Technological Displacement and Modern Slavery: Evidence From Local Labor Markets *

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Abstract

Today, an estimated 49.6 million people live in modern slavery, 27.6 million of them in forced labor, work exacted against their will. Does technological change mitigate it or sustain it? Following two agricultural technologies with opposite factor biases across Brazil's frontier, matched to the universe of federal anti-slavery inspections, we find slavery expanding where the labor-saving technology displaced workers and receding where the labor-demanding one rehired them, concentrated in cattle ranching, the sector that hires the displaced. Displacement leaves these workers easy to recruit and cheap to replace, and the slavery in our data grows where workers are abundant, not scarce. As slavery expands, workers demand a rising premium against the risk of enslavement, and cattle earnings move against every outside wage under both shocks. In addition, displacement turns into slavery only where the coercion sector was fragmented into many small farms, a pattern consistent with market power and coercion acting as substitutes, one legal and the other illegal in reducing wages.

JEL codes: J47, O13, O33, K42

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1 Introduction

The last legal abolition in the Americas came more than 130 years ago, and the International Labour Organization estimates that 49.6 million people were still living in modern slavery in 2021, 27.6 million of them in forced labor (ILO, 2022), the economically exploited form this paper studies. This is surprising, especially considering that slavery was long treated as a thing of the past (Bales, 1999; Miers, 2003; Quirk, 2011). A century of rapid technological progress, the force behind that development, has not ended it. The same progress has kept reshaping what labor is demanded, where, and from whom, more than almost any other force in history (Goldin and Katz, 1998; Acemoglu and Johnson, 2023). Left without a job, the workers it displaces could be exactly the ones coercion draws on (Bales, 1999). Modern forced labor recruits its workers with a false promise of work (ILO, 2022), and no one is more likely to believe the promise than a displaced worker with nowhere else to turn. Displacement, however, also lowers the wages of the work those workers would otherwise do. The gain from coercion is the wage it avoids paying, so lower wages leave less to gain. The two forces come from the same shock and pull in opposite directions. Does technological displacement push workers into coercion, or does it take away the reason to coerce them?

To understand formally how technological displacement could move slavery, we first lay out a model of coercion in a local labor market. Workers seek safe local work first, and the ones the safe sector rations stand where the recruiters' offers arrive, the pool from which coercion hires. The employers who hire there draw different costs of coercing, and each either hires workers honestly at the wages of free labor or recruits them with a job offer it will not honor. Workers know that some offers are false but cannot tell which, and the employer holds the worker who accepts a false one through confinement. Displacement cuts the safe sector's hiring, fills the pool with the rationed, and turns the question's two forces into prices this employer compares. First, it lowers the wages of free labor, which reduces what coercion saves (Acemoglu and Wolitzky, 2011). Second, it makes desperate workers easier to find, which reduces what coercion costs.[1] The share of employers who coerce then turns on the two rates of decline. In the Bayesian equilibrium, where the risk workers price is the risk the market produces, the number enslaved rises with displacement unless the coerced share thins faster than the pool grows, and that share rises only when what coercion costs falls proportionally faster than what it saves.

[1]The fall in the cost of coercion plausibly also runs through the scheme's own inputs, since the recruiters and the guards who hold the workers are hired from the same abundant pool, a margin the model folds into its single cost of coercion. In Lagerlöf (2009) the same pricing works in reverse, with guards costly exactly where workers are scarce.

We then take the question to Brazil's green revolution of the 2000s, when two agricultural technologies with opposite demands for labor arrived on the same frontier between 2001 and 2003. Genetically engineered soy raises yields while displacing workers, and the second maize crop that soy's shorter cycle made possible works the same land twice a year and absorbs workers instead (Bustos et al., 2016, 2020). How much each technology could raise yields was set by soil and climate, which we measure with the FAO-GAEZ potential-yield differentials, determined before either technology existed. Our empirical strategy therefore compares municipalities by their relative suitability to the two crops, before and after the technologies arrived, entering both treatments jointly in a difference-in-differences framework. Because both suitabilities enter jointly, the comparison holds fixed what makes a municipality suitable for agriculture in general and isolates the difference between a crop that displaces workers and one that absorbs them. The estimates carry a causal reading under the assumption that municipalities more and less suited to each crop would have followed similar trends had the technologies not arrived. On the outcome side, we compile a new dataset from the complete administrative record of federal anti-slavery operations in Brazil between 1995 and 2013, each originating in a local complaint.[2] We pair the operations with the individual records of rescued workers, reported from 2003 onward, and with census microdata reweighted to the composition of the rescued.

Our individual records show who is found in slavery. This population is, in general, hard to survey. Holding a worker is a crime, so the employer hides the worker and the workplace, no frame exists to sample from, and a worker still held cannot answer freely. The surveys that exist ask workers before they migrate (Bogatzki and Meierrieks, 2026), their families after (Mahmoud and Trebesch, 2010), or the workers of sectors where bondage operates in the open (Miller et al., 2026), and the freed themselves appear in case accounts and small samples (Sakamoto, 2006). We use the largest individual-level administrative record of this population, the workers the inspection teams wrote down as they freed them, more than 47,000 over two decades. The rescued are almost all men, young and with little schooling, nearly three quarters non-White among those with race recorded, and four in five worked as general agricultural laborers. The operations that freed them concentrate in cattle ranching, the country's main slavery sector since federal enforcement began in 1995, on the same frontier over which the two technologies spread.

Slavery followed the two shocks in opposite directions. Where the new soy spread, the employee jobs of all workers fell by 6 percent, and where the second maize crop spread they rose by 8 percent. Beyond this average response, an alternative test reweights the census

[2]Appendix B.1 reproduces one such complaint in full, an escaped worker's account of the ranch he fled, and narrates the operation it set off.

cells to follow the employment of the workers at risk, those matching the profile of the rescued, and the displacement concentrates on them, a fall of 13 percent under soy and a rise of 15 percent under maize. For every percent of at-risk employment the labor-saving shock destroys, the count of enslaved workers rises by 10.3 percent of its mean, and for every percent the labor-demanding shock creates, it falls by 6.0 percent. The response of forced labor to job losses is therefore 72 percent larger than the response to job gains, an asymmetry in which coercion expands faster than it recedes. The responses emerge when the technologies arrive, follow flat trends before, and run in opposite directions in the same places. Both directions and the asymmetry between them line up with the model.

An important feature of our results is that the additional slavery does not appear on the farms that adopted the technologies, where the estimates are precise zeros for both shocks. It appears in cattle ranching, a sector that received neither technology but hires the laborers the crops displace, so the response moves with the workers rather than with the crops.[3] Slavery rising in a sector the technologies never entered, where those workers are hired, is what a labor-market channel produces and what a change on the adopting farms cannot. The rise is also a rise in intensity. Enslaved workers increase with soy and decrease with maize under every denominator we construct, and the employment of the at-risk group contracts exactly where slavery expands. The shock that took these workers' jobs deepened the coercion among those who remained.

We then move from quantities to prices, as wages record both the displacement and the coercion it produced. Where soy spread, the wages that price a displaced worker's alternatives fell by 5 to 10 percent, and where maize spread they rose by the same amounts, the movement in outside options the model predicts. The exception was cattle ranching, whose posted wage rose by about 8 percent as outside wages fell and fell as they rose. Because some of its employers post offers they will not honor, every offer from the sector carries a risk of enslavement, and workers demand a premium to accept one (Akerlof, 1970; Guerrieri et al., 2010). The more employers coerce, the higher the premium the sector must post, so its wage rises where slavery expands and unwinds where it recedes. The worker prices the risk of the promise, and the census earnings recover that price as a regional premium net of composition. A common demand shock moves every sector's wage the same way. The coercion sector's wage moved against all the others under both shocks, up where soy spread and outside wages fell, down where maize spread and they rose, which is what the premium predicts and a demand shock cannot produce.

Our last set of results answers where displacement becomes coercion, and an extension

[3]Cattle ranching is the main slavery sector of Brazil's agricultural frontier, holding the largest share of forced-labor operations since federal enforcement began in 1995 (Section 2.1 and Appendix Figure G.2).

of the model says where to look. An employer who already sets wages absorbs displaced workers by paying less, within the law and without the cost of coercing anyone, while an employer who must compete for workers can underpay them only by not paying at all.[4] Concentrated land puts the hiring of displaced workers in few hands, so displacement should turn into coercion only where the coercion sector's land was dispersed. The data deliver exactly that split. We divide the sample at the median of a Herfindahl index of the sector's landholdings in 1996, measured before either technology arrived, and the entire response to both shocks comes from the dispersed half of the country, at more than twice the pooled effects. The concentrated half shows a precise zero. The two employers take the same wage from the same displaced worker, consistent with market power and coercion acting as substitutes. The workers' own starting point selects with the same logic. Municipalities that entered the period with fewer formal jobs, less literacy, or more adults with no schooling respond about twice as strongly, since a displaced worker with less to refuse is cheaper to recruit.

Because our slavery measure comes from inspections, one may worry that the estimates track enforcement or reporting rather than coercion. The first answer to this concern is the pattern itself. Both shocks are the arrival of better technology, so a detection response to modernization would move the two the same way. Detected slavery instead moves in opposite directions, each following its technology's factor bias. Another possibility is that inspectors were sent to where the technologies spread, but every inspection in our data answers a local complaint rather than federal targeting. Dismissed workers could have filled the system with grievances, but then the response would appear in the sector that dismissed them, and it is zero there. Higher incomes could have eased the path to denunciation, but then detection would rise with the shock that raises employment and wages, and that shock reduces it. Finally, the share of inspections that find slavery rises with soy and falls with maize, so what moved is what inspections find, not how many there are.

Migration and employer market power do not explain the estimates either. Population flowed out of the municipalities where slavery rose, so the pool filled with the workers who stayed rather than with arriving migrants, and migration works against the estimates. Holding neighboring municipalities' shocks fixed leaves the results in place, and in cattle ranching neither technology raises the share of large ranches. The estimates survive leave-one-state-out samples, permutation inference, and alternative sets of controls.

Our findings contribute first to the economics of coercion and forced labor. The theory on this topic began with Domar (1970), who tied coercion to labor scarcity. Chwe (1990)

[4] Russian serfdom consolidated on the same margin, among military landholders who could not compete for peasant labor and held it by restricting mobility instead (Matranga and Natkhov, 2026).

showed that pain becomes the incentive when the worker's alternatives are worth least, Genicot (2002) shows workers with the worst alternatives accepting bonded terms by choice, Lagerlöf (2009) discusses how elites choose slavery when the wages it saves cover the cost of the guards it requires, which happens at intermediate stages of agricultural development, and Acemoglu and Wolitzky (2011) studied how scarcity moves coercion through both the price of output and the worker's outside options. In a separate line, Schmitt et al. (2025) write the first model in which the employer chooses whether to exploit, recruiting with the deception the modern form uses. Our model places that choice inside the labor market that sets workers' outside options, where an occupational choice rationed in the manner of Harris and Todaro (1970) decides who stands where the offer arrives, so displacement fills the pool with the workers the safe sector passes over and moves both the wage coercion avoids and the cost of recruiting the desperate.

Empirical work on coercion studies the institutions themselves (Fogel and Engerman, 1974; Naidu, 2020; Matranga and Natkhov, 2026)[5] and their consequences, the response of schooling to price shocks that coercion muted in Puerto Rico (Bobonis and Morrow, 2014), the growth released when serfdom ended (Markevich and Zhuravskaya, 2018), the poverty the slave trades, the mita, serfdom, and the rubber economies left behind (Nunn, 2008; Dell, 2010; Buggle and Nafziger, 2021; Lowes and Montero, 2021; Araujo et al., 2026a), the inequality of the plantation colonies (Sokoloff and Engerman, 2000), the fertility still lowered where colonial labor drafts persisted as circular migration (Dupas et al., 2023), and the mistrust of strangers and of the coercing group itself (Nunn and Wantchekon, 2011; Blouin, 2022).[6] That literature reads coercion in the shadow it casts generations later. Evidence of coercion itself responding to a labor-market shock is rare. In the post-emancipation Caribbean, coercion eased and wages rose where workers could evade the plantations (Dippel et al., 2020), and in nineteenth-century Britain employers held workers through penal labor law when rising demand made them costly to lose (Naidu and Yuchtman, 2013). Both watch historical institutions where coercion moved with the worker's outside option. Closest in spirit, Hornbeck and Naidu (2014) show that a technological and environmental shock loosened the South's hold on Black labor, though there the shock relaxed coercion rather than, as here, feeding it. The nearest modern experiment randomizes productivity

[5]Slavery is the far end of a continuum of unfree labor, and modern data measure the continuum's two ingredients separately. Naidu et al. (2016) price the employer's hold, with migrant earnings in the Gulf rising when a reform loosened the employer's control over the visa. On the worker's side, Mahmoud and Trebesch (2010) find trafficking victims coming disproportionately from the regions where labor emigration is most common, and Bogatzki and Meierrieks (2026) find one in four prospective migrants in Nigeria willing to consider a trafficked route knowing the risk of forced labor.

[6]In Brazil today, slave labor has been linked to illegal resource extraction and to insecure frontier land (Araujo et al., 2024, 2026b).

inside the coercive sector itself, and large gains in Bangladeshi brick kilns leave forced labor unchanged (Miller et al., 2026). We measure the response of modern slavery to a shock in the sectors around the coercive one, one that moves the supply of workers, with one technology raising the pool and the other lowering it on the same frontier. Where the enslaved worker of the old system was a scarce asset bought at a price, the modern coerced worker is a flow rented from an abundant pool, replaced at little more than the cost of his transport. The slavery in our data grows where workers are abundant, not scarce.

The findings contribute second to the literature on agricultural technology and development. Agricultural modernization raised incomes across the developing world (Evenson and Gollin, 2003; Gollin et al., 2021), but these same technologies may generate externalities, in deforestation, water contamination, human health, homicides, conflict over land, and social unrest (Carreira et al., 2024; Dias et al., 2023; Sekhri and Shastry, 2024; Moreno-Louzada and Menezes-Filho, 2024; Falcone and Rosenberg, 2022; Caprettini and Voth, 2020). What a technology does where it arrives depends on the technology itself, on how it fits the local environment (Moscona and Sastry, 2025) and on the conditions that shaped its invention (Moscona, 2021; Moscona and Sastry, 2023). Bustos et al. (2016) locate that dependence in the demand for labor, showing that agricultural productivity growth speeds industrialization under the labor-saving technology and slows it under the labor-demanding one. Our paper expands this discussion by showing that a shock the literature documents as progress can also generate coerced labor. The direction of this externality follows the nature of the technology, the labor-saving shock feeding the coercion sector and the labor-demanding one relieving it.

The findings contribute finally to the literature on the labor market effects of technological change. Labor-saving technological change displaces workers (Acemoglu and Autor, 2011; Autor, 2015; Acemoglu and Restrepo, 2018; Autor, 2022). The displacement is visible in the local labor markets most exposed to industrial robots or to import competition, where employment and wages fall (Acemoglu and Restrepo, 2020; Autor et al., 2013). Our two shocks are that literature's pair arriving in one place, a displacement effect and a reinstatement effect on the same frontier in the same years (Acemoglu and Restrepo, 2019). The displaced adjust through several margins, such as skill investment, longer hours, or earlier retirement (Branco et al., 2025; Giuntella et al., 2025). For the workers of this paper the nearest margin, stepping down into work without a card (Dix-Carneiro and Kovak, 2019; Ulyssea, 2020), closes in the data, since soy removes employee work with and without a card together for the at-risk profile (Section 6), and the margins that remain ask for schooling or savings this population does not hold. We connect this literature to slavery, showing that for workers with no margin of adjustment displacement continues into coerced labor. Coercion sits at

the far end of a continuum of informal work, the point where the employment relation stops being merely unregulated and becomes unfree. The consequences of technical change for the most vulnerable are therefore decided below the point where the literature's data end.

The rest of the paper is organized as follows. Section 2 provides background on modern slavery in Brazil, its enforcement, and the two technologies. Section 3 presents the model and its predictions. Section 4 describes the data, and Section 5 lays out the empirical strategy. Section 6 documents the displacement of at-risk workers, and Section 7 reports the effects on slavery, their timing, their sectoral location, and their magnitudes. Section 8 tests the model's wage prediction, and Section 9 shows where the response concentrates, by the structure of the land market and by baseline outside options. Section 10 examines alternative interpretations and robustness. Section 11 concludes.

2 Background

2.1 Modern Slavery

In 2010, acting on a complaint, one of the Brazilian federal government's mobile inspection teams traveled to a farm in the state of Pará, on the Amazon frontier. Among the workers held there was a man who had tried to run away, and his deposition, taken down by the inspectors, reads: "Upon trying to leave, he was discovered by the security guard, who, together with two hired thugs, tied him up [...] for about 3 hours. They struck him on the head with a piece of wood. He still bears on his arms the marks [...] He was told not to attempt another escape [...] otherwise he would be killed."[7] The team freed him and the workers held alongside him, terminated their contracts, and recorded what it had found, as such teams did more than a thousand times over the period we study. Between 1995 and 2013, operations like this one rescued more than 47,000 workers from conditions that Brazilian law classifies as analogous to slavery, and the records those operations produced are the data of this paper, described in Section 4.

What the deposition describes is not a survival from another century, and Brazil is not the only place where such scenes occur. Slavery did not end when it became illegal everywhere. It ended as a legal institution and continued as a criminal one, on a scale that few people, and few economists, appreciate. The International Labour Organization defines forced labor as work exacted under the menace of a penalty and not offered voluntarily, a definition written for the world after abolition (ILO, 2022). The people living under that definition today outnumber the Africans embarked over the entire three and a half centuries of the

[7]Worker deposition in the GEFM anti-slavery inspection reports, Operation 120, 2010.

transatlantic slave trade, a stock at one point in time set against a cumulative flow.[8]

For most of history coerced labor was the rule rather than the exception (Acemoglu and Wolitzky, 2011), and where it persists today it persists as an economic decision. An employer coerces when the wages it avoids paying cover the costs of recruiting and holding the coerced, a comparison in which the worker appears only as a number. No country lived that rule on a larger scale than Brazil, the destination of more enslaved Africans than any other and the last in the Americas to abolish slavery, in 1888. Abolition ended the legal institution and left standing what it had built, the concentration of land, the entrenched inequality, and the uneven reach of the state across the territory (Sokoloff and Engerman, 2000; Naritomi et al., 2012). Where those legacies meet the agricultural frontier, in rural regions where formal work is scarce and oversight is thin, slavery reappears in its modern form. Three features make the setting measurable as well as relevant. The enforcement system writes down every operation it runs, the two technologies arrived on the same frontier with opposite factor bias, and the census records who stands where the shocks land.

Under Article 149 of the Penal Code, the crime is defined broadly and covers labor exacted by force or threat, debt bondage, degrading working conditions, and exhausting workdays (CPT, 2017). The cases concentrate in agriculture, cattle ranching, logging, and charcoal production, in remote or newly settled areas (Sakamoto, 2006; Costa and to Combat Forced Labour, 2009; Araujo et al., 2024). Cattle ranching alone accounts for the largest share of forced-labor operations across the northern and central-western frontier states (Appendix Figure G.2), the same frontier over which the technologies we study diffused. Enforcement runs through the Special Mobile Inspection Group (Grupo Especial de Fiscalização Móvel), created in 1995, a task force of labor inspectors, federal police, and labor prosecutors that travels to worksites under investigation (Costa and to Combat Forced Labour, 2009; Phillips and Sakamoto, 2012). A rescue ends with terminated contracts, severance paid, and referral to social assistance. Slavery in Brazil therefore persists under enforcement that is real, and whatever keeps coercion profitable is strong enough to survive the inspections.[9]

The inspection reports also describe how a person arrives at a farm like the one above, and the accounts follow a pattern. Recruitment begins with an intermediary known as a gato, who appears in a town where work is scarce and offers a regular job at a regular

[8]The SlaveVoyages Trans-Atlantic Slave Trade Database estimates that about 12.5 million Africans were embarked between the sixteenth and the nineteenth century, and that about 4.9 million of those who survived the crossing disembarked in Brazil, more than in any other territory. Appendix Figure G.1 maps the estimated prevalence across countries, concentrated where work is informal and government oversight is limited (Walk, 2023).

[9]All of the cases in our data originate from local complaints rather than from police intelligence or centrally coordinated campaigns, so the data record slavery where workers and communities report it. Section 10 treats the implications for measurement.

wage on a farm far away (Sakamoto, 2006; Costa and to Combat Forced Labour, 2009). The offer is false, but the worker discovers that only after the journey, when the promised wage has become a debt for the transport, the food, and the lodging that brought him there, his documents are held at the farmhouse, and the worksite is remote.[10]

The inspectors themselves compare what they find with the slavery Brazil abolished, and their reports put the comparison in economic terms:

> Old slavery, in its economic aspect, was more indulgent with its protagonists than modern slavery is, since the Black person brought from Africa was considered an asset forming part of the slaveholder's patrimony, and for that reason received a certain attention from the owner. In modern slavery, given the abundance of labor and the scarcity of opportunities, the worker is disposable and represents not the slightest value to the employer. (Operation 48, 2009)[11]

What the inspectors call disposability is a claim about cost. The worker represents no value to the employer because replacing him is nearly free, and replacing him is nearly free because displaced workers are abundant and opportunities scarce.

Bales (1999) estimates that an average field laborer in the American South of 1850, bought as property, sold for the equivalent of 50,000 to 100,000 dollars in today's money. The ILO's study of slave labor in Brazil adapts the comparison and finds that the modern slave is not bought at all, recording a man delivered by a gato for about 70 dollars in Eldorado dos Carajás, in southern Pará, little more than the cost of his transport (Sakamoto, 2006, Table 4).[12] The cost of acquiring a worker is now the cost of recruiting one, and it depends on how many desperate workers the local labor market holds. Abundance also lowers the wages of the work those workers could find instead, so the two forces need not push slavery the same way. The model of Section 3 takes up both forces.

2.2 *Genetically Engineered Soy and Maize Double-Cropping*

Genetically engineered soy reached Brazil from the south, smuggled from Argentina from around 2001, first into Rio Grande do Sul, and legalized for commercial use in 2003. The

[10] In one operation, inspectors found railway workers locked overnight in shipping containers (Operation 128, 2010).

[11] "*Nesse sentido, a escravidão antiga, em seu aspecto econômico, era mais indulgente com seus protagonistas do que o é a escravidão atual, eis que o negro trazido da África era considerado um bem que integrava o patrimônio do escravocrata, razão pela qual recebia certa atenção de seu proprietário; na escravidão atual, em face da abundância de mão-de-obra e da escassez de oportunidades, o trabalhador é descartável e não representa o menor valor para o patronato.*" Our translation. The same conclusion writes that the large landowners "have easily within reach this endless contingent of the excluded, willing to accept any occupation and under any circumstances" ("*têm facilmente ao seu alcance esse infindável contingente de excluídos dispostos a aceitar qualquer ocupação e sob quaisquer circunstâncias*").

[12] R$ 150 in 2006 reais, the year of the study, converted at the average exchange rate of R$ 2.18 per US dollar (2006).

technology substitutes chemical weed control for manual weeding and tillage, so it raises yields while using fewer workers per hectare. Adoption spread quickly over the municipalities whose soils and climate suited it, expanded cropland, helped make Brazil one of the world's two largest soy producers, and accelerated structural transformation, releasing labor from agriculture where it arrived (Bustos et al., 2016, 2020). For the local labor market, GE soy is a labor-saving shock.

Since the 1980s, some farmers had planted a second maize crop, the safrinha, on the same land immediately after the soy harvest, grown between March and July, before the dry season. The practice stayed small because the window between the soy harvest and the last viable maize planting date was too short. The new soy package widened that window. Glyphosate resistance made no-till planting practical, no-till and earlier varieties moved the soy harvest into January and February, and the extra weeks made room for the second crop. The safrinha then spread through the municipalities whose climate and soil could support it and became the country's main maize crop (Bustos et al., 2016, 2020). Double-cropping harvests the same land twice a year, and maize uses more labor per hectare than soy or the pasture it often replaces. Where it spread, the safrinha raised rural labor demand, a labor-demanding shock moving the local market in the opposite direction from soy.

The two shocks did not reach the countryside as independent experiments, and the connection between them shapes our empirical design. The safrinha spread after 2000 because the soy package sped up the calendar and left room for a second crop on the same land in the same agricultural year. The second crop needed no new seed of its own, so maize planting could respond as soon as the smuggled soy arrived in 2001, without waiting for legalization. The two technologies therefore arrived on the same frontier, and the suitability measures that predict their adoption are correlated at 0.82 across municipalities.[13]

3 A Model of Coercion in the Local Labor Market

The model is a local labor market in which workers at risk face two destinations, a safe sector that never coerces and a risky sector where each firm chooses between hiring workers honestly and coercing them. The pool the risky sector hires from is the residue of an occupational choice in the rationing logic of Harris and Todaro (1970), since every worker seeks safe local work first and the ones the safe sector rations stand where the recruiters' offers arrive. A firm that coerces recruits by deception and retains by confinement, so the coercive match simplifies to the restricted mobility of Acemoglu and Wolitzky (2011), entered through the false promise of a regular job at a regular wage (Schmitt et al., 2025). We study how slavery

[13] Appendix G.5 shows the variation that remains in each differential once the other is conditioned on.

responds when the labor-saving and labor-demanding technologies of Section 2 move the safe sector's hiring, and with it the pool. Coercion is itself an activity priced in this market, since recruiting by deception and replacing workers who leave are services bought from the pool, and both get cheaper when workers are abundant. The wage a coercer avoids paying is tied to the outside option and falls with the same abundance. A larger pool therefore cuts the cost of coercion and lowers its gain at once, and which of the two falls proportionally faster turns on two elasticities that the data decide. We derive the pool from the occupational choice first, and then price the market that hires from it.[14]

3.1 Environment

Market and players. A mass N of identical workers is at risk in the local labor market, and two destinations hire them, the safe sector on the left branch of Figure 1 and the risky sector on the right, where each firm chooses between hiring honestly and coercing. A common working cost would add the same amount to every wage and drop out of every comparison below, so we normalize it to zero.

The safe sector. The safe sector is local non-coercive agriculture, hiring at a wage W_A, a primitive of the model that may be formal or informal, since what sets the sector apart is the absence of coercion and not a written contract. It posts the vacancies at which the marginal product of a worker under the technology in place covers W_A, a mass J, and fills them at random, so a worker who seeks safe work is hired with probability $q = J/N$ once every worker seeks it (Lemma 1) and rationed with probability $1 - q$. The technological shocks of Section 2 move this technology, and with it the pair (W_A, q) in opposite directions. The shock that displaces labor cuts the vacancies while the product of the remaining operators rises, so q falls and W_A rises, and the labor-demanding shock hires from those seeking safe work, so q rises while W_A falls toward the low end of the local distribution.

The risky sector. The risky sector is where firms choose their conduct and where the recruiters' offers arrive. It hires from the pool derived in Section 3.2, a mass L matched one to one with an equal mass of identical firms. Inside the pool, firms have all the bargaining power, so each wage is the lowest one the worker accepts, the participation wage.

The occupational choice. Before the risky sector opens, each worker chooses where to stand, seeking the safe sector's hiring or standing where the recruiters' offers arrive. The stage carries one primitive, the first choice. Whenever the safe sector hires, $q > 0$, every worker seeks its job first, the local sector without coercion ahead of any offer that arrives from outside. The first choice is the sorting the setting documents, since the recruiter of

[14] Proofs of all results are in Appendix C.

Section 2.1 appears where local work is scarce and finds his candidates among the workers the local hiring passed over. Lemma 1 turns the choice into the pool, and the wage block of Section 3.3.1 prices the ranking it reveals.

Outside option. A worker who rejects all offers earns the outside option $\bar{u}(L)$, positive, twice differentiable, and strictly decreasing in L. More workers compete for the same alternatives. The matching inside the pool is one to one by construction, while $\bar{u}(L)$ prices what a worker who walks away earns in the surrounding market, the services and manufacturing that lie farther from these workers in practice, and that price falls as the pool grows. The surrounding sectors carry the technology only through the pool, the exclusion that Appendix C states as Assumption 2.

Coercion technology. The inspection data document two features of coercion, and the model builds in both. Recruitment is by deception.[15] A firm's conduct is hidden at the offer stage, every firm posts the same wage, and workers know only the equilibrium share p of legitimate matches. Retention is by confinement. A coercive match reduces the worker's outside option by the fixed factor $\chi \in (0, 1)$, so a worker who tries to leave succeeds with probability $1 - \chi$ and keeps nothing otherwise, and leaving is worth $(1 - \chi)\bar{u}(L)$.[16] If χ were zero, confinement would take nothing and coercion would have no object. As χ approaches one, escape is worth nothing and the worker is held outright.

