figure shows the inflation rate in Brazil between 1980 and 2020. As shown in the graph, Brazil underwent two hyperinflation periods between 1986 and 1995.The data was obtained from the International Monetary Fund, International Financial Statistics and data files.

Figure A4: Effect of Subsidies on Population Dynamics w/ & w/o Capital Accumulation



Notes: This graph shows the effects of the subsidies on total population by mesoregion. Each line represents a different mesoregion. The panel on the left shows the percent change in population induced by the subsidies in each mesoregion in the baseline calibration of the model presented in Section 5. The panel on the right shows the response one would obtain in a model without capital accumulation. We obtain such response setting $\delta = 1$ (back).

Table A1: Effect on Private Credit

Dependent Variable:	log(Total Credit Private)
	(1)
Variables	
Semiarido × Post	0.2970
	(0.3979)
Fixed-effects	
Municipality	Yes
State-Year	Yes
Fit statistics	
N Observations	11,742
Dep. Var. Mean	9.57

Notes: This table shows the difference in difference coefficients from equation 29 where the dependent variable is the log of total private credit. Controls include a linear polynomial in latitude and longitude, state times year fixed effects, as well as distance to the coast interacted with year dummies. Errors are clustered at the municipality level. *Signif. Codes: ***: 0.01, **: 0.05, *: 0.1* (back).

Table A2: Autocorrelation in Court Productivity

Dependent Variable:	$log(CourtProductivity)_t$			
	(1)	(2)	(3)	(4)
Variables				
$log(CourtProductivity)_{t-1}$	0.908^{***}			
	(0.023)			
Fixed-effects				
Year	Yes	Yes	No	Yes
Municipality	No	No	Yes	Yes
Fit statistics				
N Observations	29,513	29,513	29,513	29,513
R^2	**0.796**	**0.002**	**0.821**	**0.824**

Notes: This table shows the coefficient from a panel regression of court productivity in a year against its lag at the municipality level. Standard errors cluster at the municipality level. *Signif. Codes: ***: 0.01, **: 0.05, *: 0.1* (back).

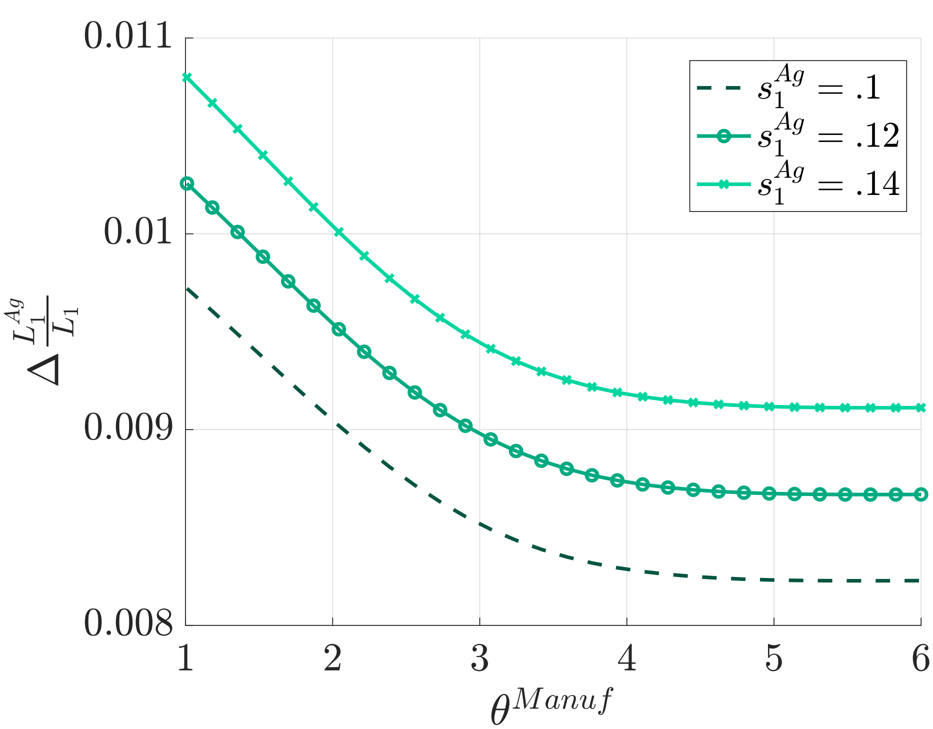
B Two Region Model Simulations

In this section we simulate a version of the model with 2 regions and 3 sectors: agriculture, manufacturing, and services. We use the same parameters as in the main quantitative exercise in Section 5. We simulate the effect of a 1 percentage point subsidy in region 1 on the outcomes studied in the reduced form part of the paper Section 3.

B.1 Effect of Agricultural Subsidies on Agricultural Employment

We first study the agricultural employment responses in region 1 at different levels of agricultural subsidies as a function of the tradability of manufactured goods. We capture different levels of tradability of manufactured goods through the manufacturing trade elasticity θ^{Manuf}. The larger this parameter is, the less intra-regionally tradable manufactured goods are. We plot the results in Figure A5.

Figure A5: Manufactured Goods Tradability and Agriculture Emp. Share



Notes: This figure shows the effect of agricultural subsidies in region 1 on the agricultural employment share in that region as a function of the tradability of manufactured goods θ^{Manuf}. Each line represents a different level of the subsidy (back).

As shown in the Figure, for a given level of tradability of manufactured goods, the larger the agricultural subsidy in a region, the larger the increase in the agricultural employment share in that region. Importantly, we also find that, for a given level of subsidy, the quantitative response of the agricultural employment share depends on how tradable manufactured goods are, with the responses being larger when tradable goods are more tradable (lower θ^{Manuf}). On the other hand, when manufactured goods are less tradable, the increase in the agricultural employment share is smaller since a share of the workers will have to produce manufactured inputs which are used for the production of agricultural goods.