Conduct and costs. Each firm chooses its conduct. A legitimate firm leaves the worker free to go. A coercive firm confines, at a fixed cost $\vartheta_i\, c(L)$, the only cost of coercing, paid to set the scheme up and keep it staffed. The draw $\vartheta_i \geq 0$ is a private, permanent characteristic of the firm, taken from a continuous distribution F whose density f is continuous and positive on an interval containing the range under study.[17] The cutoff of Section 3.3.2 stays interior to that interval, and it selects who coerces, not who participates. The factor $c(L)$ is common, positive, twice differentiable, and decreasing in the pool, normalized to one at the baseline. It is the price of the inputs that coercion buys from the local market. Deceptive recruitment runs through intermediaries who must find candidates, and a worker who escapes or collapses must be replaced, so this fixed cost falls when desperate workers are

[15] Appendix B.2 documents this premise in the reports, setting the wages recruiters promised against what workers found, and Appendix B.1 narrates one operation from complaint to rescue.

[16] Appendix B.3 documents the instruments behind χ in the reports' words, debt, distance, retained documents, and the pursuit of those who flee.

[17] The deception game prices an offer whose type the worker cannot verify, in the tradition of Akerlof (1970) and Guerrieri et al. (2010). Schmitt et al. (2025) are the closest antecedent, the first model in which firms choose whether to exploit. There the coercer also chooses confinement and threats, no pool enters costs or wages, and workers do not choose where to work. Here the pool is the rationed residue of an occupational choice in the manner of Harris and Todaro (1970), the technology moves it through the safe sector's hiring, and the pool moves the cost of coercion and the outside option, with Appendix C stating and proving every statement.

easy to find and quick to say yes.[18] The guards who keep the scheme staffed are hired from the same market, and any cheapening of the holding they bring is absorbed in the same fixed cost $\vartheta_i\, c(L)$, with the depth of confinement χ unchanged.[19]

VIABILITY. Every match produces Y, more than the outside option on the range under study, so every match can pay the participation wage.

TIMING. The occupational choice comes first. Each worker chooses whether to seek safe-sector work, the safe sector fills its vacancies, and its hiring does not reopen within the period, so a rationed worker cannot return to it. The risky sector then opens over the rationed workers. Firms post wages. The worker accepts or rejects a posted offer, and rejection pays the outside option. On acceptance the type is revealed, and the worker stays or tries to leave, succeeding against a coercive firm with probability $1 - \chi$. Production then occurs and wages are paid. Figure 1 draws the game. The clause that hiring does not reopen matters. A worker who could seek safe work again after rejecting an offer would price offers against that return rather than against $\bar{u}(L)$, and the wage block of Section 3.3.1 would re-anchor.

3.2 The Safe Sector and the Pool

The safe sector hires first, and the workers it rations are the mass the risky sector receives.

Lemma 1 (The Rationed Pool)**.** *Let the safe sector be every worker's first choice, a strict preference, at every pool in the range under study and whenever the sector hires, $q > 0$, for seeking its job over standing where the recruiters' offers arrive and over staying out. Then in any equilibrium every worker seeks safe-sector work, the pool is fed only by the rationed workers, and the whole rationed mass stands in it, $L = (1 - q)N$.*

The lemma is the rationing logic of Harris and Todaro (1970), with the sectors inverted. A fixed wage above market clearing holds one sector, workers allocate by expected earnings, and the employment probability is the term that prices the rationed sector. Here that sector is local non-coercive agriculture rather than urban manufacturing. No worker chooses the risky sector at the root, the branch drawn in Figure 1 and never taken. Nobody applies to a coercive firm. Recruitment travels to the worker, so choosing the risky sector amounts only to standing where the offers arrive, and the coercion some rationed workers then suffer is not chosen but the concealed downside of an offer the worker cannot tell from an honest

[18] Appendix B.4 documents this market, including the per-head prices recruiters charged, and Appendix B.5 adds the photographic record. Acemoglu and Wolitzky (2011) obtain a related cheapening from scale, with guns sunk before matching. Their cheapening reaches the marginal price of confinement, so abundance raises intensity. Ours hits the fixed cost of operating the scheme, and the depth of coercion stays fixed at χ.

[19] Lagerlöf (2009) prices the guarding margin from the scarcity end, where keeping scarce workers as unproductive guards is what makes slavery too costly.

one. Availability costs a rationed worker nothing, so the whole rationed mass is the pool, the accounting identity $L = (1-q)N$ that Lemma C.1 records with the flows in Appendix C. The wage ranking the first choice reveals waits for the value of the offers it declines, which Section 3.3.1 prices.

3.3 The Risky Sector

The risky sector opens over the pool of Lemma 1, the mass $L = (1-q)N$ standing where the offers arrive, and every wage below carries that mass as a parameter.

3.3.1 Wages

Suppose first that conduct is observed. A legitimate match pays the participation wage, $W_H = \bar{u}(L)$. In a coercive match the wage is set with the worker already inside. The worker can try to leave, an attempt that succeeds with probability $1-\chi$, so leaving is worth $(1-\chi)\bar{u}(L)$ and retention requires only $W_X = (1-\chi)\bar{u}(L)$. The avoided bill is $W_H - W_X = \chi\bar{u}(L)$, the depth of coercion times the outside option. The richer the worker's alternatives, the more there is to take. The fixed cost $\vartheta_i\, c(L)$ is paid whether or not the worker stays, so it enters no wage.

With conduct hidden, posting is cheap talk for a coercive firm, which never honors it. A firm that operates legally honors what it posts, since a legitimate contract can be enforced against it, while the coercive firm's promise cannot. Any offer a legitimate firm makes is mimicked at zero cost, so no posted wage can tell the two kinds of firm apart, and recruitment at a distance leaves no reputation to lean on. The worker therefore accepts a posted wage by its expected value, acceptance binds, and deception forces a premium,

$$W'_H \;=\; \bar{u}(L) + \underbrace{\tfrac{1-p}{p}\,\chi\bar{u}(L)}_{\text{risk premium}}.$$

That is, the premium multiplies the odds of a coercive match, $\frac{1-p}{p}$, by the wage lost inside one, $\chi\bar{u}(L)$. A coercive firm posts W'_H and pays W_X, so the bill it avoids is $W'_H - W_X = \frac{1}{p}\chi\bar{u}(L)$, the wage gap plus the premium it never honors. Because acceptance binds, the average wage across matches stays at $\bar{u}(L)$, so the premium shows in the posted wage and not in the average paid.

The occupational choice adds two clarifications. First, no ordering between W_A and W'_H is implied or needed. The safe sector's hiring resolves before the pool opens and does not reopen, so the recruiter's offer is judged against the $\bar{u}(L)$ of a worker who has already lost the draw for the safe job, not against W_A. Second, the recruiter does not post W_A. Deception is mimicry of the honest firms of his own market, which post W'_H, not of the safe sector's

offer, which is not his to make. Nor could the design survive the alternative. If the coercive firm posted the safe wage, the bill it avoided would be $W_A - (1-\chi)\bar{u}(L)$, which rises as the pool fills because W_A does not fall with L, gain and cost would push in the same direction, and the comparison of two rates of decline in Proposition 1 would disappear. Anchoring the avoided bill in $\bar{u}(L)$ is what makes the gain and the cost fall together.

Because acceptance binds, the offers of the risky sector also price the first choice of the environment. Every alternative to seeking safe work is worth exactly $\bar{u}(L)$, since a posted offer is accepted at its expected value, rejection pays the outside option, and staying out pays the same. The same computation is why availability costs a rationed worker nothing, so the whole rationed mass of Lemma 1 stands in the pool (Lemma C.1). A strict first choice is then exactly $q\,W_A + (1-q)\,\bar{u}(L) > \bar{u}(L)$, which for $q > 0$ is $W_A > \bar{u}(L)$, the ranking revealed rather than assumed, with no legal floor behind it (Lemma C.2, stated with the accounting in Appendix C). The ranking is the only property of W_A any result uses, and the level of W_A stays free, so the response of the safe wage to the technology is a prediction the model delivers at no cost.

3.3.2 The Coercion Margin

A firm compares the two contracts,

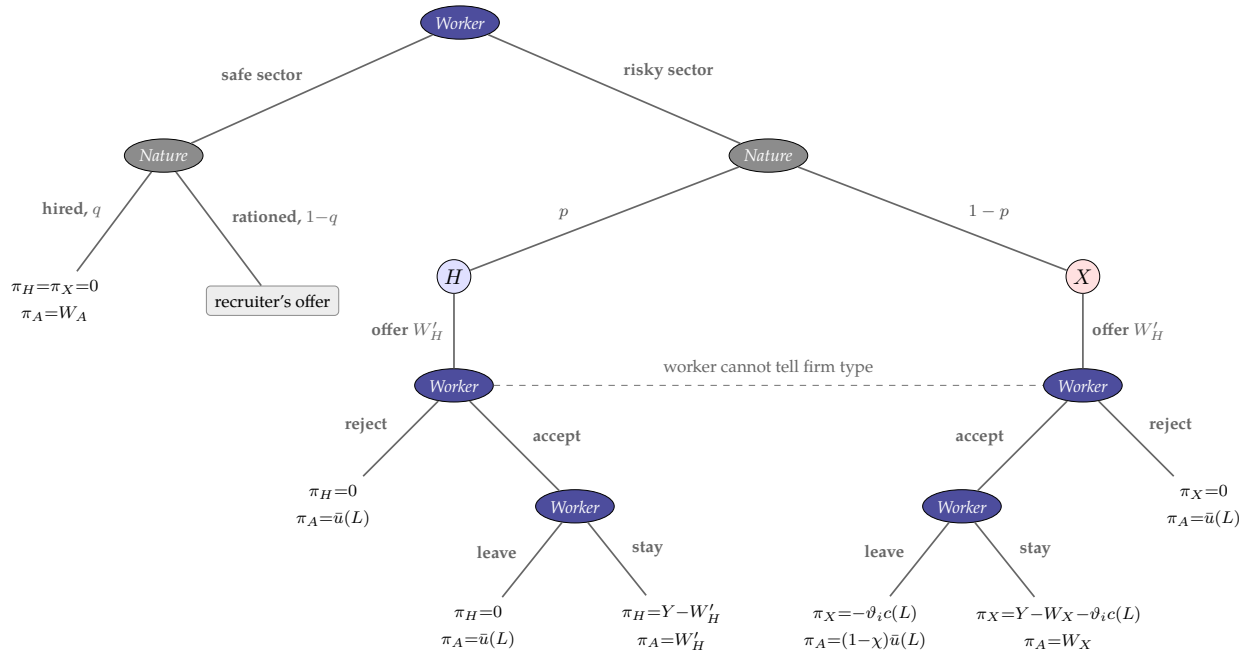
$$\pi_X - \pi_H \;=\; \big[\,Y - W_X - \vartheta_i\,c(L)\,\big] - \big[\,Y - W'_H\,\big] \;=\; \tfrac{1}{p}\,\chi\bar{u}(L) \;-\; \vartheta_i\,c(L),$$

so the common Y drops out, and the firm coerces when the avoided bill covers the cost of coercion,

$$\tfrac{1}{p}\,\chi\bar{u}(L) \;\geq\; \vartheta_i\,c(L) \qquad\Longleftrightarrow\qquad \vartheta_i \;\leq\; \vartheta^*(p,L) \;=\; \frac{\frac{1}{p}\,\chi\bar{u}(L)}{c(L)},$$

so the firms below the cutoff ϑ^* coerce and the rest stay honest, and the share of coercive matches solves $1 - p = F(\vartheta^*(p,L))$. Write $s = 1 - p$ for the coerced share. Here p is both the realized legitimate share and the worker's belief about it, so this fixed point is the consistency requirement that the belief match the composition. The belief is common to the whole pool, since the safe sector's hiring selects by the event of being rationed and not by any characteristic of the worker, so no selection enters p.

Figure 1: The Occupational Choice and the Deception Game



Notes: The worker chooses between the safe sector, local non-coercive work, and the risky sector, and the two sides meet only at the root. Under the safe branch, Nature hires with probability q, paying W_A, or rations with probability $1-q$, and the rationed worker receives a recruiter's offer. The risky sector is the deception game. Nature draws H (prob. p) or X (prob. $1-p$), both post the same wage W'_H, the dashed information set means the worker cannot tell them apart, rejecting pays $\bar{u}(L)$, and on acceptance the type is revealed and the worker may leave or stay. Leaving is worth $\bar{u}(L)$ in an honest match and $(1-\chi)\bar{u}(L)$ in a coercive one, so the coercive firm retains with $W_X = (1-\chi)\bar{u}(L)$ and the honest firm pays W'_H. No worker chooses the risky sector on purpose (Lemma 1), so the pool is exactly the $1-q$ rationed out of the safe sector.

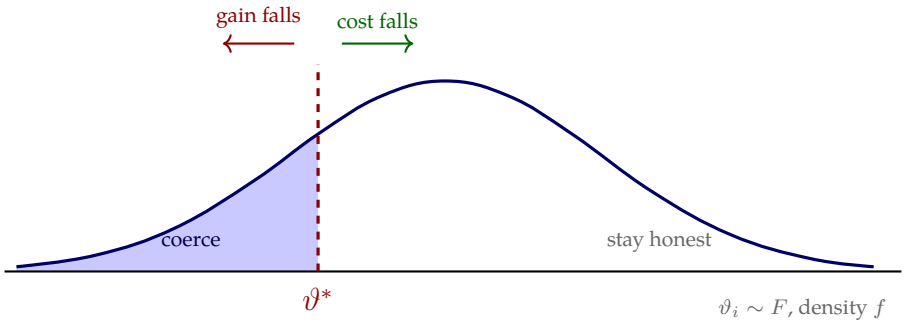


Figure 2: The coercion margin under a larger pool. The curve is the density f and the shaded area is the coercive share $F(\vartheta^*)$. The falling outside option lowers the avoided bill and pulls the cutoff left. The cheapening of coercion pushes it right. The share of coercive matches follows whichever force wins.

Proposition 1 (The Two Rates of Decline)**.** *Whether a larger pool widens or narrows the coercive set depends on which falls faster, the cost of coercion or the wage it avoids. Formally, at a stable equilibrium, the share of coercive matches rises with the pool if and only if the cost of coercion falls proportionally faster than the gain,*

$$\underbrace{-\frac{d\ln c}{d\ln L}}_{\textit{cost channel}} > \underbrace{-\frac{d\ln \bar{u}}{d\ln L}}_{\textit{gain channel}}.$$

Coercion must get cheaper faster than workers get poorer. The gain is the markup times the depth of coercion times the outside option, and one might expect deeper confinement or a higher markup to tilt the comparison, but both set the level of the gain and cancel from its slope at a fixed share, so the gain channel is exactly the rate at which the outside option falls with the pool. Lemma C.3 shows the comparison survives the equilibrium, where the feedback moves the markup and multiplies the response without changing its sign.

The mechanism departs from Acemoglu and Wolitzky (2011) in one structural respect. There, coercion substitutes for incentive pay and its return rises with the value of output, so a growing pool can reduce coercion even as it lowers the outside option. Here effort plays no role, the coercive match pays a flat retention wage, and the falling outside option enters both what coercion saves and what it costs. The response of slavery therefore turns on a race between two rates of decline rather than on the value of output.

3.4 Equilibrium

The coerced share enters the model as a belief and as an outcome, the belief workers hold when they price a posted offer and the outcome the market produces when firms choose their contract. The share workers expect sets the premium they demand, and the premium sets how many firms find coercion worth its cost. Equilibrium is the share that plays both roles at once.

When the risky sector opens, the safe stage is already resolved. Every worker has sought the safe sector's hiring, the rationed mass $L = (1-q)N$ stands in the pool (Lemma 1), and the coerced share is the one object the equilibrium still has to deliver.

Recall the posted wage, $W'_H = \bar{u}(L) + \frac{s}{1-s}\,\chi\bar{u}(L)$, where $\frac{1}{1-s}$ is the markup that acceptance by expected value forces on the wage gap. When workers believe the share is s, the bill a coercive firm avoids is $W'_H - W_X = \frac{1}{1-s}\,\chi\bar{u}(L)$, the cutoff is $\vartheta^*(s,L)$, and the coerced share that results is $F(\vartheta^*(s,L))$. An equilibrium is a share that reproduces itself,

$$s \;=\; F\big(\vartheta^*(s,L)\big).$$

A higher believed share raises the premium, the premium raises the avoided bill, and the bill

pulls more firms across the cutoff, a self-reinforcing feedback. Its strength is $\gamma \equiv f(\vartheta^*)\,\partial\vartheta^*/\partial s$, the response of the realized share to the believed one.

The belief cannot rise without limit, since the premium is paid by the legitimate firm and the firm must break even, so there is a highest viable belief, above which the honest side of the market cannot survive. Below it, exactly one share reproduces the belief that prices it, a stable equilibrium with $\gamma < 1$, whenever the density of coercion costs does not fall along the cutoff (Proposition C.1, stated and proved in Appendix C together with the viability bound and the corner at $s = 1$).

The occupational stage adds no second fixed point. Because acceptance binds, the expected value of standing in the pool is $\bar{u}(L)$ at every coerced share, so the participation margin does not depend on the share. The system is recursive, q determines $L = (1-q)N$, L determines the equilibrium coerced share $s^*(L)$ through Proposition C.1, and existence, uniqueness, and stability are inherited. This is also why displaced workers keep arriving in a market where coercion is growing, since they are exactly compensated in expectation and the entry margin never feeds back into the share.

3.5 Comparative Statics in the Pool

The statics below run in the pool, holding the technology fixed, and Section 3.7 reads them in q.

Proposition 2 (Scale and Composition)**.** *Total slavery is $S = L(1-p)$. Its response to the pool decomposes as*

$$\frac{dS}{dL} = \underbrace{(1-p)}_{\text{scale } (+)} + \underbrace{L\,\frac{d(1-p)}{dL}}_{\text{composition } (\pm)},$$

or, in elasticities,

$$\frac{d\ln S}{d\ln L} = \underbrace{1}_{\text{scale}} + \underbrace{\varepsilon}_{\text{composition}}, \qquad \varepsilon \equiv \frac{d\ln(1-p)}{d\ln L},$$

so slavery rises with the pool if and only if $\varepsilon > -1$. The composition term inherits its sign from Proposition 1 at a stable equilibrium.

When the cost channel wins, $\varepsilon > 0$, the two terms push together, and slavery rises unambiguously. When the gain channel wins, $\varepsilon < 0$, and the sign turns on the share being inelastic, $|\varepsilon| < 1$. The baseline is the special case with c constant, in which coercion does not cheapen with the pool, so the cost channel is zero, $\varepsilon < 0$ always, and the composition brace of Proposition 2 reads $(-)$. With the cost channel active the share itself can rise with displacement. The depth of coercion is fixed at χ, so prevalence moves with no prediction

for intensity. The ratio to the pool is the direct separator between the mechanisms, and the posted wage of Lemma 2 separates them further, rising with the share once outside wages are held fixed.

At the equilibrium the feedback multiplies the response of the share by $1/(1-\gamma)$ without changing its sign (Lemma C.3, stated in Appendix C). The posted wage is where the unobserved share leaves a trace in prices.

Lemma 2 (The Posted Wage)**.** *The posted wage is* $W'_H = \bar{u}(L) + \frac{s}{1-s}\,\chi\bar{u}(L)$*. Conditional on the outside option it rises with the share,*

$$\frac{\partial W'_H}{\partial s} \;=\; \frac{\chi\bar{u}(L)}{(1-s)^2} \;>\; 0,$$

and it rises with the pool outright if and only if the premium response outruns the decline of the outside option,

$$\frac{\chi\bar{u}(L)}{(1-s)^2}\,\frac{ds}{dL} \;>\; \Big[1 + \tfrac{s}{1-s}\,\chi\Big]\,\big|\bar{u}'(L)\big|,$$

with ds/dL *the equilibrium response of Lemma C.3.*

If workers took posted offers at face value, the premium and the fixed point would disappear, the cutoff would be a closed form in primitives, and Proposition 1 would hold as stated with the markup replaced by one. The same fixed-point structure arises in Schmitt et al. (2025), without the pool L entering the cutoff, and uniqueness rests on the curvature restriction on F (Proposition C.1). What the fixed point sustains is the premium, and with it the divergence of the two wages that Section 8 takes to the data.

3.6 The Shape of the Response

An inflow of workers and an equal outflow need not move slavery by the same amount. Displacement deepens the vulnerability of everyone already in the pool, since wages fall, alternatives close, and savings run down, so each arrival lands in a market that earlier arrivals have softened. Relief works on the other end. Returning demand hires the least desperate first and reaches last the workers a recruiter targets, so an outflow thins the recruiter's pool more slowly than it thins the pool itself.

Proposition 3 (Asymmetry of the Response)**.** *An inflow of workers raises total slavery by more than an equal outflow lowers it. Formally, at the stable equilibrium of Proposition C.1, let the condition of Proposition 1 hold at every pool in the range, with a gap between the two elasticities that does not narrow as the pool grows, and let the density of operating costs be differentiable and non-decreasing over the interval the cutoff moves through. Then total slavery is increasing and strictly convex in the pool, and an inflow raises slavery by more than an equal outflow lowers it.*

Total slavery is heads times the share, $S(L) = L\,s(L)$, so its slope and its curvature are

$$S'(L) \;=\; s \;+\; L\,s'(L), \qquad S''(L) \;=\; 2\,s'(L) \;+\; L\,s''(L).$$

If the share did not move with the pool, $s' = 0$, the slope would be the constant s, the curvature would vanish, and an inflow would gain exactly what an equal outflow loses. A share that keeps rising bends the line upward. An inflow counts its new heads at the higher share that the inflow itself creates, an outflow spares heads at the lower share that the outflow itself creates, and that compounding is the $2\,s'(L)$ in the curvature. The conditions of the proposition keep the second term from undoing it, since a gap between the two elasticities that does not narrow and a density that does not thin keep s' from fading as the pool grows. The baseline model bends the other way, since with c constant the share falls as the pool fills, $s' < 0$, and there slavery is concave wherever it still rises, so the shape of the response separates the cost channel from the baseline even where both predict the level rising.[20] Proposition 3 is a statement about the equilibrium itself, feedback included. The feedback adds to the convexity rather than undoing it, and the baseline's concavity extends to the equilibrium when the outside option falls gently.[21]

The strength of the response should also differ across markets. The fixed cost is the work of finding people willing to say yes, and where alternatives are poor a given displacement pushes a large mass below the threshold of desperation at which a stranger's distant offer is accepted, so recruitment cheapens fastest where the baseline outside option is worst. Either shock should then move slavery proportionally more in the poorer market. Appendix C states the comparison as Assumption 1 and derives the ranking it implies.

3.7 Comparative Statics in the Technology

The technological shocks enter the model through q, and one exclusion carries them. The technology moves the coercion sector only through the pool, entering neither $\bar{u}(\cdot)$ nor $c(\cdot)$ directly (Assumption 2, stated in Appendix C). The restriction has empirical content, since the wages of the alternative sectors fall where the labor-saving crop spreads and rise where the labor-demanding one does, the direction that congestion through the pool requires.

[20] The concavity of the baseline requires the elasticity of the distribution, $\vartheta f(\vartheta)/F(\vartheta)$, non-increasing over the interval the cutoff moves through, and an outside option that falls at a rate that does not slow. The uniform distribution with an isoelastic outside option is the leading case, where total slavery is a power of the pool, rising and concave exactly when the elasticity of the outside option is below one. The argument appears with the proof of Proposition 3.

[21] The proof collapses the fixed point of Section 3.4 into a single equation and splits the curvature of the equilibrium response into the curvature at a fixed markup, amplified by the feedback, and a part the feedback adds on its own, which is positive. The exact requirement is that $1/(1-F)$ be convex at the cutoff. A non-decreasing density implies it, and so do some declining densities, the exponential among them.

Corollary 4 (Comparative Statics in the Technology)**.** *The shock that cuts safe hiring fills the pool, and every response of the model follows it with the signs the pool delivered. Formally, at the stable equilibrium of Proposition C.1, with $L = (1-q)N$ and under Assumption 2, a fall in q raises the coerced share if and only if the cost of coercion falls proportionally faster than the outside option, and total slavery responds as*

$$\frac{d\ln S}{d\ln q} \;=\; -\left(1+\varepsilon\right)\frac{q}{1-q}, \qquad \varepsilon \equiv \frac{d\ln s}{d\ln L}.$$

Under the hypotheses of Proposition 3, total slavery is decreasing and strictly convex in q, so a destruction of safe jobs adds more slavery than an equal creation removes. The posted wage rises as q falls exactly when the premium response outruns the decline of the outside option, the condition of Lemma 2.

Every result of the model therefore reads in q through the chain $dL/dq = -N$. The labor-saving crop lowers q and raises the coerced share exactly when the cost of coercion falls proportionally faster than the outside option, which is Proposition 1 with the shock relabeled, and the two elasticities keep deciding sign, decomposition, and curvature. The same fall in q that fills the pool moves the posted wage against every alternative that prices $\bar{u}(L)$, the divergence that Section 8 takes to the data. Safe employment qN is the count the displacement section measures, so the sentence that displacement fills the pool is the accounting identity $dL = -\,d(qN)$ rather than an assumption, and the conversion between the model's elasticities and the measured employment count is recorded in Appendix C (Remark 1).

3.8 From Theory to Empirics

We now take the predictions of the model to the data. Soy expansion is labor-saving and cuts the probability q that seeking safe work ends in a job, so it fills the pool of workers exposed to coercion, maize expansion is labor-demanding and raises q, so it drains the pool, and the two crops therefore move displacement in opposite directions.

Propositions 2 and 1 concern the level of slavery and its composition. Proposition 2 predicts that a fuller pool raises the total, so slavery should rise where soy spreads and fall where maize does. Proposition 1 predicts more than a change in scale, that the coerced share within the pool moves in the same direction, so displacement raises the rate at which matches turn coercive and not only their number. The share rises because recruitment cheapens faster than the outside option it replaces. Corollary 4 reads both statements in q.

Lemma 2 predicts that the wage the coercive sector posts diverges from the wages paid outside it, rising with the coerced share once outside options are held fixed, the trace in prices of a share that is not directly observed, and Corollary 4 signs the same divergence in

the technology, the posted wage rising where q falls. The safe wage is a prediction at no cost, since no result depends on its level, and the technology moves it against q, rising with soy and falling with maize, the sign pattern Section 8 reads in the earnings data. Proposition 3 predicts that the response is convex, an inflow of workers raising slavery by more than an equal outflow lowers it, so the two crops need not be mirror images. Together, a rising share, a diverging posted wage, and a convex response are what set the model apart from the classical benchmark, in which coercion scales with the size of the pool but its share falls and the response is concave, so that only the level, and not the share or the curvature, would be shared.

We test these predictions in the census panel and the inspection records, displacement and the level first (Sections 6 and 7), and the posted wage in the census wage data for 2000 and 2010 (Section 8). Market power over the free wage substitutes for coercion and mutes the response where land is concentrated, and either shock should move slavery most where the outside option was already worst, two extensions that Section 9 takes to the data.

4 Data

Our analysis links five data sources, the Ministry of Labor's inspection records, the individual files of rescued workers, the FAO-GAEZ agro-climatic suitability grids, the Population Census microdata, and municipal agricultural statistics, merged at the level of minimum comparable areas (AMCs). Appendix Figure A.1 summarizes the sources and their linkages, and Appendix A provides further information on each.

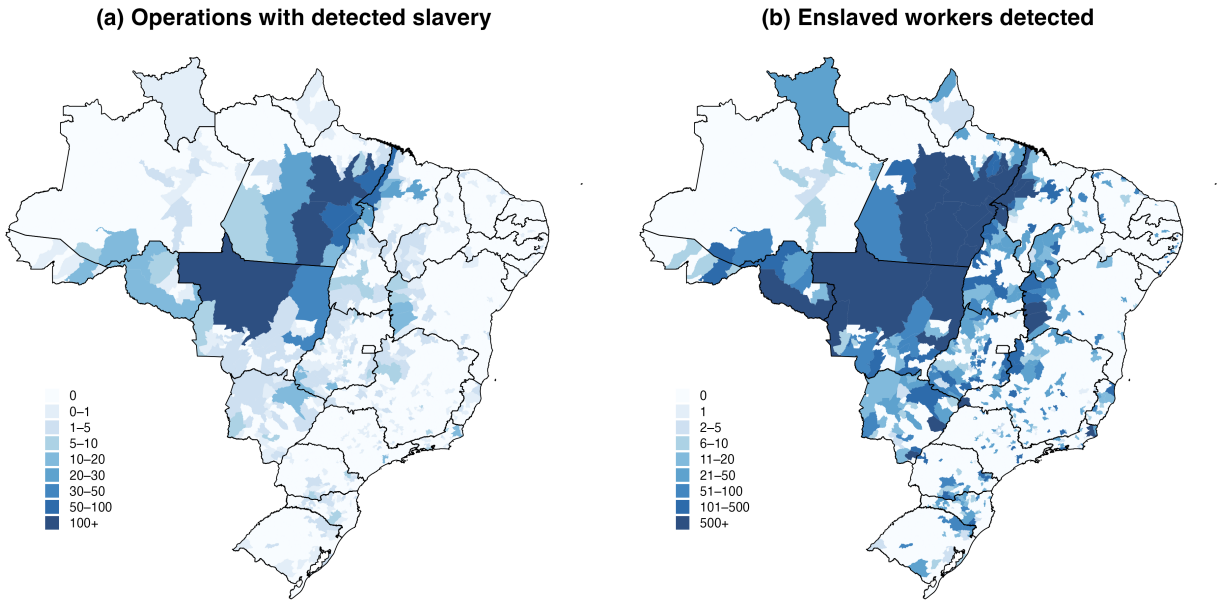
4.1 Modern Slavery Outcomes

Our slavery outcomes come from the administrative records of Brazil's Ministry of Labor and cover every labor inspection carried out between 1995 and 2013. Each record reports the date, the municipality, what triggered the operation, a local complaint or Ministry intelligence, and the number of workers found in the conditions that Article 149 defines (Section 2.1). Brazilian municipalities split and merge over the period, so our geographic unit is the minimum comparable area (AMC), the smallest grouping of municipalities whose borders stay comparable from 1980 to 2017, 3,828 areas in all, which we call municipalities for short. From these records we build a panel of AMCs by year with three outcomes, the number of operations with detected slavery and the number of rescued workers, both transformed by the inverse hyperbolic sine, and an indicator for any detection in the cell. Behind each count sits a written report, with the inspectors' narrative of the operation, the workers' depositions, and photographs of the sites. Appendix B documents the crime in this qualitative layer,

narrating one operation from complaint to rescue and collecting, across operations, the deception, the confinement, and the recruitment market that the model formalizes.

The inspections are run by federal mobile teams rather than by local authorities, whom landowners often dominate (Costa and to Combat Forced Labour, 2009). The records also reflect the institutional fact of Section 2.1, that in our period every case originates in a local complaint rather than in central targeting, so the outcomes measure where abuse is found and reported rather than where the state chose to look. Section 10.1 confronts the reporting readings that remain, and each one predicts a response in the wrong sector or with the wrong sign.[22] Figure 3 shows where that is. Operations and rescues concentrate in the central and northern frontier, in states such as Pará, Mato Grosso, and Maranhão, and thin out toward the south and the coast, a geography that matches the sector composition of Section 2.1, with cattle ranching the dominant sector of operations across exactly these states, and that overlaps the frontier over which the two technologies diffused.

Figure 3: Modern Slavery Across Brazilian Municipalities, 1995–2013

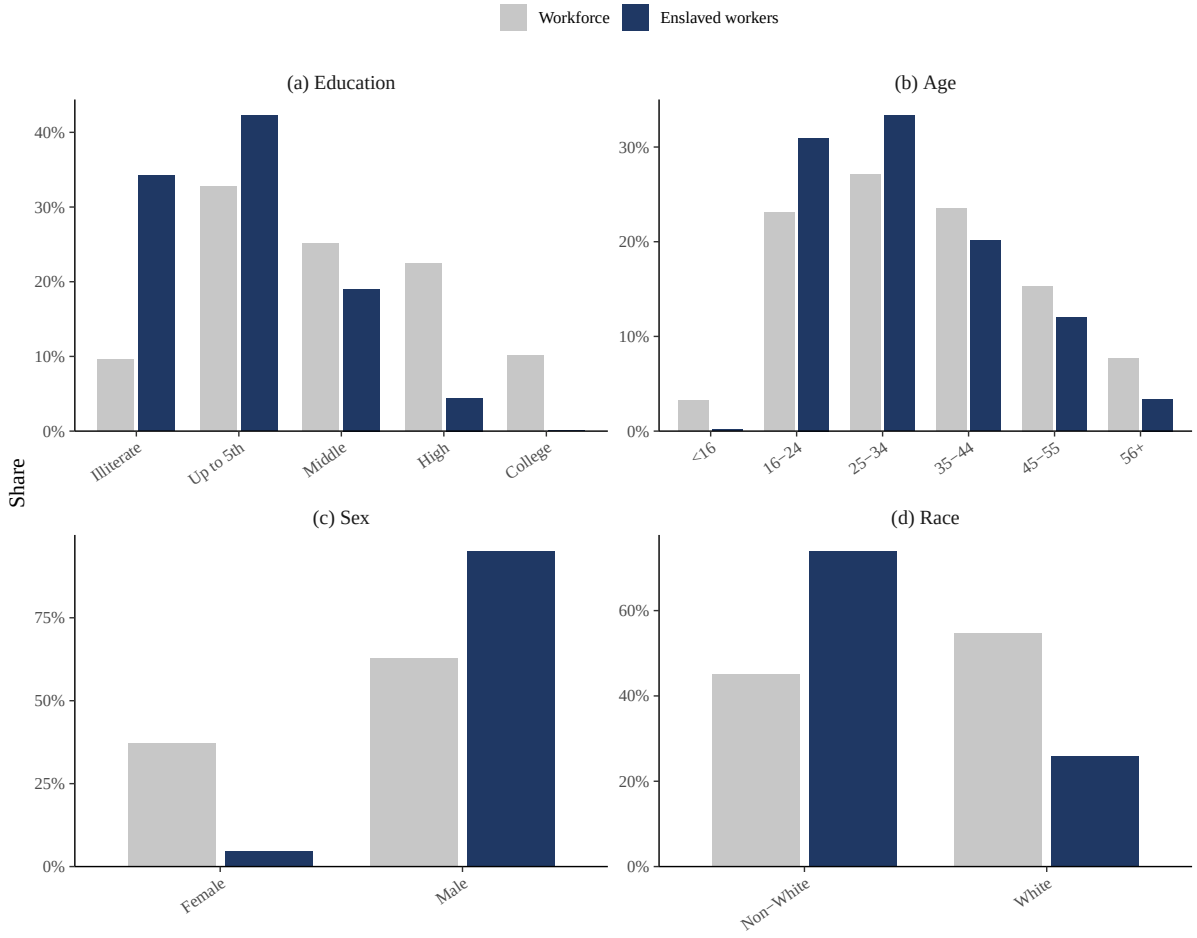


Notes: Panel (a) maps the total number of operations with detected slavery per AMC between 1995 and 2013. Panel (b) maps the total number of enslaved workers detected. *Source*: Ministry of Labor inspection records.

[22]The records do not capture the full universe of incidents. The design compares changes within municipalities over time, so detection that misses a stable share of a municipality's crime in every year enters the outcome as a place constant that the fixed effects absorb, a statement Section 10.1 derives formally and reduces to a single condition on the response of detection to the shocks. The coefficients are read as changes in observed prevalence.

For the years 2003 to 2013 the Ministry also reports individual records of the rescued workers, with education, age, sex, race, and occupation. The individual records cannot be linked to particular inspections, and race is recorded for only about a third of them, so the reweighting of Section 6 defines the weights over sex, age, and education and leaves race out. Building the weights with race, on the third of the records that report it, gives the same pattern, every coefficient keeping its sign and significance (Appendix A). They are enough to draw the profile of the rescued, and the profile is not a cross-section of the workforce. Most rescued individuals are male (95 percent) and young (a mean age of 32). Nearly three quarters of those with race recorded are non-White, a third are illiterate and nearly all have at most primary schooling, and four in five were working as general agricultural laborers when found (Figure 4). The workforce bars in the figure draw the comparison that matters. Women are roughly 37 percent of the employed but a sliver of the rescued, and the college educated, a tenth of the workforce, are absent from them entirely. Slavery risk lives in a demographically well-defined slice of the labor market. A technology shock therefore matters for coercion through what it does to these workers, and Section 6 measures displacement for exactly this group.

Figure 4: Demographic Composition of Rescued Workers and of the Workforce



Notes: Each panel compares the demographic composition of rescued workers (dark bars) with that of the general workforce (light bars), by education, age, sex, and race. *Sources*: Ministry of Labor individual rescue records and Brazilian Population Census.

4.2 Measuring the Technology Shocks

The treatments measure the opportunity each technology offered a municipality, not the use the municipality made of it. The FAO's Global Agro-Ecological Zones (GAEZ) database reports, for grid cells of five arc-minutes covering the country, roughly nine kilometers on a side, the yield each crop can attain at a location, built by combining the location's precipitation, temperature, soil characteristics, and terrain with the agronomic requirements of the crop. The attainable yields come solely from these technical requirements, so they do not respond to what farmers actually planted, to prices, or to anything inspectors later did. The database computes them under two input packages, a low-input technology, rain-fed and worked with traditional practices and manual labor, and a high-input technology with

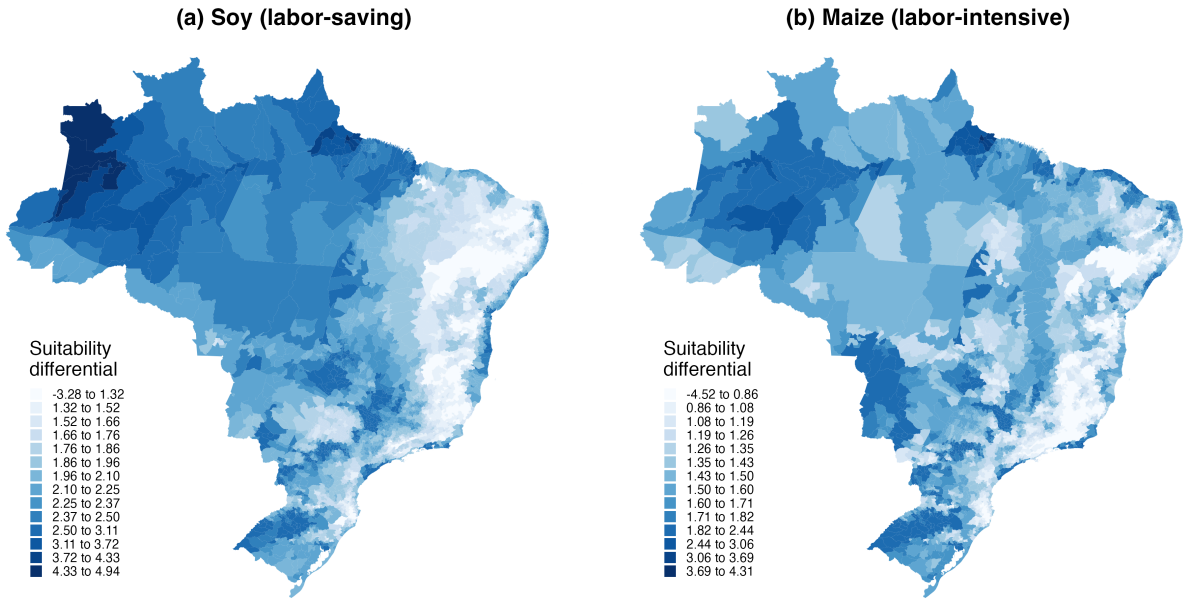
mechanization, improved varieties, and chemical inputs.

Following Bustos et al. (2020), the treatment for crop c in AMC j is the log difference between the two attainable yields,

$$A_j^c \;=\; \ln Y_j^{c,high} \;-\; \ln Y_j^{c,low}, \qquad c \in \{soy,\, maize\}, \tag{1}$$

where $Y_j^{c,high}$ and $Y_j^{c,low}$ are the attainable yields in tons per hectare under the high- and the low-input package, aggregated from the grid cells to the AMC. The differential measures the proportional yield gain the modern package could deliver at that location, which is the shock each technology delivered, since GE soy and the safrinha are ways of farming with the high-input package (Bustos et al., 2016, 2020).

Figure 5: The Two Treatments: Suitability Differentials for Soy and Maize



Notes: Each panel maps the log difference between the FAO-GAEZ attainable yield under high and low inputs, for soy in panel (a) and maize in panel (b), shaded by deciles of each differential, subdivided at the top of the scale. *Source*: FAO-GAEZ.

Both differentials, mapped in Figure 5, are highest across the agricultural frontier of the Center-West and North and lowest in the semi-arid Northeast, which is the overlap that motivates the joint design of Section 5, and within that common frontier each crop has its own geography, which is the relative variation the design uses. The two measures are correlated at 0.82 across municipalities, and Appendix G.5 plots slavery against each differential residualized on the other, the variation the joint design uses. Appendix Figures G.3

and G.4 map the two attainable-yield surfaces themselves, under the low- and the high-input package, from which the differentials are built.

4.3 Employment and Labor-Market Data

Employment comes from the 2000 and 2010 waves of the Brazilian Population Census, aggregated into demographic cells by AMC, age band, education, sex, and race. We count the workers aged 16 to 55, the range of Bustos et al. (2016), who worked for pay as employees in the census reference week, with and without a signed work card (carteira assinada), the card defining the formal margin.[23] The cell panel has more than half a million cell-year observations, and Section 6 describes the reweighting that makes it measure the employment of workers who share the rescued workers' profile. Wages come from the same census waves, real hourly wages by sector for 2000 and 2010, which the wage tests of Section 8 use to separate the coercion-prone sector, cattle ranching, from the sectors that price workers' outside options. Formal employment by sector comes from RAIS, the Ministry of Labor's matched employer-employee registry of the universe of formal contracts, which Section 7 uses as the annual denominator of the coercion rates. Baseline municipal characteristics, income per capita, population density, the rural share, and the adult schooling shares for the controls, and literacy, the formal employment share, and unemployment for the heterogeneity splits, come from the 1991 Census. Appendix A defines every variable and reports descriptive statistics.

5 Empirical Strategy

Our design compares municipalities that are more and less suitable for each technology, before and after the technologies arrived, following the potential-yield exposure designs of Bustos et al. (2016, 2020). We date the post period from 2001 to cover the earliest years of contraband use.[24] The two treatments are the suitability differentials of equation (1),

[23] Paid work in the reference week is the one employment question the 2000 and 2010 questionnaires ask in the same way. The counts leave out the self-employed, employers, unpaid family workers, apprentices, production for own consumption, and the statutory public servants that only the 2010 questionnaire separates, the margins whose questionnaire treatment changed between the two waves, so the employee counts compare cleanly across them.

[24] GE soy entered Brazil smuggled from Argentina. Bustos et al. (2020) document a break in the expansion of planted soy area starting in 2002, consistent with seed contraband, and commercial use was legalized in 2003. The annual panels therefore set $Post_t$ to one from 2001 on, and the event studies replace the post indicator with a coefficient for each year relative to 2000, so the estimates do not turn on which year is called the first post year. Appendix Table F.11 estimates the smuggling window (2001–2002) and the legal period (2003–2013) separately, and both carry the response, with the legal period the larger. The census panels have their own windows, stated with each exhibit, with the 1991 wave as the baseline of the employment panel and the 2000 wave as the baseline of the wage panel.

the log difference between each crop's attainable yield under high and low inputs, fixed by agro-climate and independent of what farmers later chose to plant. Because the two technologies diffused over the same frontier, the specifications enter them jointly.

The baseline specification is a difference in differences. For AMC j in year t we estimate

$$Y_{jt} \;=\; \alpha_j + \alpha_t + \beta^{soy}\left(A_j^{soy} \times Post_t\right) + \beta^{maize}\left(A_j^{maize} \times Post_t\right) + X_j'\gamma_t + \varepsilon_{jt}, \tag{2}$$

where Y_{jt} is a slavery outcome, α_j and α_t are AMC and year fixed effects absorbing everything permanent about a municipality and everything national about a year, and $Post_t$ equals one from 2001 on. The coefficient β^{soy} measures how much more the outcome grew after 2001 in municipalities one log point more suitable for soy, holding maize suitability fixed, and β^{maize} measures the mirror image. A positive β^{soy} for rescued workers, for example, says that municipalities handed a larger soy opportunity saw more workers rescued after 2001, relative to their own earlier levels and to less suitable municipalities. The vector X_j collects the 1991 baseline characteristics, the rural population share, income per capita, population density, and the shares of adults with at most four and with nine or more years of schooling, each interacted with year fixed effects, so that municipalities that started rural or poor may follow their own paths. Standard errors are clustered by AMC, allowing arbitrary serial correlation within a municipality over time. Because the treatments are continuous, the two coefficients aggregate dose-specific responses with weights that two-way fixed-effects estimation chooses implicitly (Callaway et al., 2024). Appendix Table F.5 therefore re-estimates equation (2) with each differential replaced by dose-group indicators, whose coefficients are treatment effects on the treated groups under the same assumption, and finds slavery rising step by step in the soy dose and falling at the top of the maize dose.

For the dynamics, the event-study version replaces the single post indicator with year-by-year terms,

$$\begin{aligned} Y_{jt} \;=\; \alpha_j + \alpha_t + \underbrace{\sum_{\tau=1995}^{1999} \mathbb{1}[t=\tau]\left(\beta_\tau^{soy} A_j^{soy} + \beta_\tau^{maize} A_j^{maize}\right)}_{\text{pre-adoption}} \\ + \underbrace{\sum_{\tau=2001}^{2013} \mathbb{1}[t=\tau]\left(\beta_\tau^{soy} A_j^{soy} + \beta_\tau^{maize} A_j^{maize}\right)}_{\text{post-adoption}} + X_j'\gamma_t + \varepsilon_{jt}, \end{aligned} \tag{3}$$

so that β_τ^{soy} and β_τ^{maize} trace the relationship between the outcome and each suitability differential year by year, relative to 2000, the last year before adoption. The pre-adoption coefficients provide the evidence on differential trends, and the post-adoption path shows when the effects emerge and whether they persist.

The estimates are intention-to-treat effects. Suitability measures the opportunity a munic-

ipality was handed, not the choice it made, so the coefficients capture the effect of differential exposure to each technology rather than of realized adoption, and endogenous take-up does not enter the treatment.

The fixed effects absorb everything permanent about a municipality and everything national about a year, so the identifying assumption is that, conditional on the baseline controls, outcomes in more and less suitable municipalities would have trended alike had the technologies not arrived. The event studies are consistent with this assumption, with pre-2000 coefficients near zero for both treatments, and the design adds a restriction no pre-test supplies, since a confounding trend common to the modernizing frontier would push the two coefficients the same way while the estimated responses move in opposite directions. Identification comes from relative suitability, from municipalities suited to soy beyond what their maize suitability predicts and the reverse. The two differentials are correlated at 0.82 across municipalities. About a third of the variance of each one is not predicted by the other, a residual spread of 0.31 log points for soy and 0.26 for maize, and it is this variation that separates the two coefficients. The correlation multiplies the variance of each estimate by 3.1, which the reported standard errors price, and reassigning one differential at a time while the other keeps its true values yields null distributions that sit about ten standard deviations from the real coefficients (Appendix Figure G.10). The municipalities more soy-tilted than their maize suitability predicts lie on the cerrado of Goiás, western Minas Gerais, and western Bahia, where the mechanized package pays most, and the ones tilted toward maize concentrate in the semi-arid Northeast, where soy is poorly suited under either package while maize still gains from modern inputs (Appendix Figure G.8). Appendix G.5 shows this identifying variation directly, plotting slavery against each differential residualized on the other. Even in these raw binned means the pattern is visible, slavery rising along the soy differential and falling along the maize one, and the fitted slopes reproduce the estimates.

The parameters of equation (2) connect the model's predictions to the data. When the outcome is total slavery, we expect the pair of signs β^{soy} positive and β^{maize} negative, since soy expansion raises the local pool L and maize expansion lowers it (Propositions 1 and 2). Section 7.2 replaces the outcome with the rate of detected slavery relative to proxies for the pool, and under the detection assumption of Section 4.1 the same pair of signs reads the condition of Proposition 1. Lemma 2 moves the test to the wage of the coercion sector, where β^{soy} should be positive once outside-sector wages are held fixed. Proposition 3 is about magnitudes rather than signs, comparing $|\beta^{soy}|$ with $|\beta^{maize}|$ in common units of displaced workers, which Section 7.4 constructs from the employment responses of Section 6. And the same coefficients compared across municipalities split by the 1991 proxies for the baseline outside option read the cheapening of recruitment, both responses larger where the proxies

are worse (Appendix C). The possibility that the coefficients reflect reporting rather than coercion is a question about the outcome, not the design, and Section 10 treats it as the first alternative interpretation.

6 Technology Adoption and the Displacement of At-Risk Workers

The model runs on the pool of workers available to coercion, and this section builds its empirical counterpart. We first verify that suitability moved adoption, then measure what adoption did to the employment of the workers slavery draws on. Section 7 asks what it did to slavery itself.

6.1 The First Stage: Technology Adoption

The suitability differentials measure what each municipality could grow, not what its farmers chose to plant. Displacement can only follow the technologies if the technologies followed the differentials, arriving where soil and climate say the modern package pays. This subsection verifies that they did, measuring adoption with IBGE's annual municipal agricultural survey (PAM), which records the harvested area of each crop for every municipality in every year, the same 1995 to 2013 window as the slavery panel, aggregated to AMCs. The appendix version of the table adds land use from MapBiomas, the satellite land-cover classification of Brazil, and the cattle herd from the agricultural censuses of 1996 and 2006.

Table 1 reports estimates of equation (2). One log point of the soy differential raises the inverse hyperbolic sine of soy harvested area by 0.43 after 2001, a large expansion from bases that are often near zero, the maize differential raises maize area by 0.21, and the cross effects are small and insignificant. The joint specification recovers the labor-saving adoption of Bustos et al. (2016) and adds its labor-demanding mirror on the same frontier. Splitting the post period into the smuggling window and the legal period, soy area starts in 2001–2002, at 0.15, and rises to 0.48 once seed is legal and no longer scarce, while maize area responds at full strength immediately, 0.30 in the smuggling window against 0.19 after (Appendix Table F.12). The full version in Appendix F (Table F.1) shows the maize differential pulling land out of pasture and cattle, the signature of the safrinha spreading over grazing land and a reallocation that matches the account of Section 2.2.

Table 1: The First Stage: Technology Adoption

	Asinh(Soy area)	**Asinh(Maize area)**
	(1)	(2)
Labor-saving	0.4301	−0.0403
	[0.0717]***	[0.0516]
Labor-intensive	−0.1178	0.2076
	[0.0804]	[0.0669]***
Observations	72,732	72,732
R-squared	0.909	0.796
AMC and Year FE	Yes	Yes

Notes: Estimates of equation (2). Outcomes are the inverse hyperbolic sine of soy and maize harvested area (PAM). Labor-saving is the soy suitability differential interacted with $Post_t$. Labor-intensive is the maize differential interacted with $Post_t$. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

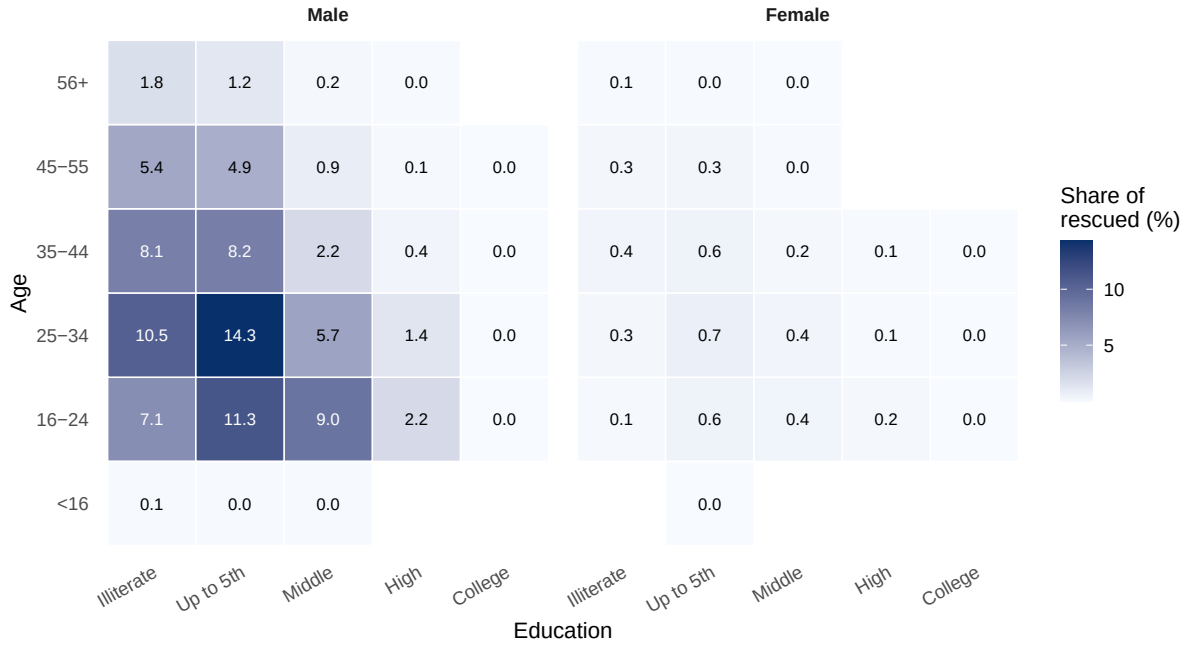
6.2 Measuring the Employment of At-Risk Workers

Slavery risk is not spread evenly over the workforce. Figure 4 made the point one margin at a time, comparing the rescued with the workforce by education, age, sex, and race separately. Figure 6 crosses the margins, distributing the rescued workers of Section 4.1 across demographic cells, age band by education by sex, and the mass sits on a handful of them. About 60 percent of all rescues fall in just six cells, men between 16 and 44 who are illiterate or schooled at most to the fifth grade, and the largest single cell, men of 25 to 34 with up to the fifth grade, holds 14 percent by itself. Among women, the college educated, and workers past 55, rescues are close to nonexistent. An average employment effect therefore dilutes the shock with cells where slavery does not happen. What the model's pool L requires is the employment of the cells where the recruiter hires.

We therefore measure the pool by reweighting the census cell panel of Section 4.3, which records employment for every cell, weighting each cell by its share among rescued workers, the weights s_c shown in the figure, fixed and national, in the reweighting tradition of DiNardo et al. (1996). The weighted series is the employment of a worker with the rescued profile. Because the weights are fixed, identification still comes from local changes in cell

employment. The composition never moves, so the estimates measure the incidence of the shocks on a fixed population rather than changes in who lives where. The weights come from the workers inspections found, so the reweighted series measures exposure to the predominantly male, agricultural form of coercion that inspections reach, and speaks less to the forms detected less often, such as the domestic servitude of women. The profile can also be built with race added, on the third of records that report it, or from education alone, with similar results (Appendix Table F.2). Matching the profile is not a claim that these individuals were enslaved. It is a claim about who stands where the shock lands.

Figure 6: Where the Weights Live: Composition of Rescued Workers by Demographic Cell



Notes: Each cell shows the share of rescued workers (percent) in an age band by education by sex cell, the same cells that define the reweighting weights s_c. The weights use sex, age, and education and leave out race, which is recorded for only about a third of the individual rescue records; Appendix Figure G.12 adds the race dimension for the records that report it. *Source*: Ministry of Labor individual rescue records, 2002–2013.

6.3 Employment Effects of the Two Shocks

We estimate equation (2) on the cell panel, with the inverse hyperbolic sine of the cell's employee counts as the outcomes and with AMC, year, and demographic-cell fixed effects, the last of which hold fixed everything permanent about a cell type, so the comparison runs within the same kind of worker over time. The panel counts the workers aged 16 to 55 who worked for pay as employees in the census reference week, the measure Section 4.3 describes, recorded the same way in the two waves, with and without a signed card. This

count is the empirical counterpart of the safe-sector employment qN of Section 3.2, so a fall in it is a fall in q that fills the pool by the identity $L = (1 - q)N$, most of it read on the signed-card margin rather than as a definition of the safe sector. The census window takes the 2000 wave, collected before the technologies arrived, as the pre period and the 2010 wave as the post, with the 1991 baseline characteristics interacted with year as controls.[25] Table 2 reports the estimates separately on each demographic half of the panel. The two shocks move employment in the directions their factor bias dictates, and they move it across the workforce rather than in one corner of it. Employment with a signed card falls with soy and rises with maize in all six groups, total employee counts follow it wherever they respond, and the margin without a card concentrates its response among the young and men.

Table 3 pools the cells and weights them to the rescued profile. Pooled, in the odd columns, employee counts fall by about 6 percent per log point of the soy differential and rise by 8 percent with maize, and the movement runs through the signed-card margin, which falls 7 percent with soy and rises 8 percent with maize while employment without a card does not move.

Reweighted to the rescued profile, in the even columns, every response grows. Employee counts fall 13 percent under soy and rise 15 percent under maize, against the 6 and 8 percent of the average worker, and the signed-card response reaches 13 and 14 percent, so the loss of employee work loads precisely on the slice of the market from which coerced workers are drawn.[26] The displaced worker did not step down into work without a card. That margin does not move for the average worker, and for the at-risk profile it falls 9 percent with soy and rises 12 percent with maize, the same directions as the signed-card margin.[27] What soy removed from the at-risk worker was employee work on both margins, and a worker left unpaid is the worker the recruiter finds, so displacement feeds the two channels of the model at once, the gain channel through cheaper outside options and the cost channel through desperate workers easy to find. Where maize spread, the movement ran in reverse, and the sector rehired the same profile, most of it with a signed card.

[25] We measure adjustment in employment rather than unemployment, as is standard in the displacement literature (Acemoglu and Restrepo, 2020; Dix-Carneiro and Kovak, 2019). Census unemployment requires a declared search for work, a margin that means little where most work is informal.

[26] Both the reweighted and the unweighted responses hold with the baseline controls.

[27] The no-card margin counts workers paid without a signed card in the reference week, recorded identically in the two waves, so a stable seasonal undercount of informal work differences out and only an undercount that moved with the shocks would bias the estimate. The signed-card margin, where most of the response sits, is not the seasonal one.