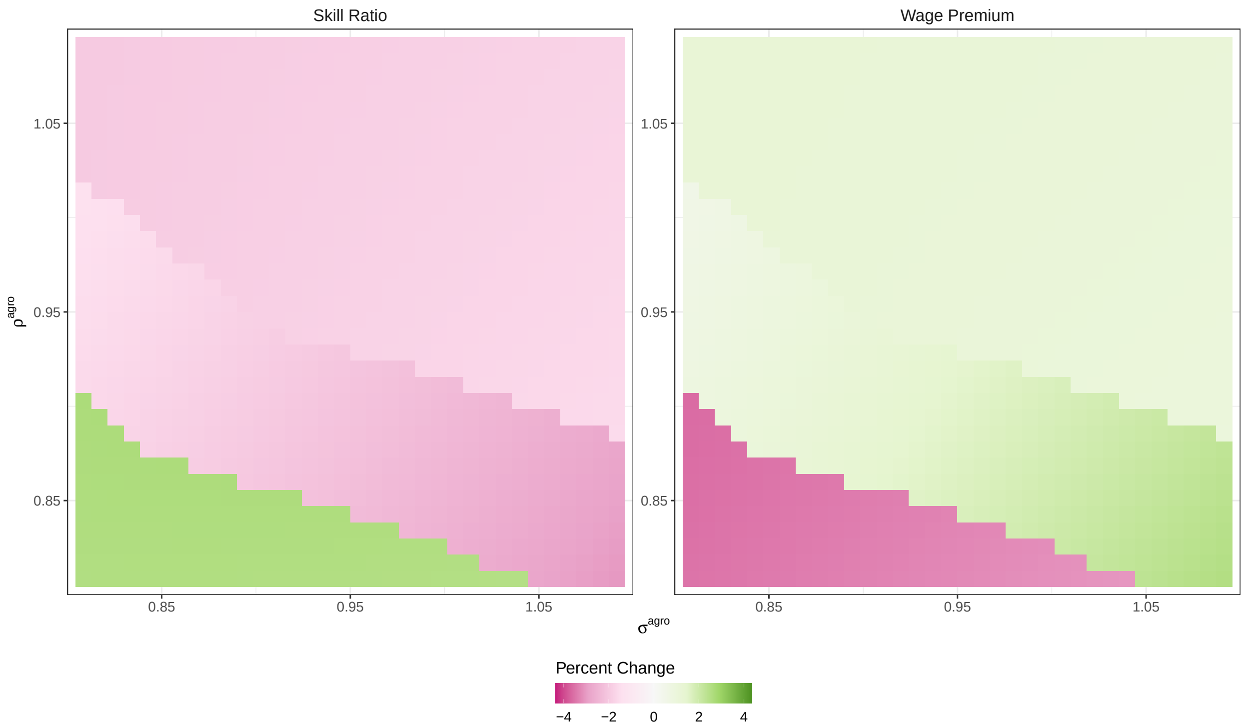
B.2 Effect of Agricultural Subsidies on the Skill Ratio and Wage Premium

We explore the effects of a 1 percentage point agricultural subsidy in region 1 on the skill ratio and wage premium as a function of the substitutability of factors in agricultural production $\{\sigma^{agro}, \rho^{agro}\}$. As a reminder, $\rho^{Agro} = \sigma^{Agro} = 1$ implies Cobb Douglas production in agriculture. On the other hand, $\rho^{Agro} < \sigma^{Agro}$ implies that high-skilled workers are relatively more complementary to capital relative to low-skilled workers, this is, there is high-skill capital complementarity. Finally, $\rho^{Agro} > \sigma^{Agro}$ implies that low-skilled workers are relatively more complementary to capital relative to high-skilled workers in agriculture, this is, there is low-skill capital complementarity.

As shown in Figure A6, different combinations of $\{\sigma^{Agro}, \rho^{Agro}\}$ have different implications for the wage premium and skill ratio responses to agricultural subsidies. For example, when $\sigma^{Agro} < \rho^{Agro} < 1$, then there is low-skill capital complementarity, but capital complements both low- and high-skilled workers. In this scenario, the agricultural subsidy has a negative effect on the skill ratio, but has almost no effect on the wage premium.

In Section 4 we find the combination of $\{\sigma^{Agro}, \rho^{Agro}\}$ that rationalize the observed response in the skill ratio and wage premium after an agricultural credit subsidy through a method of simulated moments.

Figure A6: Skill Ratio and Wage Premium Response to Agricultural Subsidy



Notes: This figure shows the skill ratio and wage premium effects of a 1 percentage point agricultural subsidy in region 1 as a function of the production function parameters $\{\sigma^{agro}, \rho^{agro}\}$ (back).

C Data Appendix

C.1 Measures of Monitoring Costs and Subsidies

We use the administrative data to obtain measures of $\varkappa_{it}^{j}$, the gross interest rate in sector j location i time period t. We measure it as a loan weighted average interest rate in a location-sector-year. In such process, we distinguish between subsidized loans, which are called "directed", versus non-subsidized loans, called "non-directed".

Denote $C_{it}^{j,l}$ the amount of new credit for a loan l for a firm in sector j location i. We partition the set of all loans in time t into directed and non-directed loans: $\mathcal{L}_t = \mathcal{D}_t \cup \mathcal{N}_t$.

We compute average interest rates by location-sector as a loan-weighted average interest rate. Denoting $R_{it}^{j,l}$ as the interest rate associated with loan l in sector j location i time period t, and $\bar{R}_{it}^{j}$ as our measure of average interest rate, then:

$$\bar{R}_{it}^{j} = \sum_{l \in \mathcal{L}_t} \frac{C_{it}^{j,l}}{\sum_{l' \in \mathcal{L}_t} C_{it}^{j,l'}} R_{it}^{j,l}$$

We can decompose this further into an average interest rate for directed loans plus an average interest rate for not-directed loans.

$$\bar{R}_{it}^{j} = \sum_{l \in \mathcal{D}_t} \frac{C_{it}^{j,l}}{\sum\limits_{l' \in \mathcal{L}_t} C_{it}^{j,l'}} R_{it}^{j,l} + \sum_{l \in \mathcal{N}_t} \frac{C_{it}^{j,l}}{\sum\limits_{l' \in \mathcal{L}_t} C_{it}^{j,l'}} R_{it}^{j,l}$$

Multiplying and dividing by the total credit in their respective category:

$$\bar{R}_{it}^{j,l} = \sum_{l \in \mathcal{D}_t} \frac{C_{it}^{j,l}}{\sum\limits_{l' \in \mathcal{D}_t} C_{it}^{j,l'}} \frac{\sum\limits_{l' \in \mathcal{D}_t} C_{it}^{j,l'}}{\sum\limits_{l' \in \mathcal{L}_t} C_{it}^{j,l'}} R_{it}^{j,l} + \sum_{l \in \mathcal{N}_t} \frac{C_{it}^{j,l}}{\sum\limits_{l' \in \mathcal{N}_t} C_{it}^{j,l'}} \frac{\sum\limits_{l' \in \mathcal{N}_t} C_{it}^{j,l'}}{\sum\limits_{l' \in \mathcal{L}_t} C_{it}^{j,l'}} R_{it}^{j,l} \tag{34}$$