Table 2: Census Employment by Demographic Group

	Education		Age		Sex	
Panel A: Asinh(Number of employees)						
	Low	High	<35	35+	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)
Labor-saving	−0.071	−0.055	−0.072	−0.050	−0.073	−0.047
	[0.022]***	[0.016]***	[0.018]***	[0.016]***	[0.018]***	[0.016]***
Labor-intensive	0.107	0.059	0.091	0.068	0.096	0.060
	[0.024]***	[0.018]***	[0.020]***	[0.018]***	[0.020]***	[0.018]***
Panel B: Asinh(Employees with a signed card)						
	Education		Age		Sex	
	Low	High	<35	35+	Male	Female
Labor-saving	−0.091	−0.061	−0.078	−0.070	−0.083	−0.064
	[0.020]***	[0.018]***	[0.019]***	[0.017]***	[0.018]***	[0.019]***
Labor-intensive	0.106	0.054	0.087	0.066	0.094	0.059
	[0.022]***	[0.020]***	[0.021]***	[0.019]***	[0.020]***	[0.020]***
Panel C: Asinh(Employees without a signed card)						
	Education		Age		Sex	
	Low	High	<35	35+	Male	Female
Labor-saving	−0.037	−0.007	−0.045	0.010	−0.032	0.001
	[0.022]	[0.016]	[0.019]**	[0.016]	[0.019]*	[0.017]
Labor-intensive	0.081	0.034	0.081	0.027	0.064	0.038
	[0.025]***	[0.018]*	[0.021]***	[0.018]	[0.021]***	[0.020]**
Number of cell-years	225,884	320,832	275,835	270,881	282,966	263,750
AMC, Year, and Cell FE	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls (× Year)	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Estimates of equation (2) on the census demographic-cell panel, the 2000 and 2010 waves, estimated separately on each demographic half of the panel with no reweighting. The outcomes are the inverse hyperbolic sine of the cell's total employee count (Panel A), its employees with a signed card (Panel B), and its employees without one (Panel C). All columns include AMC, year, and demographic-cell fixed effects and the 1991 baseline characteristics interacted with year. Education splits at primary schooling and age at 35. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 3: Technological Displacement and the Employment of At-Risk Workers

	Asinh(Number of employees)		**Asinh(With a signed card)**		**Asinh(Without a signed card)**	
	(1)	(2)	(3)	(4)	(5)	(6)
Labor-saving	−0.0606	−0.1271	−0.0740	−0.1300	−0.0167	−0.0957
	[0.0159]***	[0.0225]***	[0.0166]***	[0.0214]***	[0.0165]	[0.0242]***
Labor-intensive	0.0790	0.1531	0.0769	0.1417	0.0529	0.1265
	[0.0178]***	[0.0243]***	[0.0179]***	[0.0234]***	[0.0186]***	[0.0262]***
Reweighted to the rescued profile (s_c)	No	Yes	No	Yes	No	Yes
Number of cell-years	546,716	524,222	546,716	524,222	546,716	524,222
R-squared	0.630	0.624	0.663	0.668	0.546	0.568
AMC, Year, and Demographic-cell FE	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls ($\times$ Year)	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Estimates of equation (2) on the census demographic-cell panel of Section 4.3 (AMC $\times$ demographic cell), on the 2000 and 2010 census waves, with the 2000 wave, collected before the technologies arrived, as the pre period. The panel counts workers aged 16 to 55 who worked for pay as employees in the census reference week, the measure recorded identically in the two waves. The outcomes are the inverse hyperbolic sine of the cell's employee count, of its employees holding a signed work card, including the military, and of its employees without one. The self-employed, employers, unpaid workers, apprentices, and the statutory public servants of the 2010 questionnaire stay outside every count. Columns (2), (4), and (6) reweight cells to the demographic composition of rescued workers with the weights s_c defined in Appendix A, keeping the cell-years with positive weight. All columns include the 1991 baseline characteristics interacted with year. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

7 Technology and Modern Slavery

This section reports the estimated effects of the two technology shocks on modern slavery. We begin with the difference-in-differences estimates of equation (2) for the three slavery outcomes, together with the event studies that test for differential trends, and we read the estimates through the model's level prediction. We then turn to the coercion rate, detected slavery relative to the population coercion draws on, which asks whether the intensity of coercion changed and not only its level. We then decompose the effects by the sector of the inspected establishment, which locates the response inside the local economy and bears on how the outcomes are measured. We close by comparing the elasticities of the two shocks in common units, the comparison the model's asymmetry prediction calls for.

7.1 Baseline Estimates

The model predicts that total slavery moves with the pool of displaced workers, rising when the labor-saving shock fills the pool and falling when the labor-demanding shock drains it (Propositions 1 and 2). Table 4 carries the test, reporting estimates of equation (2) for the three slavery outcomes, operations with detected slavery, the probability that any slavery is found, and the number of enslaved workers, with and without the demographic controls

interacted with year fixed effects, which allow municipalities with different baseline demographic compositions to follow different paths. The estimates show that in municipalities handed a larger soy opportunity, slavery is detected in more operations, is more likely to be detected at all, and involves more workers, while in municipalities handed a larger maize opportunity all three outcomes move the other way. The two signs hold in every column of Table 4, the soy coefficients positive at the one percent level throughout and the maize coefficients negative at the ten percent level or better.[28] The controls moderate both sides without moving a sign.[29]

Table 4: Technology and Modern Slavery

	Asinh(Operations w/ slavery)		**Pr(Any slavery)**		**Asinh(Enslaved workers)**	
	(1)	(2)	(3)	(4)	(5)	(6)
Labor-saving	0.0367	0.0190	0.0220	0.0093	0.0909	0.0455
	[0.0071]***	[0.0059]***	[0.0036]***	[0.0036]***	[0.0155]***	[0.0148]***
Labor-intensive	−0.0230	−0.0148	−0.0119	−0.0062	−0.0518	−0.0311
	[0.0061]***	[0.0055]***	[0.0035]***	[0.0034]*	[0.0145]***	[0.0139]**
Mean of dep. var. (levels)	0.025	0.025	0.012	0.012	0.650	0.650
Observations	72,732	72,732	72,732	72,732	72,732	72,732
R-squared	0.374	0.382	0.258	0.267	0.292	0.299
AMC and Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Demographic controls (× Year)	No	Yes	No	Yes	No	Yes

Notes: Estimates of equation (2). Operations with detected slavery and enslaved workers are in inverse hyperbolic sine. Pr(Any slavery) is an indicator for at least one detection in the AMC-year. The mean of the dependent variable is reported in levels (counts, or the probability). Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

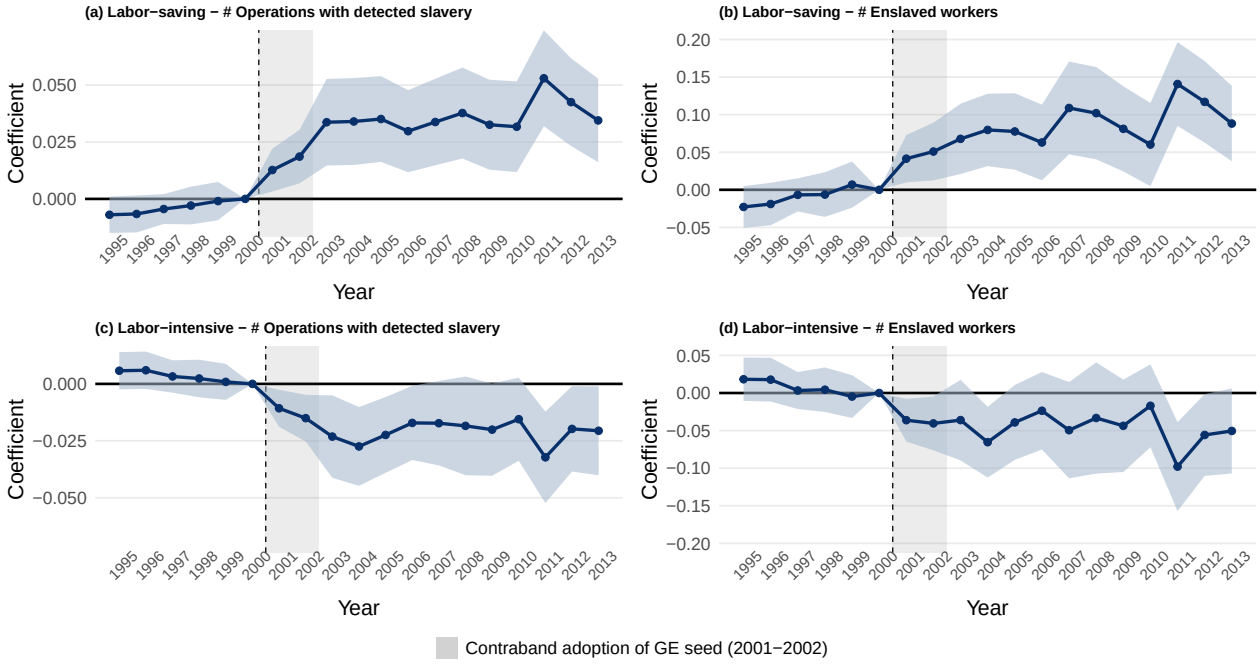
Figure 7 traces the dynamics with equation (3). The pre-adoption coefficients sit near zero for both treatments and both outcomes, consistent with the parallel trends of Section 5. The soy effects emerge between 2001 and 2003, the years the seeds crossed the border and were legalized, the grey band in the figure, and persist through 2013. The maize effects emerge in the same years, because the safrinha was waiting only on the harvest weeks the new soy varieties freed, and maize planting responded as soon as the smuggled seed arrived

[28] With zeros in the outcome, asinh coefficients cannot be read as percentage effects (Chen and Roth, 2024). This section therefore reads the table for signs and precision, and Section 7.4 states the magnitudes in counts and probabilities.

[29] The inference survives clustering by micro-region and Conley spatial corrections at cutoffs from 50 to 150 km (Appendix Table F.4). A permutation test that randomly reassigns the differentials across municipalities places the estimates far outside the placebo distribution (Appendix G). Appendix Table F.5 replaces each continuous differential with dose-group indicators and finds the same pattern step by step across the dose distribution.

(Section 2.2, Appendix Table F.12). Nothing moves before the seed crosses the border.

Figure 7: Technology and Modern Slavery: Event Studies



Notes: Estimates of equation (3). Panels (a) and (b) plot the year-by-year coefficients on the soy differential for operations with detected slavery and enslaved workers. Panels (c) and (d) plot the coefficients on the maize differential. The omitted year is 2000. The grey band marks the informal adoption of smuggled GE seed (2001–2002), before official legalization in 2003, and the dashed line the end of the clean pre period. Blue shaded areas are 95 percent confidence intervals, standard errors clustered at the AMC level.

These are the signs Propositions 1 and 2 predict, and the propositions are equally clear about what they cannot establish. If the cost of coercing falls proportionally faster than the outside option, soy expansion raises total slavery and maize expansion lowers it with no further condition. If the gain channel wins instead, the same signs require the coerced share to be inelastic. The level results of Table 4 are therefore consistent with either winner, and separating the cost channel from the baseline falls to the coercion rate of Section 7.2 and to the posted wage of Section 8, the two readings of the coerced share.

7.2 Intensity versus Scale

A rising count of detected slavery can mean coercion spreading over a larger pool at an unchanged intensity, or coercion deepening relative to the population it draws on. In the model, total slavery is heads times the coerced share, $S = L(1 - p)$, and only the second reading identifies the condition of Proposition 1. The empirical counterpart of the share

is a rate, enslaved workers relative to a measure of the population coercion draws on, and the rate rises with the soy differential and falls with the maize differential under every one of the six denominators of Appendix Table F.8, fixed at baseline, interpolated year by year between the census counts, or annual outright.

Read through the model, this is evidence that the coerced share rose, and not only the level of slavery. The separation comes from what Tables 3 and 4 imply together, enslaved workers rising while the employment of the at-risk group fell, so that slavery per employed at-risk worker rose. With a constant cost of coercion the coerced share falls whenever the pool grows, and the baseline model cannot produce that combination. The reading involves two approximations, and both should be named. The numerator is detected rather than total slavery, which is where the detection assumption of Section 4.1 enters. And the census denominators are fixed at baseline, a place constant, so the movement of the pool enters the separation through Table 3 rather than through the rate itself. The versions whose denominators do move point the same way, the year-by-year interpolated population, the annual formal employment of RAIS, and the census-year rates (Appendix Table F.8).

The same share also moves a price. Workers cannot tell honest employers in the coercion sector from coercive ones, so the wage an honest employer must post rises with the share of coercive contracts in the market, compensating workers for the risk of deception (Lemma 2). The posted wage of Section 8 can therefore help settle whether the share rose.

7.3 Effects by Sector of Activity

If the effects work through the local labor market rather than through the adopting farms, they should appear where the displaced pool is hired and not where the technologies operate. Figure 8 runs the first half of the test, drawing the baseline event studies of Figure 7 next to the same estimates computed separately for slavery found in agriculture and for slavery found outside it. The agricultural series reproduces the baseline almost one for one from the first post-adoption years, so the response of Section 7.1 is at bottom an agricultural phenomenon, and none of it comes from the adopting farms themselves. The non-agricultural series tells a slower story. It sits near zero through the mid-2000s and drifts away from it in the later years, under both shocks, as if coercion filled the complementary sector first and spread outward from there. In the pooled estimates the sectors outside agriculture account for roughly a third to half of the agricultural response, with logging, charcoal production, and construction, the frontier's other coercion-prone activities, hiring from the same pool (Section 2.1).

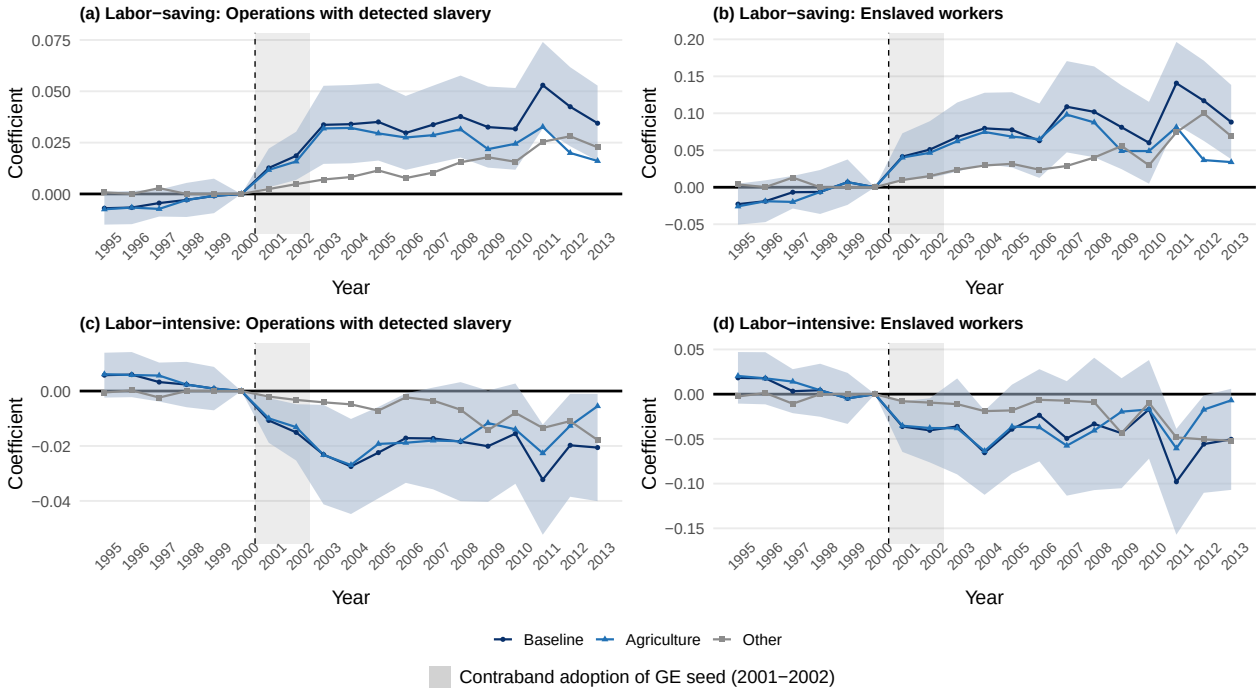
The agriculture series is itself an aggregate of very different activities, and Figure 9 opens it up, drawing the same event studies for agriculture as a whole, for cattle ranching, and for crops. Slavery found on crop farms, the blue series, stays flat near zero under

both shocks, while the response runs through cattle ranching, the grey series, which tracks the aggregate almost one for one. In the pooled version of the decomposition, the cattle-ranching coefficients reproduce the aggregate pattern, positive under soy and negative under maize, with the crop effects an order of magnitude smaller (Appendix F). With the baseline controls added, the crop effects go to exactly zero, $p \geq 0.79$ in all four estimates, and the cattle-ranching effects are essentially unchanged.

The response lands exactly where the background said the pool is hired, since cattle ranching is the dominant sector of forced-labor operations across the frontier (Section 2.1). The sector where coercion responds is the sector that hires the displaced, not the sector that adopted the technology, which is what a model that prices every match off one local pool delivers. Nor is the response the sector's own size moving, since conditioning the sector's slavery on the contemporaneous herd and pasture area leaves the estimates unchanged (Table F.16 and Section 10.4).

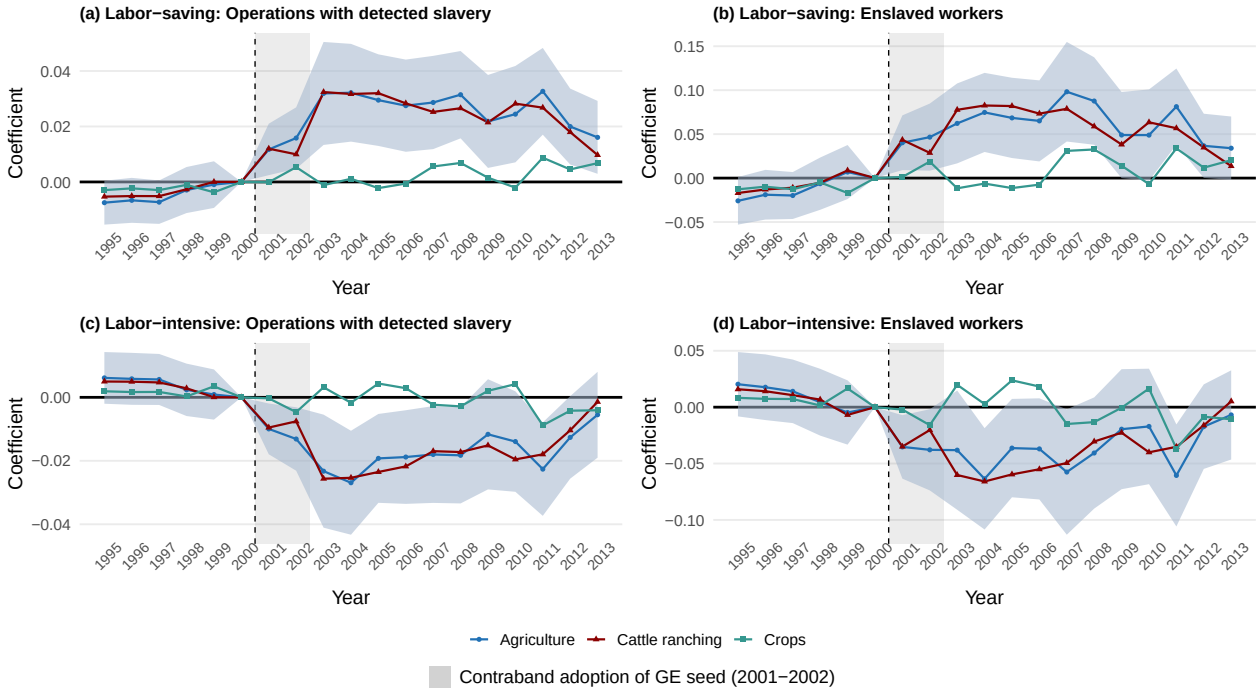
A story in which the shocks merely raised the propensity to report abuse would spread reported slavery across sectors, so effects that are zero in the adopting crops, concentrated in cattle ranching, and opposite in sign for the two shocks have the wrong shape for reporting, an argument Section 10 completes.

Figure 8: Decomposing the Baseline Response: Agriculture and Other Sectors



Notes: Estimates of equation (3). The black series reproduces the baseline outcomes of Figure 7, all operations with detected slavery and all enslaved workers. The grey series counts only slavery found at agricultural establishments, and the blue series only slavery found outside agriculture, classified by the CNAE of the inspected establishment. Panels (a) and (b) plot the year-by-year coefficients on the soy differential. Panels (c) and (d) plot the coefficients on the maize differential. The shaded area is the 95 percent confidence interval of the baseline series, standard errors clustered at the AMC level. The omitted year is 2000. The grey band marks the informal adoption of smuggled GE seed (2001–2002), before official legalization in 2003, and the dashed line the end of the clean pre period.

Figure 9: Technology and Modern Slavery by Sector of Activity



Notes: Estimates of equation (3) with the outcomes decomposed by the sector of the inspected establishment. Panels (a) and (b) plot the year-by-year coefficients on the soy differential for operations with detected slavery and for enslaved workers. Panels (c) and (d) plot the coefficients on the maize differential. Each panel draws the three sector series, agriculture as a whole in black, cattle ranching in grey, and crops in blue. The shaded area is the 95 percent confidence interval of the agriculture series, standard errors clustered at the AMC level. The omitted year is 2000. The grey band marks the informal adoption of smuggled GE seed (2001–2002), before official legalization in 2003, and the dashed line the end of the clean pre period. The pooled decomposition, including the residual sectors, is in Appendix F.

7.4 Magnitudes

The technologies moved adoption, adoption moved the employment of the workers slavery draws on, and slavery moved with it, in opposite directions under the two shocks, on each technology's own calendar, and in the sector that hires the displaced. How much it moved depends on units. The inverse hyperbolic sine our tables use is convenient for skewed counts, but its coefficients are not percentage effects, since with zeros in the outcome the implied magnitude depends on the units of the count itself (Chen and Roth, 2024). We therefore take magnitudes from the specifications whose units are well defined. The first is the probability that any slavery is found, an extensive margin that carries no such problem at all, since its treatment effect is measured in probability points whatever the units of the underlying count. The second is the twin of the table estimated in levels (Appendix Table F.7).

The employment estimates of Section 6 also put the two shocks in one common unit. Dividing the slavery response by the response of the at-risk employment gives the elasticity of coercion with respect to the employment of the workers it draws on. Both sides of the ratio read in percentages without abusing the transformation. The numerator is the level effect on enslaved workers relative to the outcome's mean, and the denominator is the asinh response of the at-risk total employment of Table 3, whose zeros are rare, under 2 percent of the estimation weight. Each percent of at-risk employment destroyed by the labor-saving shock raises the number of enslaved workers found by 10.3 percent of its mean, and each percent created by the labor-demanding shock lowers it by 6.0 percent. The same log point of the soy differential that removes 12.7 percent of the at-risk group's employee work more than doubles the enslaved workers found in a municipality-year.

The two directions are not symmetric. The labor-saving coefficients are larger in magnitude than the labor-demanding ones for every outcome of Table 4, and the differences are statistically significant for enslaved workers and for the probability of detection, and marginal for operations.[30] The elasticities put the excess at 72 percent per displaced worker, and a cluster bootstrap of the ratio, resampling municipalities and reestimating the four coefficients jointly, finds it above one in 98 percent of draws, with a 95 percent interval of 1.12 to 4.70.[31] correction would therefore need to be larger than the labor-saving shock it undoes.

The model gives this shape a reason. The cost of coercion falls as the pool fills, and the feedback makes the equilibrium response convex, steeper against a shock that fills the pool than against one that drains it (Proposition 3). In the baseline without the cost channel the response has no reason to be steeper on the filling side, so the asymmetry separates the two models by shape, as the rising rate of Section 7.2 separates them by direction. The convexity also has a concrete reading in our setting. The displacement of the labor-saving shock lands on the workers already closest to coercion. The jobs of the labor-demanding shock need not be filled from the bottom, since employers can hire first from workers higher up the queue. Each job created therefore buys less protection for the at-risk than each job destroyed takes from them, which is the model's convexity worker by worker. The dose groups read the same shape directly, with the response per log point of the soy differential rising with the dose (Appendix Table F.5). The heterogeneity results of Section 9.2, with responses about twice as large where baseline outside options were worse, point the same way.

[30] Wald tests of equal magnitudes in the specification with controls give $p = 0.014$ for enslaved workers, 0.033 for the probability of detection, and 0.053 for operations.

[31] The point value of 72 percent is the ratio of two estimated ratios and is measured with far less precision than the coefficients beneath it, so it reads as an order of magnitude. The bootstrap is clustered at the AMC level with the same draw in both panels.

8 Earnings in the Coercion Sector and in the Outside Options

A single shock to local demand moves every sector's wage the same way. In the estimates below the wage the coercion sector posts instead moves against every outside option, rising where soy displaces workers and falling where maize reabsorbs them, the price the risk of enslavement puts on a posted offer. The earnings come from the census, not from the inspection records, so the test reads coercion in prices and owes nothing to detection. Wages in the sectors that employ the displaced worker's alternatives track the outside option, $\bar{u}(L)$, which falls when the pool grows and rises when it drains. The posted wage in the coercion sector contains something more, the risk premium of Lemma 2, which moves with the coerced share. Conditional on outside wages, that wage rises when the share rises and falls when the share falls. A coercion-sector wage that moves against the outside option, given outside wages, can only come from the premium (Lemma 2). The same crop that lowers the safe-sector employment probability q of Section 3.2 fills the pool and raises the share, so the divergence below is the price trace of that channel.

The census earnings of the coercion sector are the right object for this test. Cattle ranching is the sector where coercive and legitimate employers hire from the same pool and post the same wage, and the workers the census reaches there are the free workers of the legitimate establishments, who earn what the firm posts, since a firm operating legally honors its posting (Section 3.3.1). Coerced workers are held on remote properties the enumerators do not reach, and they are in any case a vanishing share of the sector's employment. Whatever contamination they add pulls the measured earnings downward exactly where coercion is high, against the premium the test looks for, so the estimates read as a lower bound on it.

Table 5 reports the earnings responses, measured from the census microdata of 2000 and 2010 and expressed as regional premia in the two-step design of Dix-Carneiro and Kovak (2017). The first step regresses individual earnings, the monthly earnings of the main job in inverse hyperbolic sine, on demographic-cell indicators and AMC fixed effects, separately in each census wave, so that the composition of workers and the returns to their characteristics can both change over time. The estimated AMC effects are the sector's local earnings premia. The second step regresses the 2000 to 2010 change in the premium on the two suitability differentials. The table reports two versions of the exercise. The raw column drops the cell indicators, so its premium is the change in the sector's average earnings. The composition-adjusted column holds the workforce mix fixed.

The coercion sector and the alternatives move in opposite directions in every column of Table 5. In cattle ranching, earnings rise with soy and fall with maize, by 7.6 and 7.4 percent in the adjusted premia. In the alternatives the signs reverse, with services falling 9.7 percent

under soy and rising 10.4 percent under maize, and manufacturing moving the same way. The premium is the Brazilian analog of the earnings jump that appeared when a reform loosened the Gulf employer's hold on the visa, the employer's power read from the worker's pay (Naidu et al., 2016).

Table 5: Earnings Premia in the Coercion Sector and in the Outside-Option Sectors

	Cattle ranching		**Manufacturing**		**Services**	
	Raw	Adjusted	Raw	Adjusted	Raw	Adjusted
	(1)	(2)	(3)	(4)	(5)	(6)
Labor-saving	0.0449	0.0760	−0.1293	−0.0613	−0.1400	−0.0970
	[0.0228]**	[0.0236]***	[0.0199]***	[0.0174]***	[0.0097]***	[0.0080]***
Labor-intensive	−0.0684	−0.0740	0.1125	0.0704	0.1316	0.1035
	[0.0280]**	[0.0275]***	[0.0230]***	[0.0215]***	[0.0112]***	[0.0093]***
Number of AMCs	3,706	3,706	3,813	3,813	3,828	3,828
AMC and Year FE (first step)	Yes	Yes	Yes	Yes	Yes	Yes
Demographic-cell indicators	No	Yes	No	Yes	No	Yes

Notes: Two-step earnings premia following Dix-Carneiro and Kovak (2017). The first step regresses individual earnings, the monthly earnings of the main job in inverse hyperbolic sine from the 2000 and 2010 census microdata, on demographic-cell indicators (sex × age band × education × race, the cells of Section 6) and AMC fixed effects, separately by wave. The estimated AMC effects are the sector's local earnings premia. The second step regresses the 2000–2010 change in the premium on the two suitability differentials, with heteroskedasticity-robust standard errors in brackets. Columns (1), (3), and (5) omit the cell indicators, so their premia are changes in the sector's average earnings. Workers aged 16 to 55 who worked for pay in the census reference week, with the top percentile of main-job earnings trimmed within each wave and 2010 values deflated to 2000 reais. The signs of every column survive adding the 1991 baseline characteristics of equation (2) to the second step, the cattle premium at the five percent level in column (1) and the ten percent level in column (2), and the services columns at the one percent level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Consistent with Lemma 2, the two earnings series move apart on both sides of the table. Where soy drew workers into the pool, the alternatives paid less while cattle ranching paid more, and where the safrinha drained the pool, the alternatives paid more while cattle ranching paid less, the premium unwinding as the coerced share falls (Section 7.2). The safe sector's own average earnings move with the same signs the model gives W_A for free, rising where soy spreads and falling where maize does, a composition shift as the pool changes rather than the model's marginal W_A, and no result rests on its level. Two prices in the same market moving in opposite directions under the same shock is the opposite of what a common demand story delivers, and it is exactly what the risk premium requires. The earnings evidence also closes a door for measurement, since a story in which the

shocks moved reporting rather than coercion has no reason to move sectoral earnings at all (Section 10).