Defining:

$$\lambda_{it}^{j,d} \equiv \frac{\sum\limits_{l' \in \mathcal{D}_t} C_{it}^{j,l'}}{\sum\limits_{l' \in \mathcal{L}_t} C_{it}^{j,l'}}$$

$$\lambda_{it}^{j,n} \equiv \frac{\sum\limits_{l' \in \mathcal{N}_t} C_{it}^{j,l'}}{\sum\limits_{l' \in \mathcal{L}_t} C_{it}^{j,l'}}$$

as the share of all new credit in location i sector j that comes from directed resources and non-directed resources, respectively, we have:

$$1 = \lambda_{it}^{j,d} + \lambda_{it}^{j,n}$$

Also denote the share of all directed credit in location i sector j corresponding to loan l as:

$$\lambda_{it}^{j,l,d} = \frac{C_{it}^{j,l}}{\sum\limits_{l' \in \mathcal{D}_t} C_{it}^{j,l'}}$$

And a similar definition for the share of all non-directed credit in location i sector j corresponding to a loan l:

$$\lambda_{it}^{j,l,n} = \frac{C_{it}^{j,l}}{\sum\limits_{l' \in \mathcal{N}_t} C_{it}^{j,l'}}$$

We can write equation 34 as:

$$\bar{R}_{it}^{j,l} = \sum_{l \in \mathcal{D}_t} \lambda_{it}^{j,l,d} \lambda_{it}^{j,d} R_{it}^{j,l} + \sum_{l \in \mathcal{N}_t} \lambda_{it}^{j,l,n} \lambda_{it}^{j,n} R_{it}^{j,l}$$

Further defining:

$$\bar{R}_{it}^{j,d} \equiv \sum_{l \in \mathcal{D}_t} \lambda_{it}^{j,l,d} R_{it}^{j,l}$$

as the average interest rate for directed loans and:

$$\bar{R}_{it}^{j,n} \equiv \sum_{l \in \mathcal{N}_t} \lambda_{it}^{j,l,n} R_{it}^{j,l}$$

as the average interest rate for non-directed loans, we have that the overall average interest rate can be decomposed into a weighted average interest rate of the directed and non-directed loans:

$$\bar{R}_{it}^{j} = \lambda_{it}^{j,d} \bar{R}_{it}^{j,d} + \lambda_{it}^{j,n} \bar{R}_{it}^{j,n} \tag{35}$$

Our measure of $\varkappa_{it}^{j} = 1 + \bar{R}_{it}^{j}$ is given by the loan-weighted average interest rate in a location-sector. We can decompose this into a monitoring cost and a subsidy as follows. In the data, interest rates for directed loans are lower than for non-directed loans.

$$\bar{R}_{it}^{j,d} < \bar{R}_{it}^{j,n}$$

We can rewrite equation 35 as:

$$\begin{aligned}
\bar{R}_{it}^{j} &= \lambda_{it}^{j,d} \bar{R}_{it}^{j,d} + \lambda_{it}^{j,n} \bar{R}_{it}^{j,n} \\
&= \lambda_{it}^{j,d} \bar{R}_{it}^{j,d} + (1 - \lambda_{it}^{j,d}) \bar{R}_{it}^{j,n} \\
&= \bar{R}_{it}^{j,n} - \lambda_{it}^{j,d} \left(\bar{R}_{it}^{j,n} - \bar{R}_{it}^{j,d} \right)
\end{aligned}$$

Since $\bar{R}_{it}^{j,n} - \bar{R}_{it}^{j,d} > 0$, we can define:

$$\begin{aligned}
m_{it}^{j} &\equiv \bar{R}_{it}^{j,n} > 0 \\
s_{it}^{j} &\equiv \lambda_{it}^{j,d} \left(\bar{R}_{it}^{j,n} - \bar{R}_{it}^{j,d} \right) > 0 \\
\varkappa_{it}^{j} &\equiv 1 + \bar{R}_{it}^{j}
\end{aligned}$$

To obtain the same equation as in the model:

$$\varkappa_{it}^{j} = 1 + m_{it}^{j} - s_{it}^{j}$$

Intuitively, we measure monitoring costs as the loan-weighted interest rate of non-directed loans, and the implied subsidy as the interest rate differential between loan-weighted interest rates of non-directed versus directed loans weighted by the share of loans that are directed. This last weight is important because, even if directed interest rates were much smaller than non-directed, the government still decides quantity allocations, and non all firms might access such loans. We take this into account by weighting by $\lambda_{it}^{j,d}$.

D Model Appendix

D.1 Dynamic Exact Hat Algebra

The model is amenable to using dynamic exact hat algebra. We suppose that we observe the spatial distribution of economic activity somewhere along the transition path towards an unobserved steady-state. Given the initial observed endogenous variables of the model, as well as monitoring costs and policy variables, one can solve for the economy's transition path in time differences: $(\dot{x}_{t+1} = x_{t+1}/x_t)$, given any anticipated convergent sequence of future changes in fundamentals, subsidies, and frictions, without having to solve for the unobserved initial level of fundamentals.

Implementing the dynamic exact hat algebra procedure requires data on the distribution of high- and low-skilled workers across space $\{U_{nt}\}_n, \{H_{nt}\}_n$, initial capital stocks by region $\{K_{nt}\}_n, \{K_{nt+1}\}_n$, the initial share of output going to factors $\{\varphi^{j\ell}_{nt}\}_{n,j,\ell}$, bilateral trade flows by sector $\{\pi^j_{nit}\}_{n,i,j}$, initial migration flows by skill type $\{\mu^{\ell}_{nt-1}\}_{n,i,j,\ell}$, as well as subsidies and monitoring costs $\{m^j_{nt}\}_{n,j}, \{s^j_{nt}\}_{n,j}$.

In what follows we define:

$$\mathbb{v}^{\ell}_{nt} \equiv \exp(v^{\ell}_{nt})$$

and:

$$\Psi^{\ell}_{nit} \equiv \exp\left(\frac{\kappa^{\ell}_{nit}}{\beta}\right)$$

which are useful transformations for hat algebra.

Given these variables, the solution to the temporary equilibrium at $t+1$ given a change in $\dot{H}_{nt+1}, \dot{U}_{nt+1}, \dot{\Omega}_{t+1}, \dot{m}_{t+1}, \dot{s}_{t+1}$ satisfies the following system of equations:

$$\dot{P}^{j}_{nt+1} = \left[\sum_{i} \pi^{j}_{nit}\left(\dot{\varkappa}^{j}_{it+1}\dot{c}^{j}_{it}\dot{\tau}^{j}_{nit+1}\right)^{-\theta^{j}}\right]^{-\frac{1}{\theta^{j}}} \tag{36}$$

$$\dot{c}^{j}_{it+1} = \left[\left(\dot{P}^{V,j}_{it+1}\right)^{\gamma^{j}}\left(\prod_{m=1}^{J}\left(\dot{P}^{m}_{it+1}\right)^{\psi^{jm}}\right)^{1-\gamma^{j}}\right] \tag{37}$$

$$\dot{P}^{V,j}_{it+1} = \left(\varphi^{u,j}_{it} + \varphi^{z,j}_{it}\right)^{\frac{1}{\sigma^{j}-1}}\left[\varphi^{u,j}_{it}(\dot{w}^{u}_{it+1})^{1-\sigma^{j}} + \varphi^{z,j}_{it}(\dot{P}^{Z}_{it+1})^{1-\sigma^{j}}\right]^{\frac{1}{1-\sigma^{j}}} \tag{38}$$

$$\dot{P}^{Z,j}_{it+1} = \left(\varphi^{h,j}_{it} + \varphi^{k,j}_{it}\right)^{\frac{1}{\rho^{j}-1}}\left[\varphi^{h,j}_{it}(\dot{w}^{h}_{it+1})^{1-\rho^{j}} + \varphi^{k,j}_{it}(\dot{r}_{it+1})^{1-\rho^{j}}\right]^{\frac{1}{1-\rho^{j}}} \tag{39}$$

$$\dot{\pi}^{j}_{nit+1} = \frac{\left(\dot{\varkappa}^{j}_{it+1}\dot{c}^{j}_{it+1}\dot{\tau}^{j}_{nit+1}\right)^{-\theta^{j}}}{\sum_{m} \pi^{j}_{mt}\left(\dot{\varkappa}^{j}_{mt+1}\dot{c}^{j}_{mt+1}\dot{\tau}^{j}_{nmt+1}\right)^{-\theta^{j}}} \tag{40}$$

$$\dot{\varphi}^{h,j}_{it+1} = \left(\frac{\dot{P}^{Z,j}_{it+1}}{\dot{P}^{V,j}_{it+1}}\right)^{1-\sigma^{j}}\left(\frac{\dot{w}^{h}_{it+1}}{\dot{P}^{Z,j}_{it+1}}\right)^{1-\rho^{j}} \tag{41}$$

$$\dot{\varphi}^{k,j}_{it+1} = \left(\frac{\dot{P}^{Z,j}_{it+1}}{\dot{P}^{V,j}_{it+1}}\right)^{1-\sigma}\left(\frac{\dot{r}_{it+1}}{\dot{P}^{Z,j}_{it+1}}\right)^{1-\rho} \tag{42}$$

$$\dot{\varphi}^{u,j}_{it+1} = \left(\frac{\dot{w}^{u}_{it+1}}{\dot{P}^{V,j}_{it+1}}\right)^{1-\sigma} \tag{43}$$

$$\begin{aligned} I_{nt+1} = \Big[&\dot{w}^{h}_{nt+1}\dot{H}_{nt+1}w^{h}_{nt}H_{nt} + \dot{w}^{u}_{nt+1}\dot{U}_{nt+1}w^{u}_{nt}U_{nt} + \cdots \\ &\cdots + \dot{r}_{nt+1}\dot{k}_{nt+1}r_{nt}k_{nt} - \dot{P}^{X}_{nt+1}\dot{X}_{nt+1}P^{X}_{nt}X_{nt} - T_{t+1}\Big] \end{aligned} \tag{44}$$

$$\begin{aligned} E^{j}_{nt+1} = {}& \alpha^{j}I_{nt+1} + \chi^{j}\frac{P^{X}_{nt+1}X_{nt+1}}{r_{nt+1}K_{nt+1}}\sum_{m}\varphi^{k,m}_{nt+1}\sum_{i}\pi^{m}_{int+1}E^{m}_{it+1} + \cdots \\ &\cdots + \sum_{m}\left(1-\gamma^{m}_{nt+1}\right)\psi^{mj}_{nt+1}\sum_{i}\pi^{m}_{int+1}E^{m}_{it} \end{aligned} \tag{45}$$

where:

$$w^{u}_{nt+1}U_{nt+1} = \sum_{j} \varphi^{u,j}_{nt+1} \sum_{i} \pi^{j}_{int+1} E^{j}_{it+1} \tag{46}$$

$$w^{h}_{nt+1}H_{nt+1} = \sum_{j} \varphi^{h,j}_{nt+1} \sum_{i} \pi^{j}_{int+1} E^{j}_{it+1} \tag{47}$$

$$r_{nt+1}k_{nt+1} = \sum_{j} \varphi^{k,j}_{nt+1} \sum_{i} \pi^{j}_{int+1} E^{j}_{it+1} \tag{48}$$

and the government budget constraint must always bind:

$$T_{t+1} = \frac{1}{I} \sum_{i} \sum_{j} \left[s^{j}_{it+1} \frac{Y^{j}_{it+1}}{\varkappa^{j}_{it+1}} \right]$$

From the capitalists' side, we have:

$$\dot{C}^{k}_{it+1} = \left[\beta \frac{\dot{P}^{X}_{it+1}}{\dot{P}_{it+1}} \left(\frac{r_{it+1}}{P^{X}_{it+1}} + (1-\delta) \right) \right]^{\psi} \tag{49}$$

$$\dot{r}_{it+1}\dot{K}_{it+1} = \dot{P}_{it+1}\dot{C}_{it+1} + \frac{\dot{r}_{it+1}}{\dot{P}^{X}_{it+1}} \frac{P^{X}_{it+1}X_{it}}{r_{it+1}K_{it}} \left[\dot{P}^{X}_{t+1}\dot{X}_{t+1} - \dot{P}_{t+1}\dot{C}_{t+1} \right] \tag{50}$$

$$X_{t} = K_{t+1} - (1-\delta)K_{t} \tag{51}$$

The migration variables evolve according to:

$$\dot{\mathbb{v}}^{\ell}_{it+1} = \left(\frac{\dot{b}^{\ell}_{it+1}\dot{w}^{\ell}_{it+1}}{\dot{P}_{it+1}} \right) \left(\sum_{g} \mu^{\ell}_{git} \left(\dot{\mathbb{v}}^{\ell}_{gt+2} / \dot{\Psi}^{\ell}_{git+1} \right)^{\beta/\nu^{\ell}} \right)^{\nu^{\ell}} \tag{52}$$

$$\dot{\mu}^{\ell}_{nit+1} = \frac{(\dot{\mathbb{v}}^{\ell}_{nt+2}/\dot{\Psi}^{\ell}_{nit+1})^{\beta/\nu^{\ell}}}{\sum_{g} \mu^{\ell}_{git} (\dot{\mathbb{v}}^{\ell}_{gt+2}/\dot{\Psi}^{\ell}_{git+1})^{\beta/\nu^{\ell}}} \tag{53}$$

$$U_{nt+1} = \sum_{i=1}^{N} \mu^{u}_{nit} U_{it} \tag{54}$$

$$H_{nt+1} = \sum_{i=1}^{N} \mu^{h}_{nit} H_{it} \tag{55}$$

where $\{\dot{w}^{\ell}_{it+1}, \dot{P}_{it+1}\}$ solve the temporary equilibrium given $\{\dot{H}_{nt}, \dot{U}_{nt}\}$.