9 Where Displacement Becomes Coercion

The pooled estimates say how much slavery the technologies move. Two baseline traits of the local market say where. The structure of the land market decides whether displacement turns into coercion at all, and the workers' outside options decide how hard it does.

9.1 Market Power and Coercion as Substitutes

A displaced worker can be underpaid in two ways. An employer who faces no competitors can lower the wage and stay within the law, and an employer who faces many can only pay less than the market by not paying at all. Labor market power and coercion are close relatives, since an employer whom workers cannot leave for a competitor already holds part of what coercion buys (Naidu, 2020), and the modern monopsony literature measures that power with the concentration of employers (Card, 2022; Berger et al., 2022). The worker's side of the theory reads the same way, punishment binds hardest and bonded terms are accepted where alternatives are worth least (Chwe, 1990; Genicot, 2002). If the two are substitutes, the response of slavery to displacement should be weakest where the local land market was already concentrated, since there the shock is absorbed by the wage, and strongest where the market was competitive, since there the coercive margin is the one that can move.[32] We measure concentration on the eve of the shocks with the 1995–96 Agricultural Census, which counts establishments by farm-size class and by activity in every municipality. For each AMC we compute a land HHI over the size classes, for all agricultural establishments and separately for the establishments of the coercion sector, cattle ranching, and split the sample at the median of each measure.[33]

Table 6 estimates equation (2) separately on each side of the median. Where the coercion sector's land was concentrated, neither shock moves slavery, and all four coefficients sit below 0.01 in absolute value. Where it was dispersed, both shocks do, 0.047 on operations and 0.110 on enslaved workers per log point of the soy differential, -0.039 and -0.085 under maize, more than twice the pooled estimates of Table 4. The split by the concentration

[32] Concentration enters here as an exogenous baseline moderator, measured on the eve of the shocks. A companion paper takes the employers' market power itself as the object of study (Araujo et al., 2026c).

[33] The HHI weights each size class by the area it holds, with class midpoints as sizes and the open top class, 1,000 hectares and above, entering at 1,500, the midpoint it would have if the doubling of the class widths continued. Cattle establishments are those whose main activity is livestock in the census activity groups.

of all agricultural land shows the same contrast at lower intensity.[34] A market with few establishments is concentrated by construction, so a split on the HHI could sort municipalities by the size of their cattle sector rather than by the structure of its land market. Adding the log count of the sector's 1996 establishments, interacted with year, to the controls moves nothing, with the dispersed half at 0.060 and 0.141 under soy and the concentrated half still at zero.[35] The split is also read on a baseline the shocks left in place, since the size composition of livestock establishments responds to neither technology in the 1996 and 2006 censuses (Table F.15). Figures 10 and 11 draw the same splits year by year, with flat paths through the pre-period on both sides and the response opening only where land was dispersed. Appendix Figure G.18 replaces the median split with quintiles of the same concentration measure, and both shocks work almost entirely inside the most dispersed fifth, with the remaining quintiles flat at zero.

The pattern is what substitution predicts, and it has a reading inside the model. The gain from coercion is the wage it avoids paying. Where an employer already sets the wage, the honest wage sits close to the outside option and leaves the cutoff little room to move when the pool fills. Where no employer sets the wage, displacement lowers the outside option of workers whom a competitive employer cannot underpay, and the response runs through the coercive margin.

Appendix D makes the reading formal by extending the deception game of Figure 1 with exactly this alternative. The market carries an index of its concentration, and the index enters through the wage of free labor alone: every payoff a worker can walk away to, the rejected offer, the abandoned honest match, the discounted escape from a coercive one, is paid at the wage the concentrated market sets, while the cost of coercion is untouched. The cutoff and the equilibrium then carry over market by market (Corollary 5). The one added assumption is that a more concentrated market passes the pool into its wage more strongly, since an employer who sets the wage prices the workers' desperation directly. The response of the coerced share then inherits the difference between the two rates of decline, falls with concentration, and reaches zero where the wage absorbs the pool as fast as the cost of coercion falls (Proposition 6), the shape of Table 6.

[34] A split by the concentration of crop establishments alone, the sectors that adopted the technologies, separates the two sides little, so the moderation is specific to the sector that hires the displaced.

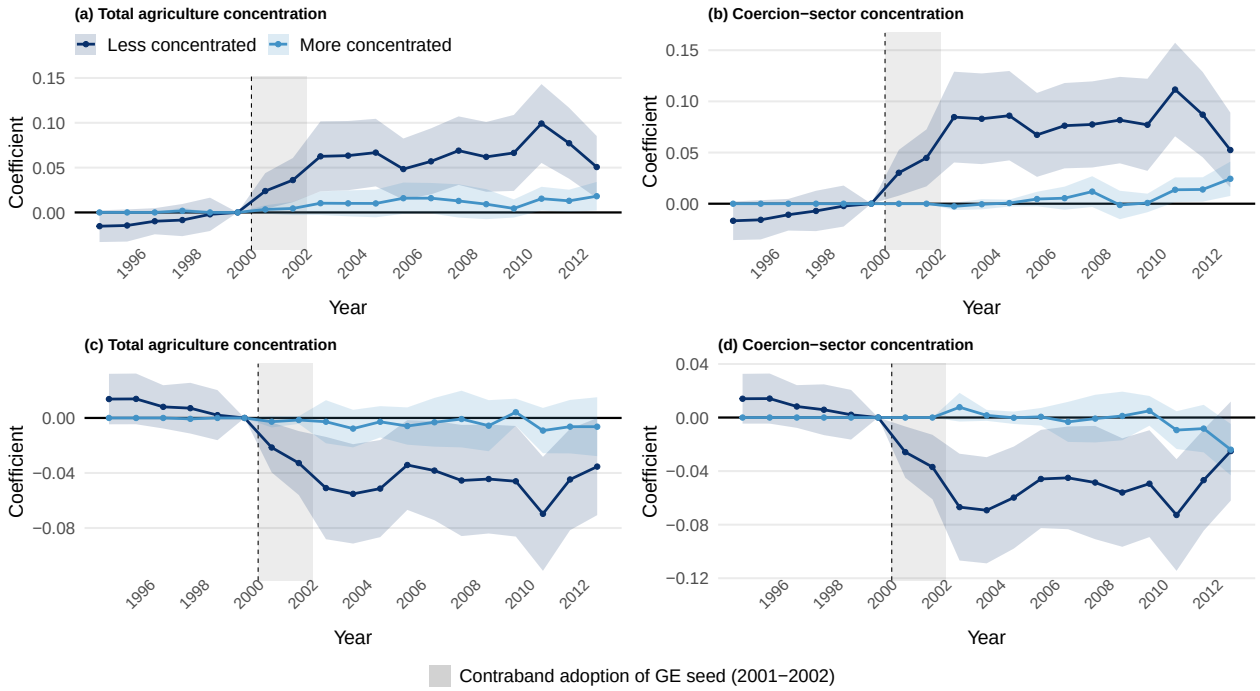
[35] The all-agriculture split with the same control also holds, and its dispersed half strengthens, to 0.044 and 0.098 under soy and -0.057 and -0.124 under maize.

Table 6: Heterogeneity by Baseline Land Concentration

	Panel A: Asinh(Operations w/ slavery)			
	Total agriculture concentration		**Coercion-sector concentration**	
	>[50th]	≤[50th]	>[50th]	≤[50th]
	(1)	(2)	(3)	(4)
Labor-saving	0.0056	0.0271	0.0024	0.0468
	[0.0037]	[0.0125]**	[0.0019]	[0.0137]***
Labor-intensive	−0.0017	−0.0279	0.0001	−0.0391
	[0.0032]	[0.0120]**	[0.0021]	[0.0121]***
Observations	36,138	36,138	36,062	36,081
R-squared	0.208	0.422	0.119	0.422
	Panel B: Asinh(Enslaved workers)			
	Total agriculture concentration		**Coercion-sector concentration**	
	>[50th]	≤[50th]	>[50th]	≤[50th]
	(5)	(6)	(7)	(8)
Labor-saving	0.0166	0.0595	0.0090	0.1100
	[0.0101]*	[0.0316]*	[0.0067]	[0.0335]***
Labor-intensive	−0.0031	−0.0568	−0.0007	−0.0846
	[0.0100]	[0.0300]*	[0.0077]	[0.0295]***
Observations	36,138	36,138	36,062	36,081
R-squared	0.157	0.341	0.102	0.342
AMC and Year FE	Yes	Yes	Yes	Yes
Baseline controls (× Year)	Yes	Yes	Yes	Yes

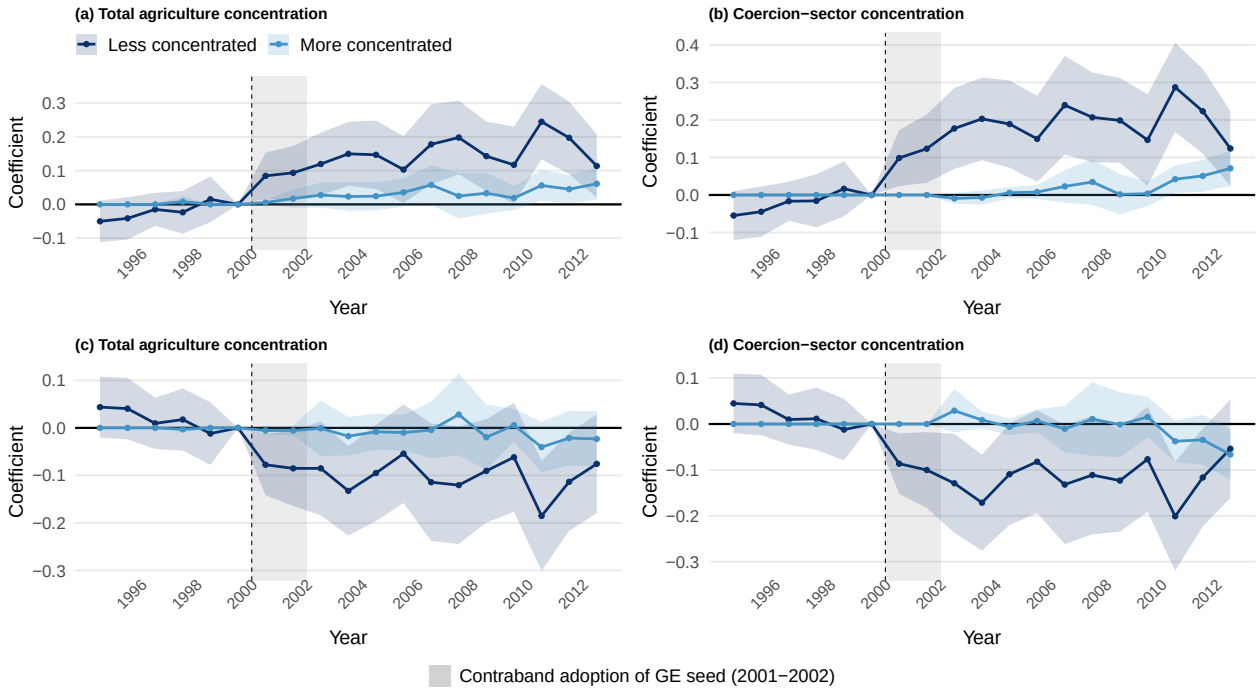
Notes: Each column estimates equation (2) on the municipalities on the side shown of the 1996 AMC median of the land HHI indicated, computed from the 1995–96 Agricultural Census counts of establishments by farm-size class, for all agricultural establishments and for the establishments of the coercion sector, cattle ranching, where the forced-labor cases of Section 2.1 concentrate. Columns marked >[50th] hold the more concentrated half. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Figure 10: Event Studies by Baseline Land Concentration: Operations with Detected Slavery



Notes: Each panel plots the year-by-year coefficients of equation (3), with the inverse hyperbolic sine of operations with detected slavery as the outcome, estimated separately on the municipalities below (dark) and above (light) the 1996 median of the land HHI shown, for the soy differential in panels (a) and (b) and the maize differential in panels (c) and (d). Shaded areas are 95 percent confidence intervals, clustered at the AMC level, and the reference year is 2000. The grey band marks the informal adoption of smuggled GE seed (2001–2002), before official legalization in 2003, and the dashed line the end of the clean pre period.

Figure 11: Event Studies by Baseline Land Concentration: Enslaved Workers



Notes: Each panel plots the year-by-year coefficients of equation (3), with the inverse hyperbolic sine of enslaved workers as the outcome, estimated separately on the municipalities below (dark) and above (light) the 1996 median of the land HHI shown, for the soy differential in panels (a) and (b) and the maize differential in panels (c) and (d). Shaded areas are 95 percent confidence intervals, clustered at the AMC level, and the reference year is 2000. The grey band marks the informal adoption of smuggled GE seed (2001–2002), before official legalization in 2003, and the dashed line the end of the clean pre period.

9.2 Outside Options and the Strength of the Response

The model also compares markets rather than moments. Under Assumption 1, stated in Appendix C, the same shock moves slavery by more where the baseline outside option is worse, because there the growth of the pool cheapens recruitment fastest, and the amplification should appear on both shocks, the harmful and the protective alike. The double amplification is what separates the prediction from the familiar fact that poor places have more slavery, a level the fixed effects already absorb. What the mechanism adds is that poor places also respond more, in both directions, so the same map of baseline disadvantage that locates slavery also locates its sensitivity to technology.

Table 7 interacts the two treatments with an indicator for the municipality's side of the 1991 median of three proxies for the baseline outside option, the formal employment share, the literacy rate, and the share of adults with no schooling. Across the splits, the responses concentrate in the worse-baseline half, at ratios that reach two to one. Below the median

of the formal share, one log point of the soy differential raises the asinh of operations by 0.023 and of enslaved workers by 0.054, against 0.016 and 0.040 above it, and the maize reductions are likewise larger below, 0.019 against 0.014 for operations. The literacy split shows the same pattern at smaller ratios, and the no-schooling split concentrates both responses in the half where schooling is scarcest, 0.028 against 0.012 under soy and 0.021 against 0.018 under maize. Across the three proxies the response to the technologies comes from the municipalities that entered the period with the worst baselines, the concentration the cheapening mechanism predicts, sharpest in the formal-share and no-schooling splits, where it appears under the harmful and the protective shock alike. Its reading in the model is the one the inspection reports of Section 2.1 state in their own words, that recruitment is cheapest where opportunities are scarcest. Figure 12 draws the same splits year by year, with flat paths through the pre-period on both sides and the response opening only in the worse-baseline half. Figure 13 repeats the figure with enslaved workers as the outcome.[36]

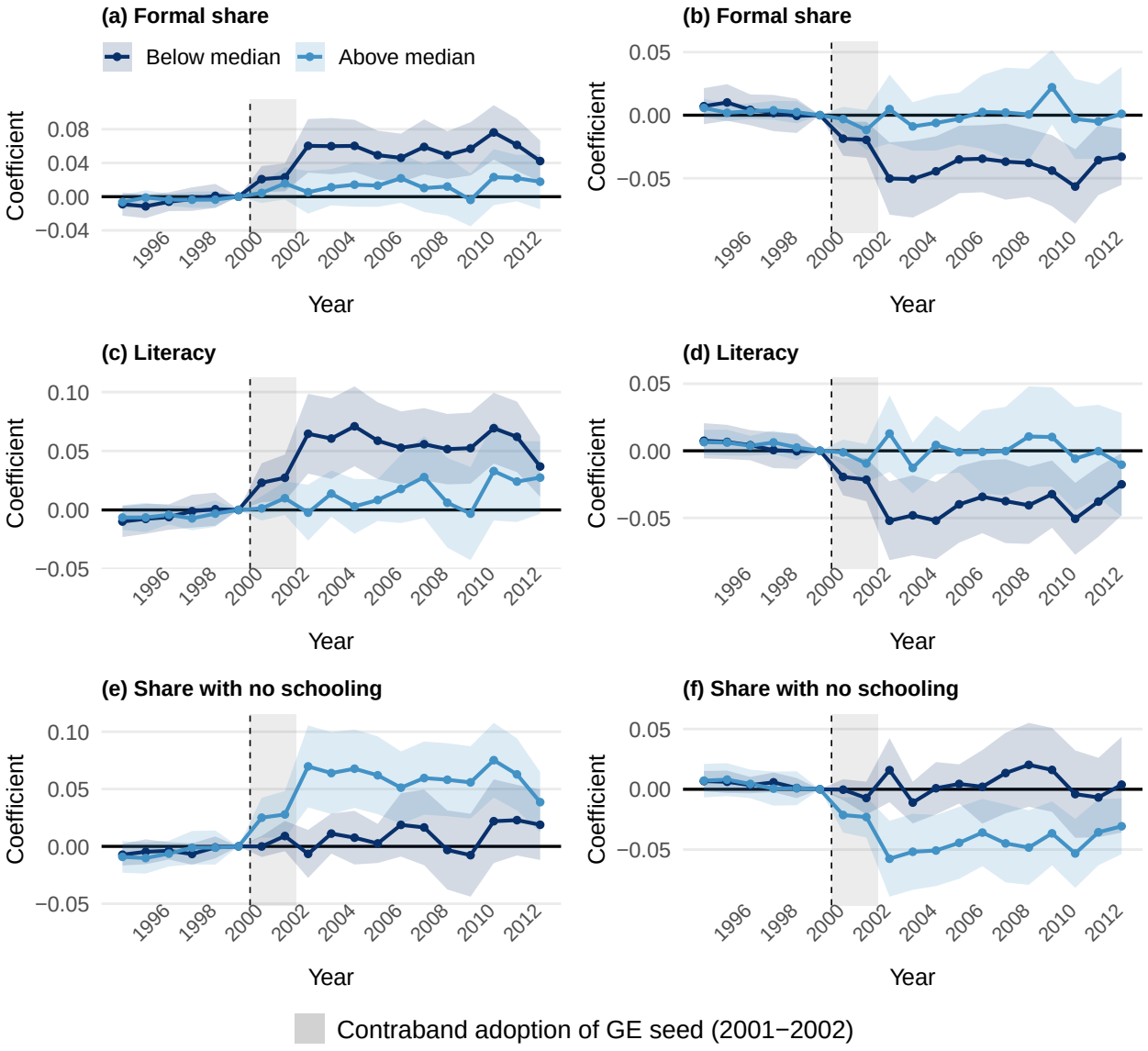
[36] Appendix Table F.9 reports a more detailed version of the table, with three further 1991 splits, the unemployment rate, the share with more than twelve years of schooling, and mean years of schooling. The unemployment split shows the sharpest concentration of the six, with both responses in the high-unemployment half. Mean schooling repeats the pattern under the labor-saving shock, and the share with more than twelve years, the one split that measures the top of the schooling distribution rather than the margin where rescued workers sit, separates the two sides little.

Table 7: Heterogeneity by Baseline Outside Options

	Panel A: Asinh(Operations w/ slavery)					
	Formal share		Literacy		Share with no schooling	
	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]
	(1)	(2)	(3)	(4)	(5)	(6)
Labor-saving	0.0233	0.0160	0.0243	0.0183	0.0116	0.0280
	[0.0098]**	[0.0084]*	[0.0095]**	[0.0082]**	[0.0074]	[0.0101]***
Labor-intensive	−0.0188	−0.0137	−0.0173	−0.0221	−0.0181	−0.0211
	[0.0088]**	[0.0077]*	[0.0083]**	[0.0086]**	[0.0082]**	[0.0089]**
Observations	72,732	72,732	72,732	72,732	72,732	72,732
R-squared	0.382	0.382	0.384	0.384	0.384	0.384
	Panel B: Asinh(Enslaved workers)					
	Formal share		Literacy		Share with no schooling	
	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]
	(7)	(8)	(9)	(10)	(11)	(12)
Labor-saving	0.0544	0.0400	0.0556	0.0502	0.0326	0.0647
	[0.0236]**	[0.0196]**	[0.0228]**	[0.0183]***	[0.0165]**	[0.0240]***
Labor-intensive	−0.0389	−0.0308	−0.0351	−0.0540	−0.0428	−0.0445
	[0.0215]*	[0.0195]	[0.0208]*	[0.0200]***	[0.0191]**	[0.0221]**
Observations	72,732	72,732	72,732	72,732	72,732	72,732
R-squared	0.300	0.300	0.301	0.301	0.301	0.301
AMC and Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Baseline controls (× Year)	Yes	Yes	Yes	Yes	Yes	Yes

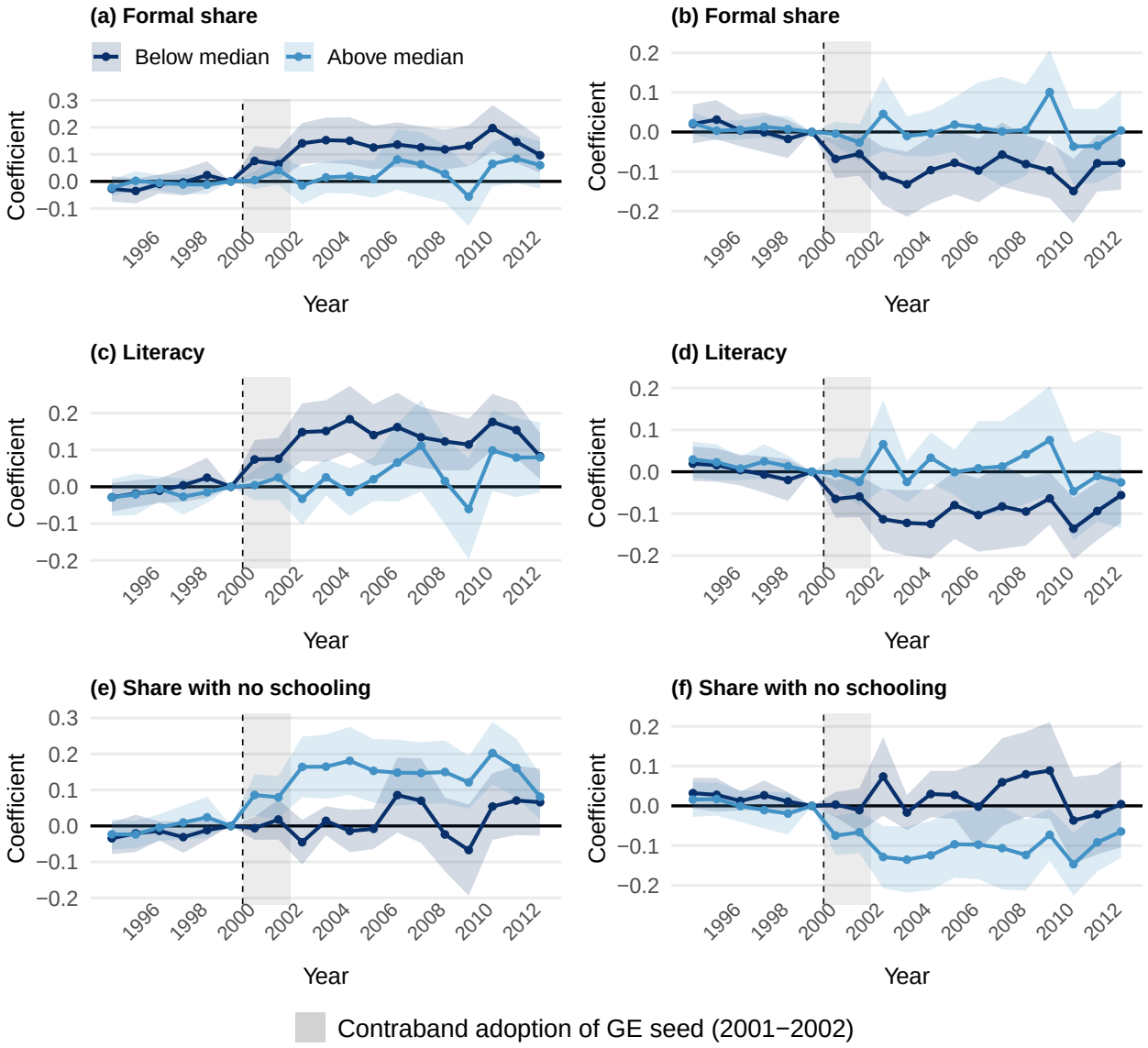
Notes: Each split reports a single estimation of equation (2) on the full panel with the two treatments, and the post indicator, interacted with an indicator for the municipality's side of the 1991 median of the split variable. The below- and above-median columns of a split therefore come from the same regression. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Figure 12: Event Studies by Baseline Outside Options: Operations with Detected Slavery



Notes: Each panel plots the year-by-year coefficients of equation (3), with the inverse hyperbolic sine of operations with detected slavery as the outcome, estimated separately on the municipalities below (dark) and above (light) the 1991 median of the proxy shown, for the soy differential in the left column, panels (a), (c), and (e), and the maize differential in the right column, panels (b), (d), and (f). Shaded areas are 95 percent confidence intervals, clustered at the AMC level, and the reference year is 2000. For the share of adults with no schooling the worse-baseline half is the one above the median.

Figure 13: Event Studies by Baseline Outside Options: Enslaved Workers



Notes: Each panel plots the year-by-year coefficients of equation (3), with the inverse hyperbolic sine of enslaved workers as the outcome, estimated separately on the municipalities below (dark) and above (light) the 1991 median of the proxy shown, for the soy differential in the left column, panels (a), (c), and (e), and the maize differential in the right column, panels (b), (d), and (f). Shaded areas are 95 percent confidence intervals, clustered at the AMC level, and the reference year is 2000. For the share of adults with no schooling the worse-baseline half is the one above the median.

10 Alternative Interpretations and Robustness

In this section we explore the alternative explanations that could also generate a positive β^{soy} and a negative β^{maize} in equation (2) without any change in coercion. Section 10.1 takes

up the possibility that the technologies changed the reporting of slavery rather than its prevalence. Sections 10.2 and 10.3 turn to contamination of the pool or the comparison group, the first through in-migration into the treated municipalities and the second through displaced workers crossing municipal borders. Section 10.4 asks whether the shocks moved the cattle sector's own scale rather than filling its labor pool, and Section 10.5 closes with the specification, inference, and sample checks.

10.1 Reporting Versus Prevalence

Because slavery is a crime, it enters the data only when someone uncovers it. Our outcomes count the slavery that inspections find, and every inspection begins with a complaint, so the estimates could in principle reflect changes in reporting rather than changes in slavery itself. Our maintained hypothesis is that the two shocks, in their intensity and their timing, are correlated with actual slavery and not with the propensity of localities to report it. The first threat is that enforcement itself responded to the shocks, with the police directing operations toward the areas the technologies transformed. As Section 4.1 records, the inspection files document what triggered each operation, and in our sample period every operation, without exception, originated in a local complaint rather than in police intelligence.[37] The complaint origin rules out operations started by the state on its own initiative.

We make the rest of the concern precise with a measurement model. Detection recovers only a fraction of the truth, so we write the detected count as true forced labor S^{*}_{jt} scaled by a detection probability, $S_{jt} = \pi_{jt}\, S^{*}_{jt}\, e^{u_{jt}}$ with $\pi_{jt} \in (0, 1]$, and let ϕ^{c} denote the response of the log detection rate to shock c after the treatment date, net of the municipality and year fixed effects. Because detected slavery is the dependent variable, any place-and-time separable detection process is absorbed by the municipality and year fixed effects, and the remaining classical error leaves β^{soy} and β^{maize} unbiased, inflating only their standard errors (Hyslop and Imbens, 2001), a result Appendix E derives. The one threat that survives fixed effects is detection that co-moves with the treatment, summarized by ϕ^{c}. Identification of the effect on true slavery requires that the shocks move detection only through the truth, not through the probability of catching it,

$$\phi^{soy} = \phi^{maize} = 0 \qquad \Longleftrightarrow \qquad E\Big[\, \varepsilon_{jt}\,(A^{c}_{j} \times Post_{t}) \,\Big|\, \alpha_{j}, \alpha_{t} \Big] = 0, \;\; c \in \{soy,\, maize\}, \tag{4}$$

where ε_{jt} is the wedge detection puts between the estimated outcome and the same transform of the truth, as Appendix E sets out. Under (4) the coefficient on detected slavery equals the coefficient on true slavery. When it fails, the estimator converges to the true effect plus the

[37] Appendix B.1 shows what such a complaint looks like, reproducing an escaped worker's denunciation and following the operation it set off from first landing to rescue.

detection response,

$$\widehat{\beta}^{c} \xrightarrow{p} \beta^{c}_{\text{true}} + \phi^{c}, \qquad \operatorname{sign}\big(\widehat{\beta}^{c} - \beta^{c}_{\text{true}}\big) = \operatorname{sign}\big(\phi^{c}\big), \tag{5}$$

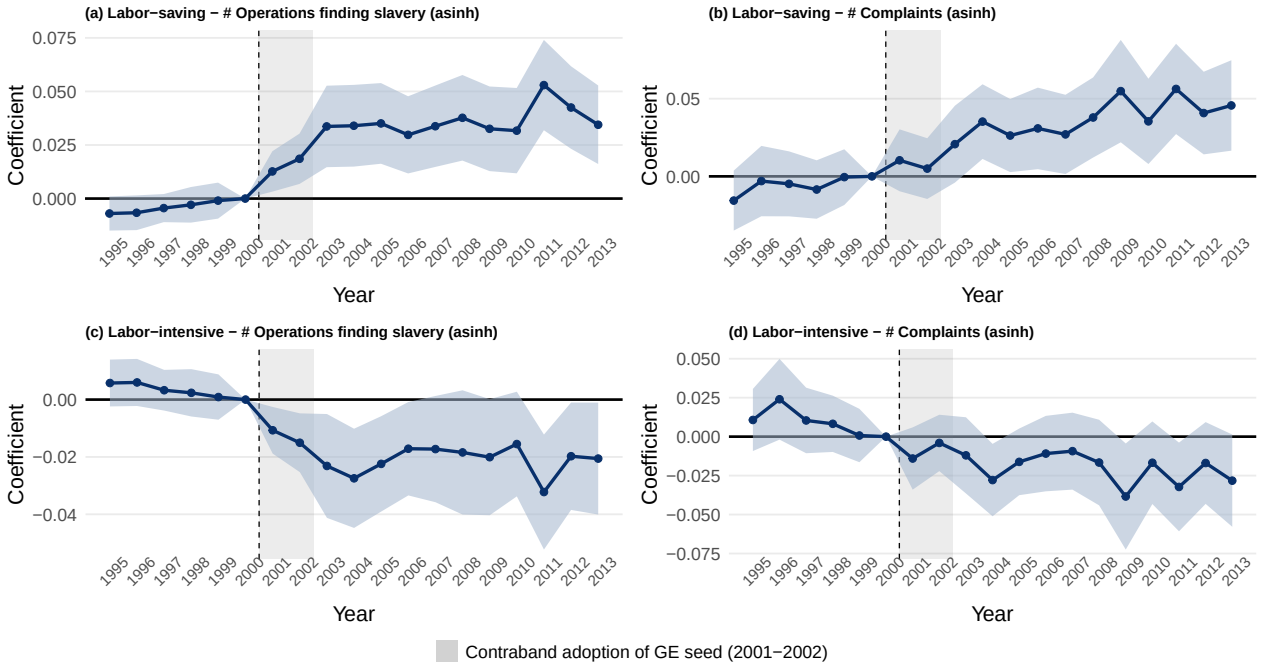
so each reporting story is a signed prediction for ϕ^c that the data can reject.

The three leading stories each imply a sign, and the data contradict each one. Enforcement following modernization predicts $\phi^{soy} > 0$ and $\phi^{maize} > 0$, the same sign for both, because both shocks are the arrival of a better technology, and the opposite estimated signs are incompatible with it. Grievances of dismissed workers predict $\phi^c > 0$ in the sector that dismissed them, yet the effects are zero in the crop sectors and concentrate in cattle ranching, which Section 7.3 shows is where the displaced are hired and not where a dismissed worker's grievance points. Easier access to denunciation predicts $\phi^{maize} > 0$, richer residents reporting more where the technology employs. The flow moves the other way. Complaints fell by 2.8 percent per log point under the shock that raised employment and rose by 3.8 percent under the one that destroyed it (Appendix Table F.10).

The response also shifts the finding rate, the share of inspections that end in a detection, up with soy and down with maize (Appendix Table F.10). Since the operation count is what a complaint wave moves first, a change in the finding rate at a given number of operations points to a change in how much true slavery there was to find. The timing separates the two further. The number of operations that find slavery responds from 2001 under both shocks, while complaints stay flat and insignificant until 2004 (Figure 14). A reporting wave would move complaints first, not three years later, so the early response is of slavery found, not of inspections invited by complaint.

Both shocks are the arrival of better technology, so a detection channel that grows with modernization would move the two coefficients in the same direction, and the estimated signs are opposite. No mean-independent detection error of the Berkson type, uncorrelated with the treatment by construction, can generate opposite signs across two shocks either, so the pattern can only come from slavery itself.

Figure 14: The Timing of Detection and of Complaints



Notes: Event-study coefficients and 95% confidence intervals from the specification of Section 5, reference year 2000. The left panels plot the inverse hyperbolic sine of the number of operations that find slavery in a municipality-year, and the right panels the inverse hyperbolic sine of local complaints (denúncias), for the soy differential in the top row and the maize differential in the bottom row. Operations that find slavery respond from 2001 under both shocks, while complaints stay flat and insignificant until 2004. The grey band marks the smuggling window (2001–2002). Standard errors are clustered at the AMC level.

10.2 In-Migration Versus Local Displacement

Our estimates attribute the growth of the pool to the displacement of residents. An alternative is that people moved instead, with the soy boom attracting migrants whose arrival expanded the local labor supply, so that coercion rose where outsiders accumulated rather than where residents lost work. For this story to produce our estimates, population must flow toward the municipalities where slavery rose and away from those where it fell.

The migration data show the opposite flows. We construct net migration rates for our AMCs from the census microdata with the cohort average method of Bustos et al. (2016), and estimate equation (2) on the 1991–2000 and 2000–2010 decades, with the second as the post period (Appendix Table F.13). Municipalities more suitable for soy lost migrants after 2000, by 1.2 percentage points of their initial population per log point of the differential with the baseline controls, and municipalities more suitable for maize gained them, by 2.3 percentage points, with the same pattern in the adoption-decade cross-section. These are the

flows structural transformation produces (Pellegrina and Sotelo, 2025; Morten and Oliveira, 2024), workers leaving where the technology released labor and arriving where it demanded labor, and they run exactly against what the in-migration story needs, since slavery rose where population flowed out and fell where it flowed in.

The confound therefore has no material to work with. Population left the municipalities where slavery rose, so the pool filled through the displacement of those who stayed and not through the arrival of outsiders, and an in-migration story would have to reverse the observed flows. If anything the outflow drains the pool the model runs on, so the measured response understates what displacement did to those who stayed. The outflow also fits the displacement reading, since Section 6 shows the employee work of at-risk workers falling with soy on both margins. Where the leavers end up is the question of the next subsection.

10.3 Spatial Spillovers

The displaced who leave a treated municipality do not vanish, and the gatos of Section 2.1 who recruit for distant worksites cross municipal borders in the other direction. Both movements threaten the comparison behind equation (2), since the municipalities that serve as controls may be treated by their neighbors' shocks, and a difference in differences between a treated place and a partially treated neighbor mixes the two effects. The concern is standard in designs that compare regional markets, and Adao et al. (2019) formalize it, showing that with spatial links the outcome of a location depends on the entire geography of shocks and not only on its own, so the stable unit treatment value assumption behind a local comparison fails. Their prescription is to put the remote shocks in the regression, and we implement its reduced form by adding to equation (2) each AMC's exposure to the surrounding market,

$$\bar{A}^{c}_{-j} \;=\; \sum_{k \neq j} \omega_{jk}\, A^{c}_{k}, \qquad \omega_{jk} \;=\; \frac{d_{jk}^{-\delta}}{\sum_{l \neq j} d_{jl}^{-\delta}}, \qquad c \in \{soy,\, maize\}, \tag{6}$$

the average of the other AMCs' suitability differentials weighted by distance d_{jk}, interacted with the post period, for decay rates $\delta \in \{1, 3\}$ running from a broad regional average to a tighter neighborhood (Appendix Table F.14).

With the neighbors' exposure added, the own effects keep their signs everywhere, hold or grow in magnitude, and stay significant in seven of the eight estimates, with the maize effect on workers at the tight decay losing precision. The growth is what partially treated controls produce, since their exposure pulled the baseline comparison toward zero, and holding the surroundings fixed removes a bias against the estimates rather than revealing one in them. The neighbor terms are zero for soy at both decays. The neighborhood's maize exposure enters positive for operations, significant at the broad decay and marginally at the

tight one, the mirror of the own-maize effect, so slavery falls where maize expanded relative to its surroundings.[38] The comparison behind equation (2) survives with the surroundings held fixed, and we find no evidence that the shocks of neighboring markets, rather than the municipality's own, produce the slavery response.

10.4 Scale in the Coercion Sector

The concentration of the response in cattle ranching invites a reading that runs through the sector rather than through its workers, scale. Maize expansion pulls land out of pasture and thins the herd (Table F.1), so its negative effect inside cattle ranching could be the sector contracting around the coercion rather than the pool draining, and the soy side could in principle reflect a sector growing and drawing more inspections. Table F.16 closes this reading. Conditioning the sector's slavery on the sector's own contemporaneous scale, the herd and the pasture area, leaves the estimates essentially unchanged, with the asinh of operations moving from 0.026 to 0.027 per log point of the soy differential, of enslaved workers from 0.060 to 0.063, and the maize side equally stable. A response that ran through the sector's size would be absorbed by the sector's size. On the soy side there is also no expansion to do the work, since neither the herd nor pasture responds to the soy differential in Table F.1.

10.5 Robustness

We close the section with the standard checks, each aimed at a different way the estimates could mislead. Against the concern that the results ride on our choice of controls, the baseline characteristics interacted with year appear next to every main estimate and moderate the soy coefficients without touching their significance (Table 4), and the event studies drawn again with the controls, or with a trend in the 1991 rural share, lie on top of the baseline path (Appendix Figure G.15). The concern that a single region drives everything, natural when the frontier states concentrate both the treatments and the outcomes, has an equally direct answer. Re-estimating equation (2) twenty-seven times, dropping one state at a time, leaves the four coefficients close to their full-sample values in every sample, with the soy effects at the one percent level throughout, including when Pará or Mato Grosso is excluded (Appendix Figure G.16). Dropping one year of the panel at a time, or the 2007 and 2008 peak of inspection activity together, does the same, with the four coefficients stable and significant in every sample (Appendix Figure G.17).

[38] Part of the broad-decay term may also absorb a common regional trend. The own effects hold at both decay rates, so the conclusion does not rest on that term.

Inference raises its own concern, since suitability is spatially correlated, nearby municipalities do not provide independent information, and conventional standard errors could overstate precision. The conclusions survive clustering by micro-region and Conley corrections at cutoffs from 50 to 150 kilometers (Appendix Table F.4). The permutation test asks the starker question, how likely estimates like ours would be if the data were only noise. Reassigning the two differentials across municipalities at random and re-estimating the model on each draw, the placebo distribution almost never produces coefficients the size of the true ones, which sit far in its tail (Appendix Figure G.9). Reassigning one differential at a time while the other keeps its true values gives the same answer, with the true coefficient of the reshuffled treatment outside the entire placebo distribution in every case, permutation p at or below 0.001 (Appendix Figure G.10), so the residual variation of each treatment holds a signal of its own despite the correlation between the two. The results are not a lucky arrangement of the data. The response also appears on the intensive and the extensive margin alike, in enslaved workers and in the probability that any slavery is found (Appendix Table F.10, Appendix Figures G.13 and G.14). Nor do the conclusions rest on the inverse hyperbolic sine, whose treatment effects Chen and Roth (2024) show depend on the units of outcomes that can be zero. Re-estimated in levels on the raw counts, the estimates tell the same story, slavery rising with the labor-saving differential and falling with the labor-intensive one (Appendix Table F.7). And the one frontier shock with the same timing and geography as ours, the closing of the mahogany market (Chimeli and Soares, 2017), which Araujo et al. (2024) link to forced labor of its own in the extraction areas, does not explain them, since controlling for exposure to its three policy windows leaves the soy effects intact (Appendix Table F.3).

11 Conclusion

For most of the century and a half since Brazil abolished slavery, the working expectation of economists and policymakers has been that development would finish what the law began (Bales, 1999). This paper measures whether it does, using the arrival of two technologies of the same green revolution, genetically engineered soy and maize double-cropping, productivity gains that spread over the same frontier in the same years with opposite needs for labor, linked to the universe of anti-slavery enforcement between 1995 and 2013. Progress turns out to have no single effect on coercion. Modern slavery rose where technology saved labor and fell where technology demanded it, each response on its own technology's calendar.

The two shocks reached coercion through the workers they displaced. The soy package cut the employment of the workers slavery draws on, young men with little schooling in

manual farm work, by far more than it cut average employment, and the maize expansion did the reverse. Slavery then moved where those workers are hired, in cattle ranching, and not in the crops that adopted the technologies. The estimates survive being read as reporting rather than prevalence, as migration rather than displacement, as the market power of employers rather than the desperation of workers, and as the neighbors' shocks rather than the municipality's own.

The census records both sides of the market moving as the model predicts, the employment and the outside wages of at-risk workers falling together where soy spread while the coercion sector's own wage rose, and the whole pattern reversing under maize. And the two directions are not symmetric, with coercion expanding faster than it recedes, so the shock that builds it appears to leave more behind than an equal shock removes.

Where displacement lands also decides what it becomes. Municipalities where the coercion sector's land was concentrated show no response, while the dispersed half carries more than twice the pooled effect, employers with market power absorbing the same displaced workers through the wage that coercion would otherwise avoid. Municipalities that entered the period with worse outside options respond about twice as strongly. The same shock, received by different markets, becomes slavery only where the coercion sector's land was dispersed.

The slavery in our data grew where displacement made workers abundant and fell where new demand made them scarce. In the model, abundance moves two prices at once, the outside options that make the deceptive offer attractive and the cost of recruiting and replacing the coerced, and which falls faster is an empirical question. The data identify the winner of that race rather than its two speeds. The coercion rate rose, the posted wage diverged, and the response was convex, the combination the model delivers only when the cost falls faster, and coercion rose faster than the pool itself. The lesson is not that technology endangers the vulnerable, but that the technology's own demand for labor decides when it does. In our setting, the labor-demanding half of the green revolution reduced slavery with no change in enforcement.

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Online Appendix to "Technological Displacement and Modern Slavery: Evidence From Local Labor Markets"

Daniel Araujo* Yuri Barreto† Gil do Vigor‡

September 4, 2026

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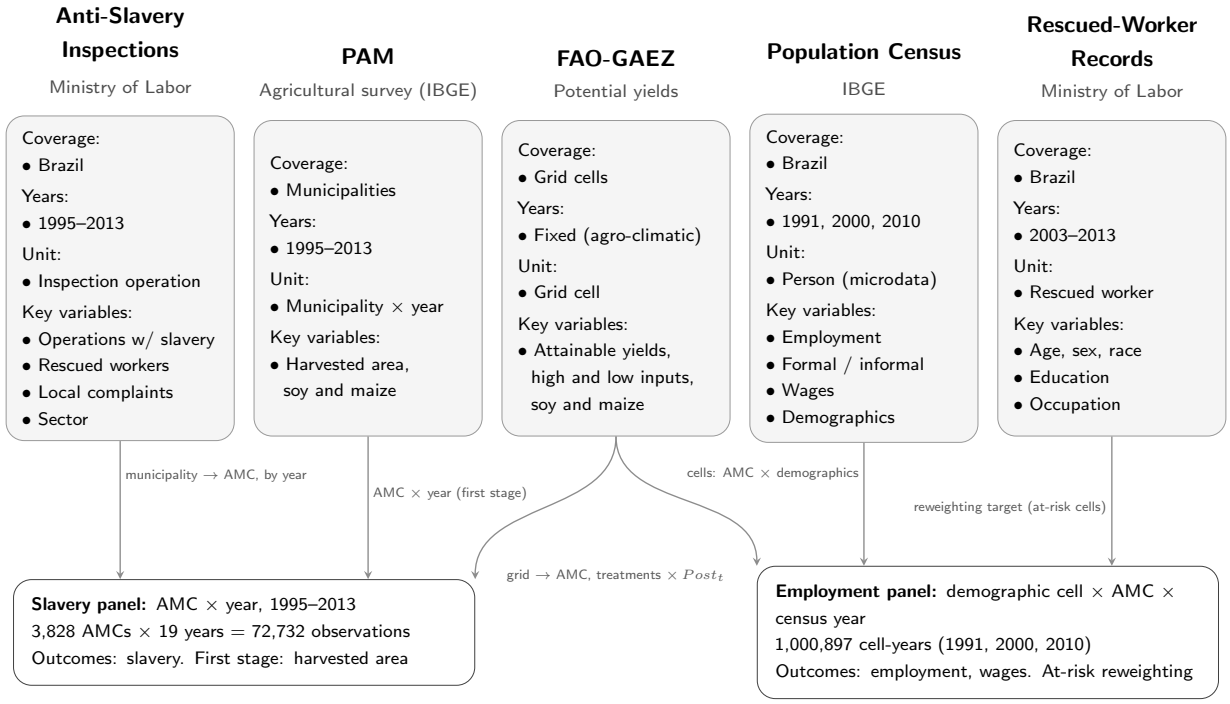
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A Data Appendix

Figure A.1: Data Linkages for the Main Analysis



Notes: The figure presents the coverage, unit, and key variables of the five data sources merged in the paper and the two estimation panels they form. Arrows indicate each merge and its key. PAM is the Produção Agrícola Municipal, IBGE's annual municipal survey of agricultural production. Its arrow points to the slavery panel because harvested area enters as the first-stage outcome on the same AMC-by-year frame. Auxiliary sources described in this appendix but not drawn: RAIS (formal employment by sector), the Agricultural Census (establishment sizes), and the 1991 Census baseline characteristics used as controls in every specification.

A.1 Outcome Definitions

Operations with Detected Slavery (asinh): The inverse hyperbolic sine transformation of the number of labor inspection operations in a municipality-year that resulted in the identification of modern slavery. This transformation accommodates the highly skewed distribution of the count variable while preserving zeros. *Source*: Brazilian Ministry of Labor.

Rescued Workers (asinh): Inverse hyperbolic sine of the annual number of individuals rescued from conditions of modern slavery, as documented by the Ministry's inspection operations in each municipality-year. *Source*: Brazilian Ministry of Labor.

Pr(Any Slavery): Dummy variable equal to one if at least one inspection in a municipality-year resulted in the discovery of modern slavery, and zero otherwise. *Source*: Brazilian Ministry of Labor.

Local Complaints (asinh): Inverse hyperbolic sine transformation of the count of local complaints (denúncias) that initiated labor inspections in a given municipality-year. *Source*: Brazilian Ministry of Labor.

Share of Operations Finding Modern Slavery: The proportion of labor inspections in a municipality-year that resulted in the identification of modern slavery cases, set to zero in municipality-years with no inspection. *Source*: Brazilian Ministry of Labor.

A.2 Treatment Definitions

Labor-Saving Technology (Soy): Municipality-level measure of the productivity gain from genetically engineered soy, constructed as the log difference between the FAO-GAEZ attainable yields for soy under high- and low-input conditions, following the methodology in Bustos et al. (2020). In the specifications the differential is interacted with the post period, equal to one from 2003 on, the first year of legal commercial use. *Source*: FAO Global Agro-Ecological Zones (GAEZ) project.

Labor-Intensive Technology (Maize): Productivity gain from maize double-cropping, defined in the same way, as the log difference between attainable maize yields under high- and low-input conditions, interacted with the same post period. The two treatments enter the specifications jointly. *Source*: FAO-GAEZ.

A.3 Controls and Baseline Characteristics

Log Income Per Capita (1991): Natural logarithm of municipality per capita income in 1991. *Source*: 1991 Brazilian Census.

Log Population Density (1991): Logarithm of the population per square kilometer in each

municipality in 1991. *Source*: 1991 Brazilian Census.

Share Rural (1991): Share of a municipality's population living in rural areas in 1991. *Source*: 1991 Brazilian Census.

Share with at Most Four Years of Schooling (1991): Share of adults aged 18 and older with four or fewer years of completed schooling, computed from the census microdata and pooled within the AMC. *Source*: 1991 Brazilian Census microdata.

Share with Nine or More Years of Schooling (1991): Share of adults aged 18 and older with nine or more years of completed schooling, computed the same way. *Source*: 1991 Brazilian Census microdata.

The heterogeneity analysis of Section 9.2 splits municipalities by the following 1991 baseline characteristics.

Literacy Rate (1991): Share of the population aged 5 and older identified as literate, from the published municipal tabulation. *Source*: 1991 Brazilian Census.

Formal Employment Share (1991): Proportion of the municipal population with formal employment contracts as reported in 1991. *Source*: 1991 Brazilian Census.

Unemployment Rate (1991): Share of the labor force that was unemployed in 1991. *Source*: 1991 Brazilian Census.

No Education Share (1991): Proportion of the population with no formal schooling. *Source*: 1991 Brazilian Census.

High School or More (1991): Share of the population that completed at least high school education. *Source*: 1991 Brazilian Census.

Years of Schooling (1991): Average years of formal education among the population in 1991. *Source*: 1991 Brazilian Census.

Formality and Informality Counts (1991, 2000, 2010): Total number of formal and informal

jobs in the AMC as reported in the respective Census year, transformed using the inverse hyperbolic sine. *Source*: Brazilian Population Census (1991, 2000, 2010).

Establishment Size (hectares): Number of agricultural establishments in the AMC by land size category (0–1, 1–2, 2–5, 5–10, 10–20, 20–50, 50–100, >100 hectares). *Source*: Brazilian Agricultural Census (1996, 2006, 2017).

A.4 Census Cell-Level Employment Panel and the At-Risk Reweighting

The employment analysis of Section 6 runs on a demographic-cell panel built from the census microdata of 2000 and 2010, counting the workers who worked for pay as employees in the reference week, with or without a signed card, and leaving the self-employed, employers, unpaid workers, apprentices, and the statutory public servants of the 2010 questionnaire outside every count. A cell interacts sex, four age bands within the 16 to 55 sample (16–24, 25–34, 35–44, and 45–55), five education levels (illiterate, up to fifth grade, middle school, high school, and college), and race, collapsed to White and non-White, within an AMC. Following Section 4.3, the sample holds workers aged 16 to 55 who worked for pay in the census reference week, and each cell counts the sampled workers of that type, split into formal and informal by the signed work card (carteira assinada). The result is a panel of more than half a million cell-years, each split into formal and informal employment, across 3,828 AMCs.

The reweighting targets the composition of the rescued. From the individual records of rescued workers for 2003–2013, pooled under the assumption that the demographic composition of forced labor is stable over the period, we count rescues in each sex-by-age-by-education cell and define s_c as that cell's share of all rescued workers. Race is recorded for only about a third of the records, so we leave it out of the weights, which keeps every record in the count. Building the weights with race instead, on the third of the records that report it, gives the same pattern with slightly smaller magnitudes, the at-risk employees response at -0.11 and $+0.13$ against the baseline -0.13 and $+0.15$ (Table F.2). The weighted columns of Table 3 estimate the cell-level regression by weighted least squares with weights s_c, so each cell counts in proportion to its share of the rescued and cell types never observed among the rescued receive zero weight. The mean weight is 0.020. The at-risk counts behind the rate denominators of Section 7.2 use the same weights, cell employment multiplied by s_c and summed within the AMC, fixed at their 2000 census values.

The composition the weights select, and how concentrated they are, can be read from the composition figure of the main text and two exhibits here. Figure 4 sets the composition of the workforce against that of the rescued along each dimension of the cell definition, and the direction of the reweighting is visible in every panel, toward men, toward the young, and toward the bottom of the schooling distribution. Table A.1 lists the ten largest cells, all of them men with at most middle school, which together hold 85 percent of the weight. The largest single cell, men aged 25 to 34 with at most fifth-grade schooling, holds 14 percent on its own. Figure A.2 plots the full distribution over the 49 cell types observed among the rescued, out of 60 possible, from a spike of single-rescue cells on the left to the handful that dominate on the right. The inverse of the sum of squared weights puts the effective number of cells at about twelve. The eleven cell types never observed among the rescued are the profile's complement, since eight of them are female cells and five are college cells, and several are nearly empty in the census itself, pairing minors with schooling they could not yet have completed.

Table A.1: The Ten Largest Reweighting Cells

Sex	**Age**	**Education**	**Weight s_c**	**Cumulative**
Male	25–34	Up to 5th grade	0.143	0.143
Male	16–24	Up to 5th grade	0.113	0.256
Male	25–34	Illiterate	0.105	0.360
Male	16–24	Middle school	0.090	0.451
Male	35–44	Up to 5th grade	0.082	0.533
Male	35–44	Illiterate	0.081	0.614
Male	16–24	Illiterate	0.071	0.686
Male	25–34	Middle school	0.057	0.743
Male	45–55	Illiterate	0.054	0.797
Male	45–55	Up to 5th grade	0.049	0.846

Notes: Cell types with the largest shares of rescued workers, 2003–2013, over sex, age, and education, on all rescue records. The weight s_c is the cell type's share of all rescued workers. The last column cumulates down the table.

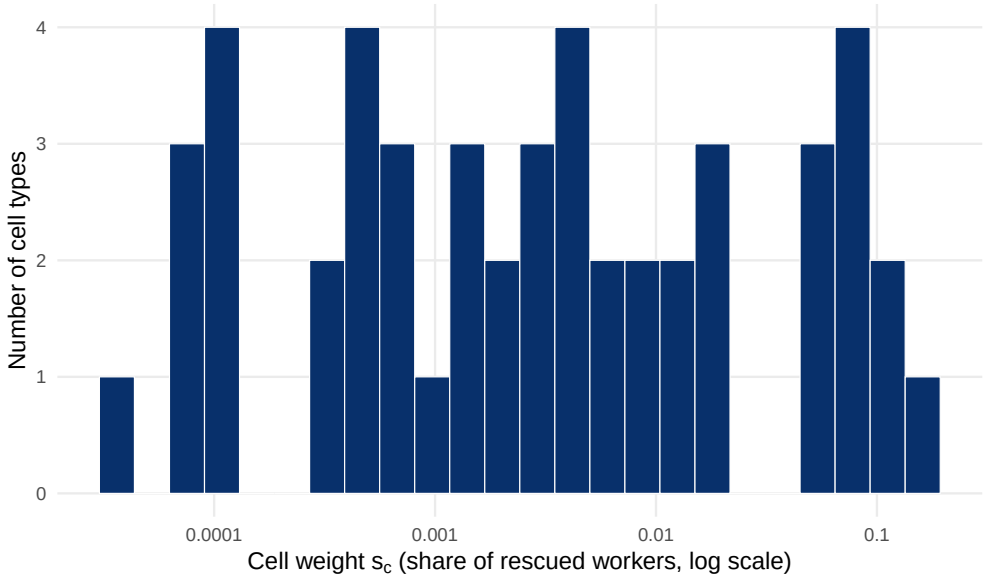


Figure A.2: Distribution of the Reweighting Cell Weights

Notes: The 90 cell types observed among the rescued, of 120 possible. The horizontal axis is on a log scale. The spike on the left collects cells with a single rescued worker.

A.5 Descriptive Statistics

Table A.2: Descriptive Statistics

	Mean	SD	Min	Max	N
Panel A: Slavery panel (AMC × year, 1995–2013)					
Operations w/ detected slavery	0.025	0.363	0	30	72,732
Enslaved workers	0.650	12.465	0	1,195	72,732
Inspection operations	0.052	0.678	0	57	72,732
Pr(Any slavery)	0.012	0.108	0	1	72,732
Labor-saving differential (A^{soy})	1.872	0.551	−3.284	4.937	72,732
Labor-intensive differential (A^{maize})	1.329	0.459	−4.521	4.310	72,732
Rural population share, 1991	0.451	0.227	0	0.978	72,732
Log income per capita, 1991	10.982	0.469	9.462	13.127	72,732
Log population density, 1991	−1.314	1.305	−7.012	4.795	72,732
Literacy rate, 1991	0.657	0.175	0.131	0.965	72,732
Share with ≤4 years of schooling, 1991	0.741	0.112	0.283	0.967	72,732
Share with ≥9 years of schooling, 1991	0.121	0.062	0	0.533	72,732
Panel B: Census demographic-cell panel (AMC × cell, 2000/2010)					
Employees	17.5	92.1	0	14,239	546,716
Employees with a signed card	10.6	66.9	0	10,131	546,716
Employees without a signed card	6.8	28.5	0	4,108	546,716
At-risk weight s_c	0.0108	0.0206	0	0.1125	546,716

Notes: Panel A reports summary statistics for the AMC-by-year slavery panel (3,828 AMCs, 1995–2013). Operations with detected slavery and rescued workers are the two main outcomes (asinh-transformed in the regressions). The labor-saving (soy) and labor-intensive (maize) differentials are the log difference of FAO-GAEZ attainable yields of equation (1). Panel B reports the census demographic-cell panel (age band × education × sex × race × AMC) for the 2000 and 2010 census waves, counting workers aged 16 to 55 who worked for pay as employees in the reference week. The reweighting weight s_c matches the demographic composition of rescued workers.

B Case Evidence from Inspection Reports

The model of Section 3 rests on premises about how coercion operates, deception at the moment of recruitment, confinement that prices the exit, and recruitment itself as a service with a price. This appendix documents those premises in the primary records of enforcement, the operation reports of the Special Mobile Inspection Group. We first narrate a single operation from complaint to rescue, then collect excerpts across operations for each premise in turn, and close with the photographic record. Quotations are our translations. The Portuguese originals, with obvious errors of the scanned transcription corrected, appear in footnotes, and a passage quoted only in a footnote appears there in translation followed by the original. Operation numbers restart within each mobile team, so the same number can name different operations in the same year, and citations therefore carry the establishment along with the number.