As is clear from this system of equations solving this system of equations does not require knowing the levels of fundamentals at time t $\{\Omega_{t}\}$.

D.2 Numeric Algorithm for Dynamic Hat Algebra

Given an initial allocation of the economy at time t: $(U_0, H_0, w_0^u, w_0^h, r_0K_0, K_0, K_1, \mu_{-1}, \pi_{ni0})$ and given an anticipated convergent sequence of changes in fundamentals $\{\dot{\Omega}_t\}$, initiate the algorithm at $t = 0$ with a guess for th path of $\{\dot{\mathbb{v}}_{t+1}^{\ell}\}$, and a path of consumption rates of the capitalist $\{\dot{C}_{t+1}^{k}\}$ such that they converge to $\dot{\mathbb{v}}_{T+1}^{\ell} = 1, \dot{C}_{t+1}^{k} = 1$ for a sufficiently large T. Taking as given the initial conditions:

$$(U_0, H_0, w_0^u, w_0^h, r_0K_0, K_0, K_1, \mu_{-1}, \pi_{ni0})$$

and given data on previous period trade shares π_{ni0}, factor shares $\varphi_{i0}^{jh}, \varphi_{i0}^{jk}, \varphi_{i0}^{ju}$, wage bill $w_{nt}^h H_{nt}, w_{nt}^u U_{nt}$, payments to capital $r_{nt}K_{nt}$, then:

1. For all $t \geq 0$ use $\{\dot{\mathbb{v}}_{t+1}^{\ell}\}$ and μ_{-1} to solve for the path of migration shares across times $\{\mu_t^{\ell}\}$

2. Use the path for $\{\mu_t^{\ell}\}$ and U_0, H_0 to get a path for $\{U_{t+1}, H_{t+1}\}$

3. Solve for a temporary equilibrium and obtain the capital stock in the next period consistent with the growth rate of consumption.

    (a) Given $\dot{H}_{nt+1}, \dot{U}_{nt+1}, \dot{K}_{nt+1}$, guess values for $\dot{w}_{nt+1}^u, \dot{w}_{nt+1}^h, \dot{r}_{nt+1}$. Note that we have $\dot{K}_1$ by assumption, since we have K_0, K_1.

    (b) Obtain $\{\dot{c}_{it+1}^{j}, \dot{P}_{nt+1}^{j}, \dot{\pi}_{nit+1}^{j}\}$ consistent with equations 36, 37 40, 38, 39

    (c) Given $\dot{P}_{nt+1}^{j}$ compute $\dot{P}_{nt+1}^{x}, \dot{P}_{nt+1}$

    (d) Given $\dot{P}_{nt+1}^{x}, \dot{P}_{nt+1}$ and an initial guess for the change in consumption $\dot{C}_{t+1}^{k}$, find $R_{t+1} = r_{t+1}/P_{t+1}^{X}$ consistent with the Euler Equation 49

    (e) Use the capitalist budget constraint to find the change in investment consistent with the change in consumption and the changes in prices, $\dot{X}_{t+1}$ in equation 50

    (f) Obtain the capital stock K_{t+2} consistent with this change in investment using equation 51

    (g) Compute factor shares in $t+1$, $\{\varphi_{it+1}^{h,j}, \varphi_{it+1}^{k,j}, \varphi_{it+1}^{u,j}\}$ with equations 41, 42, 43

    (h) Given initial payments to high, low-skilled workers, and capital $\{w_{nt}^u U_{nt}, w_{nt}^h H_{nt}, r_{nt}K_{nt}\}$ as well the variables above obtained above, obtain $\{I_{nt}\}$ in $t+1$ using equation 44

    (i) Using income, the factor shares, trade shares, obtain $\{E_{nt+1}^{j}\}$ using equation 45

(j) Given expenditure, and factor shares in the second period, check whether factor market clears in equations 46, 47, 48:

- Note that this last step gives us a natural next guess of factor prices:

$$w_{nt+1}^{u,(1)} = \frac{1}{U_{nt+1}} \sum_j \varphi_{nt+1}^{u,j} \sum_i \pi_{int+1}^j E_{it+1}^j$$
$$w_{nt+1}^{h,(1)} = \frac{1}{H_{nt+1}} \sum_j \varphi_{nt+1}^{h,j} \sum_i \pi_{int+1}^j E_{it+1}^j$$
$$r_{nt+1}^{(1)} = \frac{1}{K_{nt+1}} \sum_j \varphi_{nt+1}^{k,j} \sum_i \pi_{int+1}^j E_{it+1}^j$$

(k) Repeat these steps for each time period to obtain paths for

$$\{\dot{w}_{nt+1}^u, \dot{w}_{nt+1}^h, \dot{r}_{nt+1}, \dot{P}_{nt+1}^j\}$$

as well as evolution of the capital stocks $\{K_{t+2}\}$

4. Given $\{\dot{w}_{nt+1}^u, \dot{w}_{nt+1}^h, \dot{P}_{nt+1}^j\}$ as well as the migration shares obtained in the first step $\{\mu_{nit}^\ell\}$, and the initial guess for the value functions $\left\{\dot{\mathbb{V}}_{t+1}^{\ell,(0)}\right\}$ to solve backwards for a new guess of value functions $\left\{\dot{\mathbb{V}}_{t+1}^{\ell,(1)}\right\}$ that satisfies equation 52

5. Solve backwards for $R_{it}^{(1)}$ using the fact that

$$R_{iT+1} = \frac{1}{\beta} - (1-\delta)$$

and that

$$R_{it}^{(1)} = \frac{R_{it+1}^{(0)}}{\dot{R}_{it+1}}$$

6. Given this new path of $\{R_{it}^{(1)}\}$ obtain a new guess for the changes in consumption consistent with the Euler equation 49

$$\left[\dot{C}_{it+1}^{(1)}\right]^{1/\psi} = \beta \frac{\dot{P}_{it+1}^X}{\dot{P}_{it+1}} \left(R_{it+1} + (1-\delta)\right)$$