B.1 The Anatomy of a Case

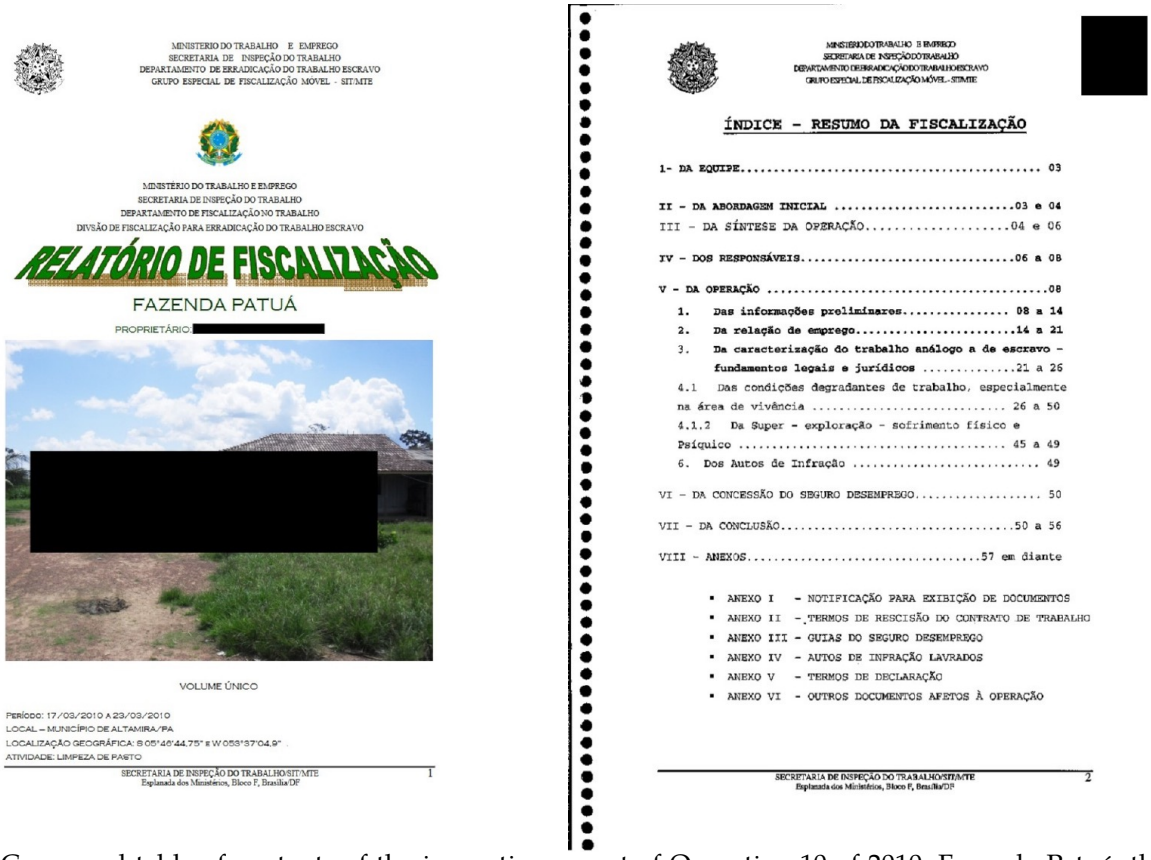
Operation 10 of 2010 reached Fazenda Patuá, a cattle ranch in São Félix do Xingu, in southern Pará, because one worker escaped from it, and ended two days later with the case ruled founded under Article 149 and seven workers rescued. The complaint that set it off, which the operation report transcribes, contains the crime whole:

> …the gato kept all the documents of the complainant and of the other workers… they lived in shacks of tarp and zinc at the far post of the ranch. The food was only rice and beans, from time to time game meat. The water came from the river… they never received a cent… and they still had to pay the bill at the canteen. And it was said that no one would be let out before paying his debt. And he himself was owing more than 2,000 reais… they were watched the whole time by capangas, who went armed for all the world to see… a month before he managed to flee, two companions left, and there was no more news of them. The complainant left at night, walked to the village of Taboca, and from there rode a lift to São Félix do Xingu.[1]

[1] "…que o gato ficou com todos os documentos do denunciante e dos demais trabalhadores… que moravam em barracos de lona e zinco, no retiro da fazenda. A comida era só arroz e feijão. De vez em quando carne de caça. A água era do rio… que nunca receberam nem um centavo… e que eles tinham ainda pagar a conta na cantina. E que foi falado, que não deixaram ninguém sair enquanto não pagar a dívida. E que ele era devendo mais do que 2.000 R$… que eles ficaram o tempo todo vigiados por capangas, que andaram armados para todo mundo ver… que um mês antes que ele conseguiu fugir, saíram dois colegas, mas não era mais retorno. E o denunciante saiu à noite, andou a pé até na vila Taboca, de onde ele veio de carona até São

The elements the model works with are all in this account before any inspector has seen the farm. The retained documents and the canteen debt are the price of leaving, and the armed watch raises it. The promise that no one leaves before the debt is paid converts wages owed into a lock, and the only exit that remains is the one the complainant took, at night, on foot, leaving the balance behind.

Figure B.1: The Report of Operation 10 of 2010



MINISTERIO DO TRABALHO E EMPREGO
SECRETARIA DE INSPEÇÃO DO TRABALHO
DEPARTAMENTO DE ERRADICAÇÃO DO TRABALHO ESCRAVO
GRUPO ESPECIAL DE FISCALIZAÇÃO MOVEL - SIT/MTE

MINISTÉRIO DO TRABALHO E EMPREGO
SECRETARIA DE INSPEÇÃO DO TRABALHO
DEPARTAMENTO DE FISCALIZAÇÃO NO TRABALHO
DIVSÃO DE FISCALIZAÇÃO PARA ERRADICAÇÃO DO TRABALHO ESCRAVO

RELATÓRIO DE FISCALIZAÇÃO

FAZENDA PATUÁ

PROPRIETÁRIO: [redacted]

VOLUME ÚNICO

PERÍODO: 17/03/2010 A 23/03/2010
LOCAL – MUNICÍPIO DE ALTAMIRA/PA
LOCALIZAÇÃO GEOGRÁFICA: S 05°46'44.75" E W 053°57'04.9"
ATIVIDADE: LIMPEZA DE PASTO

SECRETARIA DE INSPEÇÃO DO TRABALHO/SIT/MTE 1
Esplanada dos Ministérios, Bloco F, Brasília/DF

MINISTÉRIO DO TRABALHO E EMPREGO
SECRETARIA DE INSPEÇÃO DO TRABALHO
DEPARTAMENTO DE ERRADICAÇÃO DO TRABALHO ESCRAVO
GRUPO ESPECIAL DE FISCALIZAÇÃO MÓVEL - SIT/MTE

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SECRETARIA DE INSPEÇÃO DO TRABALHO/SIT/MTE 2
Esplanada dos Ministérios, Bloco F, Brasília/DF

Notes: Cover and table of contents of the inspection report of Operation 10 of 2010, Fazenda Patuá, the operation this subsection narrates. The report runs to 56 pages, from the team, the complaint, and the identification of those responsible, through the finding of work analogous to slavery, to the annexes with the rescued workers' records. The black bars cover names of individuals. *Source*: GEFM inspection reports.

The team that flew out of São Félix do Xingu on March 17, 2010 combined labor inspectors of the Ministry of Labor, a prosecutor of the Labor Prosecution Service, and federal police officers, with air support from two IBAMA helicopters. The complainant, located in Xinguara, rode along to guide it. Landing at the farm's headquarters after a 240-kilometer

Félix do Xingu." Operation report 10/2010, GEFM. The report preserves the complainant's spoken register.

flight, the inspectors searched the main house, an adjacent shed, and the pasture-clearing fronts, and could not confirm they had the right property. Only the owner's first name matched the complaint, the eleven workers interviewed that afternoon corroborated none of its circumstances, and the one element that did match, a tarp shelter at a distant work front "with proof that the environment sheltered, precariously, workers," was not one the complainant could place, so the team returned to base unable yet to tie the property to the complaint.[2]

The next morning decided the case, and not through anything the team found so much as through what the farm did overnight. An overflight of the surrounding coordinates turned up no other candidate property, so the helicopters put down at Patuá a second time. A small plane had just landed with provisions, chartered, according to the farm's own manager, to carry the remaining workers back to town on the owner's orders, "owing to the fright of the previous day's visit."[3] The tarp shelter inspected the day before had been torn down by the employer during the night, three workers had been ordered to flee on foot to a neighboring ranch some forty kilometers away, and the owner, arriving at the farm, went into the forest and did not identify himself to the team for the rest of the operation.[4]

What remained on the ground confirmed the complaint's substance, and its coercive core before anything else. Eleven workers were clearing pasture regrowth, the roço de juquira, on piece rates set by labor contractors, nine hours a day, Monday to Saturday, and none had been paid. Among the complaints they listed in deposition is the absence of "any prospect of receiving payment for the work done."[5] Purchases of food and clothing accumulated against those unpaid wages in the employer's accounts, and the report leaves no doubt about what that arrangement is, writing that the practice "configures forced labor when the employer, using threat, keeps the employees on his property, and sells

[2] "De resto, foi localizado numa frente de trabalho a existência de um barraco de lona, com prova de que o ambiente abrigava, de forma precária, trabalhadores." The report adds that the team returned "for a very simple reason: the complainant could not recall the precise location of the work front where he had labored" ("por uma razão muito simples: o denunciante não conseguiu se recordar da precisa localização da frente de trabalho onde laborara").

[3] "…havia um pequeno avião, que acabara de pousar na fazenda, trazendo mantimentos, cujo frete, segundo se apurou, tinha em vista retornar com os trabalhadores para a cidade de São Félix do Xingu, a mando do proprietário, consoante declaração do preposto dele, o vaqueiro/gerente, face ao susto que passara com a visita do dia anterior."

[4] "Constatou-se de plano, que o barracão de lona, visitado no dia anterior, 17 de março, havia sido destruído pelo empregador. […] o empregador determinou que três trabalhadores fugissem para a fazenda vizinha, distando em torno de uns 40 km da fazenda Patuá. O proprietário da fazenda, ao chegar na fazenda, imediatamente evadiu-se, escondendo-se no meio do mato e, desde então, até o final da operação, não se identificou perante a equipe."

[5] "sentem falta de perspectiva de recebimento pelo trabalho realizado."

them products at elevated prices. The employees, in view of the high values, never manage to settle their debts, and are impeded from leaving the properties."[6] The legal analysis concludes in the same terms, that the facts fall plainly under the legal type of Article 149 of the Penal Code, debt servitude.[7] Nothing turns on whether such a debt is genuine. Here it was of the employer's own making, run up at his store at his prices against wages he withheld, and the law does not ask, since Article 149 makes it a crime to restrict a worker's movement by reason of debt owed to the employer, whatever the debt's origin.[8]

Around that coercive core the report catalogs the degradation in which the men lived and worked. None of the eleven had a signed work card, and the workers declared that "the employer never requested any document for the purpose of registering the employment contract."[9] The manual workers slept in two shelters the inspectors liken to *taperas*, abandoned ruins, one a plastic tarp without walls and the other a wooden depot without doors, with no sanitary installation of any kind.[10] They bathed and drew water in the igarapé, stored it in containers set directly on the ground, and cooked rice, beans, beef, and manioc flour on a stove improvised from bricks and an iron bar, eating seated on the ground. The report notes that only the cowhands and their wives received "more dignified treatment." In deposition the workers listed pains in the head, back, legs, feet, and hands, hunger before and after lunch, and the walk into the brush in the dark and under rain for want of a latrine, so that "the body wakes aching after a badly slept night."[11]

The inspectors close the report in their own voice rather than in the language of infractions. "Perhaps we have not yet been reached by the natural indignation of knowing that there are Brazilians, workers, who live in shacks without the least condition of hygiene,

[6] "A prática do *truck system* configura trabalho forçado quando o empregador, usando de ameaça, mantém os empregados em sua propriedade, e lhes vende produtos (alimentos e vestuário) por preços elevados. Os empregados, tendo em vista os altos valores, jamais conseguem saldar suas dívidas, sendo impedidos de deixar as propriedades."

[7] "Restou nitidamente evidenciada a subjacência dos fatos ao tipo legal do art. 149 do CPB, a servidão por dívida."

[8] Article 149 of the Penal Code reaches whoever reduces a person to a condition analogous to slavery "quer restringindo, por qualquer meio, sua locomoção em razão de dívida contraída com o empregador ou preposto."

[9] "Declararam que o empregador jamais solicitou qualquer documento para fins de registro do contrato de emprego."

[10] "Os demais trabalhadores braçais, roçadores de pasto, foram encontrados residindo em dois abrigos, assemelhados a taperas (um consistia em um barraco de lona plástica sem paredes e o outro era um depósito de madeira sem portas), desprovidos de qualquer infraestrutura, especialmente qualquer tipo de instalação sanitária."

[11] "Que como não há banheiro os depoentes quando sentem vontade de fazer necessidades fisiológicas, têm que sair do barraco no escuro, debaixo de chuva; [...] os recipientes que acondicionam a água ficam depositados diretamente no chão; [...] o corpo amanhece todo doído após a noite mal dormida."

deprived of basic sanitary installations, drinking water unfit for human consumption," they write, and they answer the objection they have evidently heard before, that such men would live no better at home: "that is the discourse of backwardness, and of those who wish this reality maintained."[12] The report separates the eleven into the pasture crew housed in the two shelters and the cowhands quartered by the main house, and the rescue reached the crew of the shelters. The operation ended with seven workers rescued, two of them women, terminations paid on the spot, ten infraction notices, and the conclusion "that work analogous to slavery was practiced, a crime provided for in Article 149 of the Penal Code, by submission of workers to degrading working conditions and by debt servitude."[13]

B.2 Deception at Recruitment

In the model no posted offer separates a coercive farm from a legitimate one, and the reports show why the distinction cannot easily be read off the promise. Workers found on a coffee farm in Minas Gerais (Operation 93 of 2009) had been recruited by a gato who promised a wage for the harvest that the piece rate they found on arrival could not produce.[14] On the farm of Operation 39 of 2009, hands promised a daily wage had received, over years, nothing at all. The promised values, the report concludes, "were nothing but a lure."[15] At Fazenda Scala II (Operation 37 of 2012, Tocantins) the pay the workers believed

[12] "Talvez ainda não tenhamos sido alcançados pela natural indignação de saber que existem brasileiros, trabalhadores, que vivem em barracos sem a menor condição de higiene; desprovidos de instalações sanitárias básicas, ingerindo água imprópria para o consumo humano. E nem se argumente que, em seus lares, a vida deixaria de lhes reservar melhores condições. Este é o discurso do atraso e de quem deseja a manutenção desta realidade."

[13] "…conclui-se pela prática do trabalho análogo ao de escravo, crime previsto no artigo 149 do Código Penal, por submissão de trabalhador a condições de trabalho degradante e por servidão por dívida."

[14] "They stated that they come from the municipalities of Pedreiras and Timbiras, in the state of Maranhão, where they were recruited by the 'gato', who had promised them that they would manage to earn a wage of R$ 1,800.00 to R$ 2,000.00 during the coffee harvest." ("Informaram que são oriundos dos municípios de Pedreiras e Timbiras, no estado do Maranhão, onde foram arregimentados pelo 'gato', que havia lhes prometido que conseguiriam receber salário de R$ 1.800,00 a R$ 2.000,00 durante a safra do café.") The same interviews record the arithmetic of the deception, "Although they had not yet been paid, they had already realized that the amount paid per sack harvested would never be enough to reach the promised pay, all the more with the deductions being announced, tools, protective equipment, tickets, and food." ("Que embora ainda não tivessem recebido salário, já haviam percebido que o valor pago por saca colhida jamais seria suficiente para que obtivessem a remuneração prometida, ainda mais com todos os descontos que estavam sendo anunciados (ferramentas, EPIs, passagens, alimentação).") Operation report 93/2009.

[15] "For the services rendered there was a promise of payment of amounts varying from R$ 12.00 to R$ 20.00 per day of work. As the interviews established, such amounts, however, were nothing but a lure, since in fact they never received any of the promised money." ("Pelos serviços prestados havia promessa de pagamento de valores variáveis de R$ 12,00 a R$ 20,00 por dia de trabalho. Como se comprovou no decorrer das entrevistas, tais valores, contudo, não passavam de engodo, pois, efetivamente, jamais receberam qualquer quantia do dinheiro prometido.") Operation report 39/2009.

they had accepted was consumed by deductions no one had disclosed, which the report characterizes as fraud in recruitment.[16]

A single deposition from Operation 85 of 2009, on a ranch in the Marabá region of Pará, contains the full sequence. The worker declared "that the work would be paid by the day, and that the day would be twenty reais; that after arrival at the farm it was said the work would be paid by the job; … that he has not yet received any amount in money; … that he does not return home because he has no money to pay the fare."[17] The promise recruited him, the revision arrived with him, and the fare he could not pay held him. Other reports revise other margins of the same offer. The gato of Operation 78 of 2009 took the workers' cards "promising to sign them" and never did, and had promised proper lodging to men who found a tarp shack.[18] The cane cutters of Operation 106 of 2010 had been promised decent housing and unemployment insurance after the harvest, neither of which existed.[19]

A promise of this kind costs nothing to make and nothing to break, which is the sense in which the model treats conduct as hidden at the offer stage.

B.3 Confinement and the Cost of Leaving

In the model a coerced worker can leave, at a price, and the reports document the instruments that set the price. The most common is debt. On the farm of Operation 18 of 2009 the indebtedness "often began before the worker reached the farm," since the gato advanced the transport and travel expenses against future wages, and the report names the practice by its function, "used to keep them captive, bound to the commitment of settling their debts."[20] At Fazenda Talismã (Operation 31 of 2010, São Félix do Xingu), a worker reported

[16] "The recruited workers believed they would receive a remuneration up to five times higher than that practiced in their region of origin, which proved untrue owing to the abusive deductions taken from their pay, thereby characterizing fraud in recruitment." ("Os trabalhadores aliciados acreditavam que iriam receber uma remuneração até cinco vezes maior do que a praticada em sua região de origem, fato que não se mostrou verdadeiro, em virtude dos descontos abusivos sofridos na remuneração, caracterizando, assim, a fraude no recrutamento.") Operation report 37/2012.

[17] "que o serviço seria pago na diária e que a diária seria de 20 (vinte) reais; que após a chegada na fazenda [foi dito] que o serviço seria pago por empreita; [...] ainda não recebeu qualquer quantia em dinheiro; [...] que não volta para casa porque não tem dinheiro para pagar a passagem." Operation report 85/2009.

[18] "que o 'gato' reteve sua CTPS, prometendo assiná-la, mas não cumpriu; que o 'gato' não disse ao depoente que iriam ficar em barraco de lona mas em alojamento." Operation report 78/2009.

[19] "Também foram iludidos, segundo depoimentos colhidos, pela promessa de recebimento de benefícios como moradia digna e recebimento do seguro-desemprego após o término da safra, o que de fato não ocorreu." Operation report 106/2010.

[20] "Este endividamento começava muitas vezes antes de o trabalhador chegar à fazenda, na medida em que o gato custeava o transporte até a fazenda e as despesas de viagem para posterior desconto dos salários. [...] Esta prática vil de endividamento dos trabalhadores é utilizada para mantê-los cativos, presos ao compromisso de saldar suas 'dívidas'." Operation report 18/2009.

that he was not allowed to go to town until the job was done, "and when this one ends, another begins," while two armed capangas watched the crew.[21]

Geography sets the price of leaving even where no one stands guard over it. At the farms of Operation 69 of 2010, in Buriticupu, Maranhão, the report reasons that wages paid months late, "allied to the geographic isolation of the property," sixty-five kilometers of dirt road from the nearest junction, "characterizes restriction of liberty" by itself.[22] An inspector writing in Operation 38 of 2012 states the rule in general form: "the worker who receives no wages, who is lodged in a place of difficult access and who has no transport at his disposal, will be irremediably imprisoned in the place where he finds himself."[23] The lock is sometimes literal. In Operation 128 of 2010, on the maintenance fronts of a railway concessionaire in São Paulo state, workers reported being locked inside the lodgings, from the outside, during the night, and one declared he had been quartered several times in containers at the work front. The camps sat in closed forest reachable only by the company's own trains, which workers could board only with express authorization, and a supervisor twice forbade the driver to stop for them, "as punishment."[24]

Violence appears at the margin where debt and distance do not suffice. Workers reached by Operation 14 of 1996, in the Xinguara region, reported that those who tried to flee were hunted "by armed men and dogs."[25] The complaint behind Operation 13 of 2010 described thirty-seven workers held under the armed watch of seven gunmen, one worker murdered.[26] And at Fazenda Brasil Verde (Operation 005 of 1997), later the subject of the Inter-American Court of Human Rights' first judgment on contemporary slavery, the only road out of the property passed directly by the manager's house, and a group of twelve

[21] "O informante cita ainda que não lhe é permitido vir à rua até terminar todo o serviço e que quando encerra este, começa-se outro. Ele e seus companheiros trabalhavam vigiados por dois capangas armados." Operation report 31/2010.

[22] "ficou constatado o atraso salarial, este pago de forma irregular, a cada dois meses, o que, aliado ao isolamento geográfico da propriedade (65 km do entroncamento rodoferroviário em Buriticupu/MA, em estrada de chão e curvas sinuosas), caracteriza cerceamento de liberdade." Operation report 69/2010.

[23] "o trabalhador que não recebe salários, que esteja alojado em local de difícil acesso e que não tenha transporte à sua disposição, estará irremediavelmente preso ao local onde se encontra." Operation report 38/2012.

[24] "alguns trabalhadores relatam que chegaram a ser trancados nos alojamentos, pelo lado de fora, no período noturno". "que o alojamento era trancado por fora, durante o período noturno; que o declarante, durante o período em que trabalhou, ficou acomodado, por diversas vezes em conteiners, na frente de trabalho". "[o supervisor] por mais de uma vez proibiu o maquinista da composição de fazer o transporte dos mesmos, tendo adotado tal postura como 'castigo' aos trabalhadores." Operation report 128/2010.

[25] "Vários trabalhadores denunciaram a perseguição por homens armados e cães àqueles que tentaram fugir." Operation report 14/1996.

[26] "[...] que estavam sob vigilância armada de sete pistoleiros e que um trabalhador tinha sido assassinado por um dos pistoleiros." Operation report 13/2010.

workers escaped anyway.[27] At a reforestation company in Tocantins the violence entered the record photographically. After the manager beat a worker, breaking ribs and cutting his head with pistol blows, and fired twice beside his body on the ground, the inspectors photographed the bullet marks in the walls and in the refrigerator of the lodging and seized four firearms at the farm, and a second worker confirmed the account (Operation 10 of 2010 at NEEN Agropecuária, a different operation from the Patuá case that shares its number, panels (b) and (c) of Figure B.3).[28]

The reports also record what happens to the worker whose attempt to leave is caught. A worker interviewed in Operation 66 of 2009 described an earlier farm where two armed men watched the crew, where he tried to leave and was stopped with threats, and from which he finally fled with three companions, walking some sixty kilometers to town, pursued by the farm's guaxebas.[29] The complaint that opened Operation 61 of 2010 came from a worker who fled the farm "so as not to be beaten by the gato."[30] And the instrument does not require a frontier. At a plywood factory in Amazonas (Operation 23 of 2011), whose workers were Chinese and could not speak Portuguese, employees were beaten "by pushes and blows with sticks" and had to ask permission to leave the premises at all, "under penalty of receiving very high fines or being assaulted."[31] Debt, distance, retained documents, and the threat of pursuit are the instruments the model collects into a single price of leaving.

[27] "The sheds found stand 8 km from the farm's headquarters, and any movement aimed at leaving the farm goes through the PA-150, the access necessarily by a road very close to the manager's house, the office, and the workshops. Despite all these obstacles, a group of 12 workers managed to flee." ("Os barracões encontrados ficam a 8 km da sede da fazenda e qualquer deslocamento que tenha como finalidade a saída da fazenda se dá através da PA-150, sendo o acesso necessariamente por estrada bem próxima à casa do gerente, escritório e oficinas. Apesar de todos esses empecilhos, um grupo de 12 trabalhadores conseguiu fugir.") Operation report 005/1997.

[28] "espancou o trabalhador [...]. Além de chutes nas costelas (com fraturas) e socos no rosto, ainda desferiu coronhadas de revólver na cabeça do obreiro, causando-lhe ferimento; [...] com o depoente ainda no chão, efetuou dois disparos, ao lado do corpo do depoente." Operation report 10/2010, NEEN Agropecuária e Florestadora, Araguacema, Tocantins.

[29] "que no local tinha 2 pessoas armadas vigiando os trabalhadores; que tentou sair do local, mas foi impedido [...] mediante ameaças; que [...] viu peões machucados pelo [gato]; que fugiu do local com outros 3 trabalhadores, andando cerca de 60 km até chegar na cidade; que foi perseguido pelas guaxebas." Operation report 66/2009.

[30] "Apuração de denúncia [...] noticiando a prática de trabalho degradante na fazenda Buriti, de onde fugiu o trabalhador denunciante para não ser espancado pelo gato." Operation report 61/2010.

[31] "comumente os empregados chineses eram agredidos [...], por meio de empurrões e pauladas". "eram obrigados a pedir autorização aos prepostos da empresa em quaisquer momentos em que necessitassem se ausentar das dependências da sede, sob pena de receberem altíssimas multas ou serem agredidos." Operation report 23/2011.

B.4 The Cost of Obtaining Workers

In the model displacement lowers the cost of obtaining a coerced worker, and the reports show that cost in two parts, the price of recruitment as a service and the ease with which the desperate accept an offer. The first part is quoted per head. In Operation 155 of 2009, sixteen men were delivered to a worksite in Rondônia by a recruiter who "charged the amount of R$350.00 per recruited worker, making a total of R$5,400.00 paid for the sixteen workers hired in that municipality."[32] In Operation 128 of 2010, in São Paulo state, the recruiter "would have received, according to the workers' declarations, the amount of R$50.00 for each recruited worker."[33] In these records a worker has a price, and it is the price of finding and moving him.

The second part of the cost is not paid to anyone, because desperation does the convincing on its own. The inspectors of Operation 14 of 2011, in Mato Grosso, explain why hiring on these terms is feasible at all, writing that the condition of these workers, "who in their great majority can only draw their own name, makes the hiring of this labor force viable, because, longing urgently for work, they submit to whoever offers them that opportunity, even in total submission to degrading conditions of work and life."[34] The report of Operation 03 of 1995 shows the market that collects them, beginning "at the descent from the bus at the town's station, where the worker is invited to lodge in one of the local boarding houses, until the gato appears to pay the bill and take the peão to the work front, from which he will never manage to settle the debt thus created."[35] At the extreme the desperate pay for their own recruitment. The cane cutters of Operation 74 of 2010 financed their own transport as an "investment" against wages that never came,[36] and the construction workers

[32] "foram aliciados no município de Canindé-SE, por uma pessoa que cobrou a importância de R$ 350,00 por trabalhador arregimentado, perfazendo um total de R$ 5.400,00 o montante pago pelos 16 (dezesseis) trabalhadores contratados naquele município." Operation report 155/2009. The report states both figures as quoted, though sixteen workers at R$ 350.00 would make R$ 5,600.00. The per-head price is the number the argument uses.

[33] "Parte dos trabalhadores foi aliciada na cidade de Santo Amaro da Purificação, no Estado da Bahia, por uma pessoa que, segundo declaram os trabalhadores, teria recebido o valor de R$ 50,00 por cada trabalhador recrutado." Operation report 128/2010.

[34] "O nível sócio-econômico desses trabalhadores, que, em sua grande maioria, apenas sabe desenhar o nome, viabiliza a contratação dessa mão de obra, porque, ansiando urgentemente por trabalho, sujeitam-se àqueles que lhes possibilitam essa oportunidade, mesmo em total submissão a condições degradantes de trabalho e de vida." Operation report 14/2011.

[35] "o aliciamento de mão-de-obra em toda a região inicia-se na descida do ônibus na rodoviária da cidade, onde o trabalhador é convidado a se hospedar em uma das pensões locais, até que o gato aparece para pagar a conta e levar o peão para a frente de trabalho, de onde jamais conseguirá saldar a dívida gerada." Operation report 03/1995.

[36] "These workers paid with their own money for the transport to the towns of Ipiaçu and Canápolis, since the recruiter would not do it. As the promise was that they would have good wages, the workers judged

of Operation 144 of 2013 paid the gato both for the transport and for the job itself, in a transaction on which, the report notes, "the survival of the employees depends entirely."[37] In Operation 155 of 2009 the recruiter collected from both sides, R$350 per head from the employer and R$350 from each worker for the journey, and one worker sold a bullock to pay it.[38] A worker in that position needs little convincing and less guarding, and the inspectors' conclusion quoted in Section 2, an endless contingent of the excluded willing to accept any occupation and under any circumstances, states the same fact as a rule.