7. Use this path as the new set of equilibrium conditions $\left\{\dot{\mathbb{V}}_{t+1}^{\ell,(1)}\right\}, \left\{\dot{C}_{t+1}^{(1)}\right\}$

8. Check if $\left\{\dot{\mathbb{V}}_{t+1}^{\ell,(1)}\right\} \approx \left\{\dot{\mathbb{V}}_{t+1}^{\ell,(0)}\right\}, \left\{\dot{C}_{t+1}^{(1)}\right\} \approx \left\{\dot{C}_{t+1}^{(0)}\right\}$ and repeat until convergence

D.3 Model Derivations

D.3.1 Solution to Migration Problem

Start from the value function

$$\mathbb{V}_{it}^{\ell} = \log u_{it}^{\ell} + \max_{\{g\}_1^N} \left\{ \beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell,} \right] - \kappa_{git}^{\ell} + \nu_{\ell} \epsilon_{gt}^{\ell} \right\}$$

Taking expectation over the idiosyncratic shock:

$$\mathbb{E}[\mathbb{V}_{it}^{\ell}]_{\epsilon} = \log u_{it}^{\ell} + \mathbb{E}_{\epsilon} \left[\max_{\{g\}_1^N} \left\{ \beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell} \right] - \kappa_{git}^{\ell} + \nu_{\ell} \epsilon_{gt}^{\ell} \right\} \right]$$

Since $\epsilon_{gt}^{\ell} \sim Gumbel(0,1)$, by properties of Gumbel, we have the following:

$$\begin{aligned} \epsilon_{gt} &\sim Gumbel(0,1) \Rightarrow \\ \nu_{\ell} \epsilon_{gt} &\sim Gumbel(0, \nu_{\ell}) \Rightarrow \\ \beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell} \right] - \kappa_{git}^{\ell} + \nu_{\ell} \epsilon_{gt}^{\ell} &\sim Gumbel \left(\beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell} \right] - \kappa_{git}^{\ell}, \nu_{\ell} \right) \end{aligned}$$

Then we are taking the max over several Gumbel distributions. The nice thing is that, again, using properties of the Gumbel distribution:

$$\max_{\{g\}_1^N} \left\{ \beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell} \right] - \kappa_{git}^{\ell} + \nu_{\ell} \epsilon_{gt}^{\ell} \right\} \sim Gumbel \left(\nu_{\ell} \log \left(\sum_g \exp \left(\frac{\beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell} \right] - \kappa_{git}^{\ell}}{\nu_{\ell}} \right) \right), \nu_{\ell} \right)$$

which means that the expectation of this distribution with respect to the shocks is equal to:

$$\begin{aligned} \mathbb{E}_{\epsilon} \left[\max_{\{g\}_1^N} \left\{ \beta \mathbb{E}_t \left[\mathbb{V}_{gt+1} \right] - \kappa_{git}^{\ell} + \nu_{\ell} \epsilon_{gt}^{\ell} \right\} \right] &= \nu_{\ell} \log \left(\sum_g \exp \left(\frac{\beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell} \right] - \kappa_{git}^{\ell}}{\nu_{\ell}} \right) \right) \\ &= \nu_{\ell} \log \left(\sum_g \left[\exp \left(\beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell} \right] \right) \left(\exp(-\kappa_{git}^{\ell}) \right) \right]^{1/\nu_{\ell}} \right) \\ &= \nu_{\ell} \log \left(\sum_g \left[\exp \left(\beta \mathbb{E}_t \left[\mathbb{V}_{gt+1}^{\ell} \right] \right) \left(\exp(\kappa_{git}^{\ell}) \right) \right]^{1/\nu_{\ell}} \right) \end{aligned}$$

which can also be written as:

$$\nu_\ell \log \left(\sum_g \left[\exp\left(\beta \mathbb{E}_t \left[\mathbb{V}^\ell_{gt+1} \right] \right) / \left(\exp(\kappa^\ell_{git}) \right) \right]^{1/\nu_\ell} \right)$$

So that:

$$v^\ell_{it} = \log u^\ell_{it} + \nu_\ell \log \left(\sum_g \left[\exp\left(\beta \mathbb{E}_t \left[\mathbb{V}^\ell_{gt+1} \right] \right) / \left(\exp(\kappa_{git})^{-1} \right) \right]^{1/\nu_\ell} \right) \tag{56}$$

In terms of population flows, the probability that an individual moves from location i to location g in period t is given by:

$$\mu^\ell_{git} = P \left[\beta \mathbb{E}_t \left[\mathbb{V}^\ell_{gt+1} \right] - \kappa^\ell_{git} + \nu_\ell \epsilon_{gt} \geq \max_{m \neq g} \left\{ \beta \mathbb{E}_t \left[\mathbb{V}^\ell_{mt+1} \right] - \kappa^\ell_{git} + \nu_\ell \epsilon_{mt} \right\} \right]$$

The crucial point is that the object on the right hand side is also Gumbel:

$$\max_{m \neq g} \left\{ \beta \mathbb{E}_t \left[\mathbb{V}^\ell_{gt+1} \right] - \kappa^\ell_{git} + \nu_\ell \epsilon^\ell_{gt} \right\} \sim Gumbel \left(\nu_\ell \log \left(\sum_{m \neq g} \exp \left(\frac{\beta \mathbb{E}_t \left[\mathbb{V}^\ell_{mt+1} \right] - \kappa^\ell_{git}}{\nu_\ell} \right) \right), \nu_\ell \right)$$

On the other hand, the object on the left is distributed as:

$$\beta \mathbb{E}_t \left[\mathbb{V}^\ell_{gt+1} \right] - \kappa^\ell_{git} + \nu_\ell \epsilon_{gt} \sim Gumbel \left(\beta \mathbb{E}_t \left[\mathbb{V}^\ell_{gt+1} \right] - \kappa^\ell_{git}, \nu_\ell \right) \tag{57}$$

The probability that one random variable distributed Gumbel $X \sim Gumbel(\alpha_x, \tilde{\beta})$ is greater than another random variable $Y \sim Gumbel(\alpha_y, \tilde{\beta})$ is given by:

$$P(X > Y) = \frac{\exp\left(\alpha_x\right)^{1/\tilde{\beta}}}{\exp\left(\alpha_x + \alpha_y\right)^{1/\tilde{\beta}}}$$

Define the mean of each of the options in equation 57 as:

$$CV^\ell_{git} \equiv \beta \mathbb{E}_t \left[\mathbb{V}^\ell_{gt+1} \right] - \kappa^\ell_{git}$$

Then, we have:

$$
\begin{aligned}
\mu_{git}^{\ell} &= \frac{\exp\left(CV_{git}^{\ell}\right)^{\nu_\ell}}{\exp\left(CV_{git}^{\ell}\right)^{1/\nu_\ell} + \exp\left(\nu_\ell \log\left(\sum_{m\neq g} \exp\left(CV_{mit}^{\ell}\right)^{1/\nu_\ell}\right)\right)^{1/\nu_\ell}} \\
&= \frac{\exp\left(CV_{git}^{\ell}\right)^{1/\nu_\ell}}{\exp\left(CV_{git}^{\ell}\right)^{1/\nu_\ell} + \exp\left(\log\left(\sum_{m\neq g} \exp\left(CV_{mit}^{\ell}\right)^{1/\nu_\ell}\right)\right)} \\
&= \frac{\exp\left(CV_{git}^{\ell}\right)^{1/\nu_\ell}}{\exp\left(CV_{git}^{\ell}\right)^{1/\nu_\ell} + \left(\sum_{m\neq g} \exp\left(CV_{mit}^{\ell}\right)^{1/\nu_\ell}\right)}
\end{aligned}
$$

which implies that:

$$
\mu_{git}^{\ell} = \frac{\exp\left(\beta \mathbb{E}_t\left[\mathbb{V}_{gt+1}^{\ell}\right] - \kappa_{git}^{\ell}\right)^{1/\nu_\ell}}{\sum_m \exp\left(\beta \mathbb{E}_t\left[\mathbb{V}_{mt+1}^{\ell}\right] - \kappa_{mit}^{\ell}\right)^{1/\nu_\ell}}
$$

which, is the expression we derive in the main text.

D.3.2 Welfare Under Counterfactuals

The indirect utility of a worker of type ℓ can be rewritten as:

$$
v_{nt}^{\ell} = \log b_{nt}^{\ell} + \log C_{nt}^{\ell} + \nu_\ell \log \sum_{g=1}^{N} \exp\left(\beta v_{gt+1}^{\ell} - \kappa_{gnt}^{\ell}\right)^{1/\nu_\ell}
$$

Add and subtract βv_{nt+1}^{ℓ}, which can also be written as:

$$
\beta v_{nt+1}^{\ell} = \nu_\ell \log\left(\exp\left(\beta v_{nt+1}^{\ell}\right)^{1/\nu_\ell}\right)
$$

You thus get:

$$v_{nt}^{\ell} = \log b_{nt}^{\ell} + \log C_{nt}^{\ell} + \beta v_{nt+1}^{\ell} + \underbrace{\nu_{\ell} \log \left(\sum_{g=1}^{N} \exp \left(\beta \left(v_{gt+1}^{\ell} - v_{nt+1}^{\ell} \right) - \kappa_{gnt}^{s} \right)^{1/\nu_{\ell}} \right)}_{\text{Option Value}} \quad (58)$$

Using the share of individuals that stay within their own labor market, and exploiting the fact that $\kappa_{nnt}^{\ell} = 0$, then:

$$\begin{aligned} \mu_{nnt}^{\ell} &= \frac{\exp\left(\beta v_{nt+1}^{\ell}\right)^{1/\nu_s}}{\sum_{m=1}^{N} \exp\left(\beta v_{mt+1}^{\ell} - \kappa_{mit}^{\ell}\right)^{1/\nu_s}} \\ &= \frac{1}{\sum_{m=1}^{N} \exp\left(\beta v_{mt+1}^{\ell} - \beta v_{nt+1}^{\ell} - \kappa_{mit}^{\ell}\right)^{1/\nu_{\ell}}} \end{aligned}$$

Taking logs from this equation:

$$\log(\mu_{nnt}^{\ell}) = -\log \left(\sum_{m=1}^{N} \exp \left(\beta v_{mt+1}^{\ell} - \beta v_{nt+1}^{\ell} - \kappa_{mit}^{\ell} \right)^{1/\nu_s} \right)$$

which means that:

$$-\nu_{\ell} \log(\mu_{nnt}^{\ell}) = \nu_{\ell} \log \left(\sum_{m=1}^{N} \exp \left(\beta v_{mt+1}^{\ell} - \beta v_{nt+1}^{\ell} - \kappa_{mit}^{\ell} \right)^{1/\nu_s} \right)$$

Thus, plugging this back into the equation in 58, we get:

$$v_{nt}^{\ell} = \log b_{nt}^{\ell} + \log C_{nt}^{\ell} + \beta v_{nt+1}^{\ell} - \nu_{\ell} \log \left(\mu_{nnt}^{\ell} \right)$$

Iterating this equation forward, one gets:

$$v_{nt}^{\ell} = \sum_{m=t}^{\infty} \beta^{m-t} \log C_{nm}^{\ell} b_{nm}^{\ell} - \nu_{\ell} \sum_{m=t}^{\infty} \beta^{m-t} \log \mu_{nnm}^{\ell}$$

This is crucial, because it allows us to get expected lifetime utilities in the baseline economy as:

$$v_{nt}^{\ell} = \sum_{m=t}^{\infty} \beta^{m-t} \log \left(\frac{C_{nm}^{\ell} b_{nm}^{\ell}}{\left(\mu_{nnm}^{\ell}\right)^{\nu_{\ell}}} \right) \quad (59)$$

From equation 59, we can obtain expected lifetime utilities in both baseline as well as counterfactual economies as:

$$v_{nt}^{\ell} = \sum_{m=t}^{\infty} \beta^{m-t} \log\left(\frac{C_{nm}^{\ell} b_{nm}^{\ell}}{\left(\mu_{nnm}^{\ell}\right)^{\nu_{\ell}}}\right)$$
$$v_{nt}^{\prime\ell} = \sum_{m=t}^{\infty} \beta^{m-t} \log\left(\frac{C_{nm}^{\prime\ell} b_{nm}^{\prime\ell}}{\left(\mu_{nnm}^{\prime\ell}\right)^{\nu_{\ell}}}\right)$$

Define the compensating variation in consumption for market n at time $t = 0$ for skill ℓ to be the scalar δ_n^{ℓ} such that the expected lifetime in the counterfactual is equal to the expected lifetime utility at baseline plus receiving this constant amount to infinity:

$$v_{n0}^{\prime\ell} = v_{n0}^{\ell} + \sum_{m=0}^{\infty} \beta^{m} \log\left(\delta_n^{\ell}\right)$$

Note that since δ_n^{ℓ} is constant, this gives us:

$$\log\left(\delta_n^{\ell}\right) = (1-\beta)\left(v_{n0}^{\prime\ell} - v_{n0}^{\ell}\right)$$

Using again, the equation for present discounted value of utility in equation 59, we get that:

$$\log\left(\delta_n^{\ell}\right) = (1-\beta) \sum_{m=0}^{\infty} \beta^{m} \log\left(\frac{u_{nm}^{\prime\ell}/u_{nm}^{\ell}}{\left(\mu_{nnm}^{\prime\ell}/\mu_{nnm}^{\ell}\right)^{\nu_{\ell}}}\right)$$

This can also be written as:

$$\begin{aligned}
\log\left(\delta_n^{\ell}\right) &= \sum_{m=0}^{\infty} \beta^{m} \log\left(\frac{u_{nm}^{\prime\ell}/u_{nm}^{\ell}}{\left(\mu_{nnm}^{\prime\ell}/\mu_{nnm}^{\ell}\right)^{\nu_{\ell}}}\right) - \sum_{m=0}^{\infty} \beta^{m+1} \log\left(\frac{u_{nm}^{\prime\ell}/u_{nm}^{\ell}}{\left(\mu_{nnm}^{\prime\ell}/\mu_{nnm}^{\ell}\right)^{\nu_{\ell}}}\right) \\
&= \log\left(\frac{u_{n0}^{\prime\ell}/u_{n0}^{\ell}}{\left(\mu_{nn0}^{\prime\ell}/\mu_{nn0}^{\ell}\right)^{\nu_{\ell}}}\right) + \sum_{m=0}^{\infty} \beta^{m+1} \left[\log\left(\frac{u_{nm+1}^{\prime\ell}/u_{nm+1}^{\ell}}{\left(\mu_{nnm+1}^{\prime\ell}/\mu_{nnm+1}^{\ell}\right)^{\nu_{\ell}}}\right) - \log\left(\frac{u_{nm}^{\prime\ell}/u_{nm}^{\ell}}{\left(\mu_{nnm}^{\prime\ell}/\mu_{nnm}^{\ell}\right)^{\nu_{\ell}}}\right)\right] \\
&= \log\left(\frac{u_{n0}^{\prime\ell}/u_{n0}^{\ell}}{\left(\mu_{nn0}^{\prime\ell}/\mu_{nn0}^{\ell}\right)^{\nu_{\ell}}}\right) + \sum_{m=1}^{\infty} \beta^{m} \left[\log\left(\frac{\dot{u}_{nm}^{\prime\ell}/\dot{u}_{nm}^{\ell}}{\left(\dot{\mu}_{nnm}^{\prime\ell}/\dot{\mu}_{nnm}^{\ell}\right)^{\nu_{\ell}}}\right)\right]
\end{aligned}$$

Denoting:

$$\hat{x}_t = \left(\dot{x}_t^{\prime}/\dot{x}_t\right)$$

As the ratio of relative time changes between two counterfactual paths, and using the fact that $u'^{\ell}_{n0} = u^{\ell}_{n0}$ and $\mu'^{\ell}_{nn0} = \mu^{\ell}_{nn0}$, one obtains:

$$\log\left(\delta_n^{\ell}\right) = \sum_{m=1}^{\infty} \beta^m \log\left(\frac{\hat{u}_{nm}^{\ell}}{\left(\hat{\mu}_{nnm}^{\ell}\right)^{\nu_{\ell}}}\right)$$

In the case in which amenities are not changing across counterfactuals nor time, we have:

$$\log\left(\delta_n^{\ell}\right) = \sum_{m=1}^{\infty} \beta^m \log\left(\frac{\hat{C}_{nm}^{\ell}}{\left(\hat{\mu}_{nnm}^{\ell}\right)^{\nu_{\ell}}}\right)$$

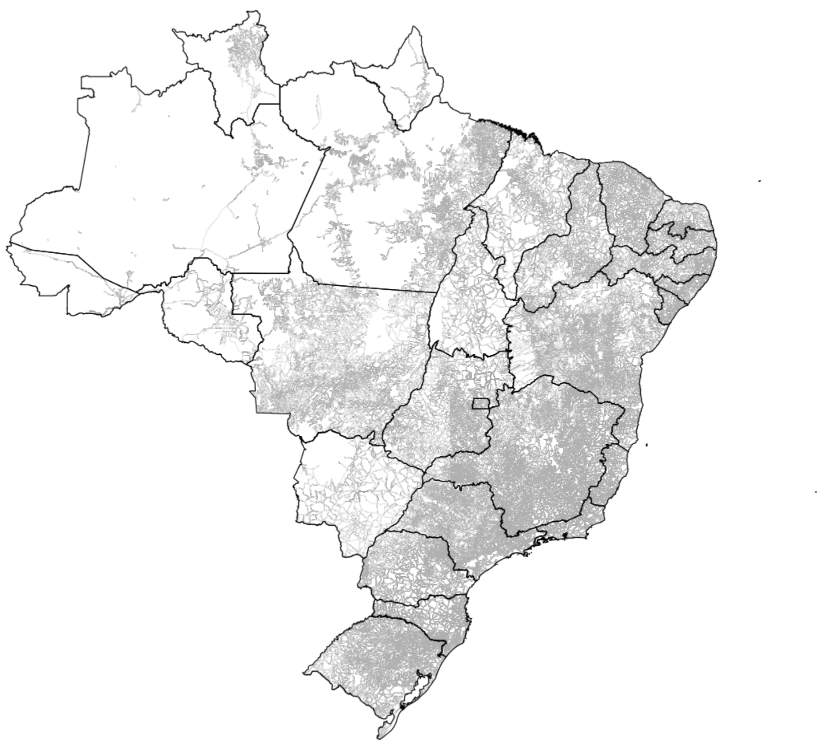
which is the main equation we use for consumption equivalent change in welfare.

E Estimation Appendix

E.1 Road Network

To construct estimates of trade costs across space, we use a shapefile with information on the type of road, the speed limit, as well as the quality of the road from IBGE.[59]

Figure A7: Road Network: Computing Trade Costs



Notes: This figure shows the road network used to estimate trade costs across regions using ArcGIS network Analyst Package (back).

The road network is classified into:

- *Autoestrada*: express way, with speed limit of 100 km/h
- *Rodovia*: urban road with a speed limit of 50 km/h
- *Outros*: other types of roads, we assign a speed limit of 20km/h

Using these speeds, we use ArcGIS network analyst to solve for the shortest path from any origin to all destinations in terms of speed.

[59] https://geoftp.ibge.gov.br/cartas_e_mapas/bases_cartograficas_continuas/bc250//.