The reports treat the replacement of workers as a routine as established as their recruitment. Inspectors in Operation 15 of 1996 dismantled the tarp shacks they found precisely because "new crews of workers would arrive" to reoccupy them.[39] Operation 05 of 2009 records "a large rotation of workers since the beginning of the works," every cohort lodged in the same zinc shed.[40] And the report of Operation 12 of 1998 lists the trade's standing procedures, constant rotation of crews across worksites, false names for gatos and workers alike, and imprecise directions to the properties, designed so that a complaint like the one that opens this appendix cannot find its way back.[41] What Section 2 records as a single price, the seventy dollars a recruiter spent to deliver a man, these reports show as a functioning market, with per-head rates, standing intermediaries, and replacement on schedule.

B.5 Photographic Record

Figure B.2 reproduces four photographs from the record of Operation 120 of 2010, at a ranching and sawmill property in Pará whose crews included twenty-four workers lodged in palm-covered shelters with earthen floors and no walls. The photographs show what the

the 'investment' worth it." ("estes trabalhadores pagaram com dinheiro próprio o transporte até as cidades de Ipiaçu e Canápolis, pois o aliciador não se dispôs a fazê-lo. Como a promessa era de que teriam bons salários, tais trabalhadores acharam que valeria a pena o 'investimento'.") Operation report 74/2010.

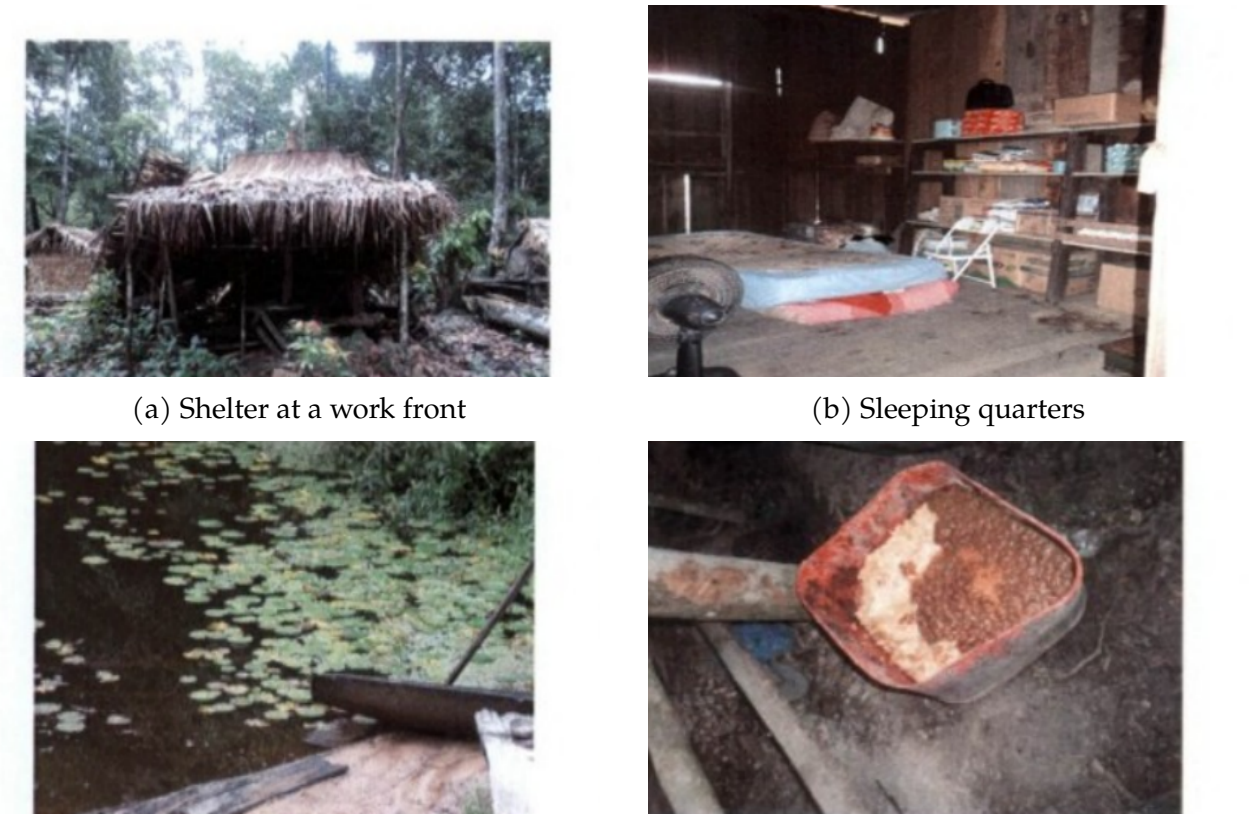
[37] "constata-se que a sobrevivência dos empregados depende inteiramente dessa transação que é feita com o aliciador, conhecido como 'gato', no jargão dos trabalhadores. [...] Todos os trabalhadores narraram pagamentos de transporte e da vaga para a qual se apresentaram." Operation report 144/2013.

[38] "cobrando dos trabalhadores a importância de R$ 350,00, sob promessas de bons salários", and, from one worker's deposition, "vendeu um garrote" to pay for the journey to Chapadão do Sul. Operation report 155/2009.

[39] "os barracos de lona plástica foram desativados, com a finalidade de não reaproveitá-los, já que chegariam novas turmas de trabalhadores." Operation report 15/1996.

[40] "A equipe de fiscalização apurou ainda que existia uma rotatividade grande de trabalhadores desde o início da obra, e que todos já haviam sido alojados no barracão de zinco ou nas casas inacabadas." Operation report 05/2009.

[41] "tanto os empregadores como os 'gatos' utilizam-se das seguintes práticas: a) mantêm constante rotatividade dos trabalhadores em relação aos locais de trabalho; b) não se relacionam entre si com os nomes verdadeiros; c) dificultam ou dão informações imprecisas quanto à localização das propriedades." Operation report 12/1998.



(a) Shelter at a work front

(b) Sleeping quarters

(c) Bathing and washing water

(d) Kitchen utensil

Figure B.2: The Photographic Record of an Inspection

Notes: Photographs reproduced from the public report of Operation 120/2010 (Special Mobile Inspection Group), a ranching and sawmill property in Pará. No identifiable face appears.

depositions elsewhere in this appendix describe, the shelter at a work front, the sleeping quarters where mattresses lay on the floor without bedding, the stream in which workers bathed, in which the report records stingrays and electric eels, and the state of the kitchen. All are reproduced from the public operation report, and no identifiable face appears in any of them. The camera documents half the crime. Debts live in the recruiter's account books, retained documents in a drawer at the headquarters, and the lock on a door works at night. What the photographs do show is the isolation those instruments exploit, forest on every side of a shelter that holds a crew's whole life, and the depositions quoted through this appendix supply the rest.

Figure B.3 adds what the record holds when the violence itself leaves marks. The first panel shows the injuries of a worker on a ranch in Pará who, accused by the employer of stealing two telephones and a perfume, was beaten, thrown to the ground, and hurt on the face, shoulder, and hip, and went on working with the bruises the inspectors



(a) Injuries of a beaten worker



(b) Bullet marks on the workers' refrigerator



(c) Firearms seized at the farm



(d) Untreated wounds

Figure B.3: The Photographic Record of Coercion

Notes: Photographs reproduced from the public reports of Operations 110/2011 (Pará), 10/2010 (Tocantins), and 39/2009 (Espírito Santo). No identifiable face appears in any panel.

photographed.[42] The second and third panels come from the reforestation farm of Operation 10 of 2010, where the shots fired beside a beaten worker left the holes the inspectors photographed in the lodging's refrigerator, and the firearms collected at the farm were laid out and recorded at seizure. The last panel is coercion by neglect, the leg of a worker at Fazenda Jerusalém, injured on the way to work and left, in the report's words, "to this day with the wounds infected, for want of assistance and medicine."[43] No face appears in any panel.

The enforcement system has also put the violence on film. *Precisão*, a documentary produced by the International Labour Organization and the Labour Prosecution Service

[42] "laborava com diversos hematomas e, segundo declaração do empregado, tais ferimentos foram causados pelo [empregador] sob a acusação de furto de dois celulares e um perfume." Operation report 110/2011.

[43] "relatou haver sofrido acidente quando ia de bicicleta para o trabalho e por falta de assistência e remédios até hoje tem as feridas infeccionadas." Operation report 39/2009.



(a) "Foram várias."



(b) "foi marcado com o ferro do gado."

Figure B.4: Branded with the Cattle Iron

Notes: Frames from *Precisão* (OIT/MPT, 2019), a documentary of testimonies of workers rescued from slave labor in Brazil, reproduced with attribution. The burned-in subtitles are the film's own. The frames show no eyes or full face.

from the testimony of six rescued workers, records a worker who was branded with the farm's cattle iron, across the torso and on the face. The marks are the curved bite of the branding iron, and the subtitle under the second frame reads "he was branded with the cattle iron."[44] Figure B.4 reproduces the two frames. Section 2 quotes the inspectors' essay on what distinguishes this slavery from the old. The branding iron is the older institution's clearest surviving mark, an instrument of property applied to a man the operation had to rescue rather than buy.

[44] *Precisão* (2019), produced by the International Labour Organization (OIT Brasil) and the Ministério Público do Trabalho, released on the National Day to Combat Slave Labor and distributed publicly with English and Spanish subtitles. Frames reproduced as scholarly quotation with attribution (Law 9.610/1998, Article 46, III). The worker gave his testimony publicly in the film. The frames show no eyes or full face.

C Equilibrium and Proofs

The pool is derived from an occupational choice made before the market opens (Section 3.2). A mass N of identical workers chooses between the safe sector, local non-coercive agriculture hiring at the primitive wage W_A, and the risky sector of Section 3.1. The safe sector posts a mass J of vacancies, at which the marginal product of a worker under the technology in place covers W_A, and fills them at random, so a worker who seeks safe work is hired with probability $q = J/N$ once every worker seeks it. Each worker's first choice is the safe sector whenever it hires, the hypothesis Lemma 1 carries, and the ranking $W_A > \bar{u}(L)$ that the rest of the appendix uses is what that choice reveals, derived in Lemma C.2 below rather than assumed, with no legal floor behind it.

Lemma 1 (The Rationed Pool)**.** *Let the safe sector be every worker's first choice, a strict preference, at every pool in the range under study and whenever the sector hires, $q > 0$, for seeking its job over standing where the recruiters' offers arrive and over staying out. Then in any equilibrium every worker seeks safe-sector work, the pool is fed only by the rationed workers, and the whole rationed mass stands in it, $L = (1-q)N$.*

Proof of Lemma 1. Workers play their strictly preferred opening action in any equilibrium, so under the first choice of the hypothesis every worker seeks safe-sector work, and the pool can only contain rationed workers. That the whole rationed mass stands in it, $L = (1-q)N$, is the availability argument of Lemma C.1. ■

Lemma C.1 (Participation)**.** *A rationed worker who stays in the market is available to its offers. Not being available and rejecting an offer both pay $\bar{u}(L)$, and the worker prices a posted offer at its expected value, which the wage block of Section 3.3.1 shows equals $\bar{u}(L)$, so the expected value of standing in the pool is $\bar{u}(L)$ whatever the coerced share. Availability therefore costs nothing, and the convention that the indifferent worker accepts, the same one the participation wage uses, has every rationed worker stand where the offers arrive. The whole rationed mass is then the pool,*

$$L \;=\; (1-q)\,N,$$

and the risky sector absorbs the rationed by this accounting identity.

Proof of Lemma C.1. The expected value of accepting the posted offer is

$$p\,W'_H + (1-p)\,W_X = p\,\bar{u}(L) + (1-p)\chi\bar{u}(L) + (1-p)\bar{u}(L) - (1-p)\chi\bar{u}(L) = \bar{u}(L),$$

and rejection pays $\bar{u}(L)$, so the value of standing in the pool is $\bar{u}(L)$, whatever the coerced share, and the value of not standing in it is $\bar{u}(L)$. The two payoffs are equal, so availability

costs nothing and selects nothing by itself. The tie is broken by the convention the model already uses at the acceptance node, that the indifferent worker accepts. The rationed mass is therefore the pool, $L = (1 - q)N$. ■

Lemma C.2 (The Revealed Ranking)**.** *Let every worker's first choice be the safe sector, as in the hypothesis of Lemma 1, and let $q > 0$. Then $W_A > \bar{u}(L)$ at every pool in the range under study.*

Proof of Lemma C.2. By the display in the proof of Lemma C.1, every opening action other than seeking safe-sector work is worth $\bar{u}(L)$, while seeking is worth $q\,W_A + (1 - q)\,\bar{u}(L)$. The first choice is a strict preference for seeking, so $q\,W_A + (1 - q)\,\bar{u}(L) > \bar{u}(L)$, and for $q > 0$ this is $W_A > \bar{u}(L)$. ■

Because acceptance binds, the expected value of standing in the pool is $\bar{u}(L)$ at every coerced share, so the participation margin does not depend on the share in any variant of the pre-market stage. The system is recursive, q determines $L = (1-q)N$, and L determines the equilibrium share $s^*(L)$ through Proposition C.1. Existence, uniqueness, and stability are inherited, and no new fixed point arises. This is why displaced workers keep arriving in a market where coercion is growing, since they are exactly compensated in expectation and the entry margin never feeds back into the share.

Proposition 1 (The Two Rates of Decline)**.** *Whether a larger pool widens or narrows the coercive set depends on which falls faster, the cost of coercion or the wage it avoids. Formally, at a stable equilibrium, the share of coercive matches rises with the pool if and only if the cost of coercion falls proportionally faster than the gain,*

$$\underbrace{-\frac{d\ln c}{d\ln L}}_{\text{cost channel}} > \underbrace{-\frac{d\ln \bar{u}}{d\ln L}}_{\text{gain channel}}.$$

Proof of Proposition 1. At a fixed share s the cutoff is $\vartheta^* = \frac{1}{1-s}\,\chi\bar{u}(L)/c(L)$, so

$$\frac{\partial \ln \vartheta^*}{\partial \ln L} = \frac{d\ln \bar{u}}{d\ln L} - \frac{d\ln c}{d\ln L},$$

which is positive exactly when the displayed condition holds. The markup $\frac{1}{1-s}$ and the depth χ enter the cutoff multiplicatively, so they set its level and cancel from the log derivative. At a stable equilibrium the share then moves with the cutoff, since Lemma C.3 gives $ds/dL = \frac{f(\vartheta^*)}{1-\gamma}\,\partial\vartheta^*/\partial L$ with $\gamma < 1$ by Proposition C.1 and $f(\vartheta^*) > 0$, so $ds/dL > 0$ if and only if the condition holds, which establishes the proposition. ■

The belief cannot rise without limit, because the premium is paid by the legitimate firm and the firm must break even, $Y \geq W'_H$. The posted wage rises with the belief, so there is

a highest viable belief $\bar{s}$, the share at which it reaches output, and beliefs above $\bar{s}$ cannot sustain the honest side of the market, bad offers driving out good ones as in Akerlof (1970). When $Y \geq (1+\chi)\,\bar{u}(L)$ on the range under study, $\bar{s} \geq \frac{1}{2}$, and the bound stays clear of any coerced share below one half.

The bound also handles the corner at $s = 1$, which the fixed point cannot rule out on its own. As $s \to 1$ the markup diverges, the cutoff outruns every draw, and the realized share approaches one, so the corner is consistent with beliefs by construction, whatever the shape of T. It is no equilibrium of the game, however. A market believed fully coercive has no honest firm whose posting deception could copy, workers refuse every offer, and employment collapses, so the corner is a market that has shut down, not a pattern of conduct. Viability is what removes it, and it is on $[0, \bar{s}]$ that we characterize the equilibrium.

Proposition C.1 (Equilibrium)**.** *The market mixes honest and coercive firms, and when the density of coercion costs does not fall along the cutoff, exactly one coerced share reproduces the belief that prices it. Formally, write $T(s) = F(\vartheta^*(s, L))$ for the coerced share produced when workers believe the share is s, let $\bar{s}$ solve $\frac{\bar{s}}{1-\bar{s}}\,\chi\bar{u}(L) = Y - \bar{u}(L)$, and assume*

$$T(0) \;>\; 0 \qquad \textit{and} \qquad T(\bar{s}) \;<\; \bar{s}. \tag{C.1}$$

Then $s = T(s)$ has a solution $s^* \in (0, \bar{s})$. If in addition the density of coercion costs is non-decreasing over the range the cutoff spans, that solution is unique on $[0, \bar{s}]$, the iteration $s_{t+1} = T(s_t)$ converges to it monotonically from any starting point in $[0, \bar{s}]$, and

$$\gamma \;\equiv\; T'(s^*) \;<\; 1. \tag{C.2}$$

The first inequality in (C.1) is the assumption that some firms draw coercion costs low enough, below the cutoff at a belief of zero, so some firms coerce even against the belief that none do and a coercion-free equilibrium does not exist. The second is the substantive assumption, that at the highest viable belief fewer firms coerce than workers fear, and it is what selects among fixed points. A convex curve that starts above the diagonal can cross it twice, at a low share and a high one, and the second inequality puts the viability bound between the two crossings, so the high one falls beyond the range where the honest side of the market survives. We maintain the condition on the range under study. The density condition is what buys uniqueness and stability, since it bends the curve upward along the cutoff.[45]

[45] The second inequality tightens as c falls, because a cheaper scheme raises every cutoff. The non-decreasing density is sufficient rather than necessary, the exact requirement, the strict convexity of T on $[0, \bar{s}]$, appears with the proof, and the uniform distribution, with support starting at zero, satisfies it.

Proof of Proposition C.1. Throughout, the cutoff $\vartheta^*(s, L)$ stays interior to the interval on which f is continuous and positive, as Section 3.1 maintains, so F has the derivatives the argument takes. Differentiating the map twice,

$$T''(s) \;=\; F''\left(\frac{\partial \vartheta^*}{\partial s}\right)^2 + F'\,\frac{\partial^2 \vartheta^*}{\partial s^2}, \qquad \frac{\partial \vartheta^*}{\partial s} = \frac{\chi \bar{u}(L)}{(1-s)^2 c(L)} > 0, \quad \frac{\partial^2 \vartheta^*}{\partial s^2} = \frac{2\chi \bar{u}(L)}{(1-s)^3 c(L)} > 0,$$

so T is continuous and increasing, and the strict convexity the uniqueness argument needs is the first display being positive when f is differentiable. The non-decreasing density of the proposition delivers it without differentiating, since a convex increasing F composed with the strictly convex increasing $\vartheta^*(\cdot, L)$ is strictly convex when $f > 0$. T is then continuous, increasing, and strictly convex on $[0, \bar{s}]$, above the diagonal at zero and below it at $\bar{s}$ by the two inequalities of (C.1). Write $g(s) = T(s) - s$, convex, with $g(0) > 0$ and $g(\bar{s}) < 0$. Continuity and the sign change give a crossing. If g vanished twice, convexity would keep its secant slopes non-decreasing, so g could never return below zero after the second crossing, against $g(\bar{s}) < 0$, and the crossing s^* is unique. Since g is convex and ends below zero, $g'(s^*) < 0$, which is the crossing slope below one, $\gamma = T'(s^*) < 1$. For the iteration $s_{t+1} = T(s_t)$, T is increasing, above the diagonal on $[0, s^*)$ and below it on $(s^*, \bar{s}]$, so iterates starting below s^* rise toward it and stay below, iterates starting above fall toward it and stay above, and in both cases the bounded monotone limit is a fixed point, which is s^*. ■

The curve of the realized share against the believed one starts above the diagonal by the first inequality, ends below it by the second, and bends upward with the density. A continuous curve that starts above the diagonal and ends below it must cross, which is existence. A convex curve with those endpoints crosses exactly once and from above, which is uniqueness. And crossing from above is $\gamma < 1$ at the crossing, which is stability, since near s^* a belief that overshoots produces a share that undershoots and revision returns the market to the crossing.

Proposition 2 (Scale and Composition)**.** *Total slavery is $S = L(1-p)$. Its response to the pool decomposes as*

$$\frac{dS}{dL} \;=\; \underbrace{(1-p)}_{\text{scale } (+)} \;+\; \underbrace{L\,\frac{d(1-p)}{dL}}_{\text{composition } (\pm)},$$

or, in elasticities,

$$\frac{d\ln S}{d\ln L} \;=\; \underbrace{1}_{\text{scale}} + \underbrace{\varepsilon}_{\text{composition}}, \qquad \varepsilon \equiv \frac{d\ln(1-p)}{d\ln L},$$

so slavery rises with the pool if and only if $\varepsilon > -1$. The composition term inherits its sign from

Proposition 1 at a stable equilibrium.

Proof of Proposition 2. Differentiating $S = L(1-p)$ with respect to L gives the first display. For the second, multiply both sides by L/S. The left side becomes the elasticity of total slavery, since $d\ln S/d\ln L = (L/S)\,dS/dL$. On the right side, $S = L(1-p)$ gives $L/S = 1/(1-p)$, so the scale term becomes $(1-p)/(1-p) = 1$ and the composition term becomes

$$\frac{L}{1-p}\,\frac{d(1-p)}{dL} \;=\; \frac{d\ln(1-p)}{d\ln L} \;=\; \varepsilon.$$

The sign of the composition term is the sign of ε, read from Proposition 1 at the stable equilibrium that proposition conditions on. ■

Lemma C.3 (The Equilibrium Response)**.** *At the equilibrium of Proposition C.1,*

$$\frac{ds}{dL} \;=\; \frac{f(\vartheta^*)}{1-\gamma}\,\frac{\partial\vartheta^*}{\partial L}, \qquad \frac{dS}{dL} \;=\; s + L\,\frac{ds}{dL},$$

so the share moves with the sign of $\partial\vartheta^*/\partial L$, which is the condition of Proposition 1, and the feedback multiplies the response by $1/(1-\gamma)$ without changing its sign.

Proof of Lemma C.3. Differentiate $s = F(\vartheta^*(s,L))$ totally and solve. $S = Ls$ gives the second display. Since $\gamma < 1$ by Proposition C.1, the sign of ds/dL is the sign of the partial. ■

The feedback changes magnitudes rather than signs, Proposition 1 still decides the direction, and $1/(1-\gamma)$ is the multiplier the equilibrium applies to it. The multiplier itself moves. When the density does not thin along the cutoff, γ rises as c falls relative to the outside option, so the amplification concentrates where the inflow is largest.

Lemma 2 (The Posted Wage)**.** *The posted wage is $W_H' = \bar{u}(L) + \frac{s}{1-s}\,\chi\bar{u}(L)$. Conditional on the outside option it rises with the share,*

$$\frac{\partial W_H'}{\partial s} \;=\; \frac{\chi\bar{u}(L)}{(1-s)^2} \;>\; 0,$$

and it rises with the pool outright if and only if the premium response outruns the decline of the outside option,

$$\frac{\chi\bar{u}(L)}{(1-s)^2}\,\frac{ds}{dL} \;>\; \left[1 + \tfrac{s}{1-s}\,\chi\right]\left|\bar{u}'(L)\right|,$$

with ds/dL the equilibrium response of Lemma C.3.

Proof of Lemma 2. The first display differentiates the premium at a fixed $\bar{u}(L)$. For the second, the total derivative is

$$\frac{dW_H'}{dL} \;=\; \left[1 + \tfrac{s}{1-s}\,\chi\right]\bar{u}'(L) \;+\; \frac{\chi\bar{u}(L)}{(1-s)^2}\,\frac{ds}{dL},$$

with $\bar{u}'(L) < 0$, so $dW'_H/dL > 0$ exactly when the second term outruns the first, which rearranges to the displayed condition. ■

Proposition 3 (Asymmetry of the Response)**.** *An inflow of workers raises total slavery by more than an equal outflow lowers it. Formally, at the stable equilibrium of Proposition C.1, let the condition of Proposition 1 hold at every pool in the range, with a gap between the two elasticities that does not narrow as the pool grows, and let the density of operating costs be differentiable and non-decreasing over the interval the cutoff moves through. Then total slavery is increasing and strictly convex in the pool, and an inflow raises slavery by more than an equal outflow lowers it.*

Proof of Proposition 3. Write t for the equilibrium cutoff and $A(L) = \chi\bar{u}(L)/c(L)$. The fixed point $s = F(t)$ with $t = A/(1-s)$ collapses into the single equation

$$H(t) \;=\; A(L), \qquad H(t) \equiv t\,\big(1 - F(t)\big).$$

Since $H'(t) = 1 - F - t\,f = (1-s)(1-\gamma)$, stability is exactly $H' > 0$, and the stable branch $t(L)$ is differentiable with $t' = A'/H'$. The log slope of A is the assumed lead, $\delta(L) = d\ln A/d\ln L$, the percentage fall of the cost over that of the outside option, positive and non-decreasing. From $\delta = L\,A'/A$, differentiating once more gives $A'' = (A/L^2)\big[\delta^2 - \delta + L\,\delta'\big]$, so $2A' + LA'' = (A/L)\big[\delta^2 + \delta + L\,\delta'\big]$. Differentiating $S = L\,F(t(L))$ twice, the terms collect into

$$S'' \;=\; \frac{f\,A}{L\,H'}\Big[\delta^2 + \delta + L\,\delta'\Big] \;+\; \frac{L\,(A')^2}{(H')^3}\Big[2f^2 + (1-F)\,f'\Big].$$

The first bracket is positive since $\delta > 0$ and $\delta' \geq 0$, the second since $f > 0$ and $f' \geq 0$, so $S'' > 0$, and $S' = F + L\,f\,A'/H' > 0$. For Δ with $[L-\Delta,\, L+\Delta]$ in the range,

$$S(L+\Delta) - S(L) - \big[S(L) - S(L-\Delta)\big] \;=\; \int_0^{\Delta} \big[S'(L+t) - S'(L-t)\big]\,dt \;>\; 0$$

since $S'' > 0$, so an inflow raises slavery by more than an equal outflow lowers it. ■

The baseline branch of the discussion holds the markup fixed. With c constant the cutoff elasticity at the fixed markup is $-\nu(L)$, the rate at which the outside option falls, and the cutoff falls with the pool. Write $\alpha(\vartheta) = \vartheta f(\vartheta)/F(\vartheta)$ for the elasticity of the distribution. Then

$$S' \;=\; F(\vartheta^*)\big[1 - \alpha(\vartheta^*)\,\nu(L)\big], \qquad S'' \;=\; \vartheta^{*\prime}\big[f\,(1 - \alpha\nu) - F\,\nu\,\alpha'\big] - F\,\alpha\,\nu'.$$

An α non-increasing over the interval the cutoff moves through and an outside option that falls at a rate that does not slow, $\nu' \geq 0$, sign both terms of S'' where slavery still rises, so $S'' < 0$, slavery is concave wherever it rises, and an equal outflow removes more than the

inflow adds. Under the uniform distribution with an isoelastic outside option, $\alpha = 1$ and ν is constant, so $S \propto L^{1-\nu}$, rising and concave exactly when $\nu < 1$.

The comparison of the response across markets is stated here rather than in the main text. The condition is the recruitment story of Section 3.6 as a comparative, and the result reads it from the data.

Assumption 1 (Steeper Cheapening in Poorer Markets)**.** *Across markets, the elasticity of the coercion cost with respect to the pool is larger in magnitude at every pool where the baseline outside option is lower.*[46]

Comparison across markets. Compare two markets that differ only in the level of the outside option and in the elasticity of the coercion cost, and let the distribution of operating costs have constant elasticity, $\vartheta f(\vartheta)/F(\vartheta) = k$, over the range the cutoffs span, so that a one percent rise in the cutoff always draws in the same percentage of additional coercive firms. With the markup held fixed, the proportional response of slavery to the pool is larger in the poorer market at every pool if and only if Assumption 1 holds.

The distribution condition keeps the comparison clean. In proportional terms the power family $F \propto \vartheta^k$ looks the same at every scale, so the same percentage push to the cutoff produces the same percentage response of the share in both markets, and a difference in responses can come only from the push itself, the elasticity of the coercion cost, never from where each market sits on the distribution. Like Proposition 3, the comparison holds the markup fixed, and it extends to the equilibrium when the elasticity advantage outweighs the gap in feedback multipliers.[47]

Write k for the constant value of $\vartheta f/F$, the elasticity of the share with respect to the cutoff, positive since the cutoff is interior and $f > 0$. At the fixed markup the proportional response is $d\ln S/d\ln L = 1 + k\,[\eta(L) - \nu(L)]$, where $\nu(L)$ is the percentage fall in the outside option and $\eta(L)$ the percentage fall in the coercion cost when the pool grows by one percent at L. A multiplicative difference in the outside option leaves its elasticity unchanged, so the markets share $\nu(L)$, and they share k because the elasticity of F is the same constant wherever each market's cutoff sits. At every pool the responses then differ by $k\,[\eta_2(L) - \eta_1(L)]$, with market two the poorer one, and this difference is positive

[46] The market this assumption describes is the recruiters' market of Appendix B.4, where the reports record what finding a worker willing to say yes costs per head.

[47] In levels the poorer market also starts from a smaller stock, so the proportional statement is the one the model delivers cleanly. At the equilibrium the response is scaled by $1/(1-\gamma)$, and under the constant-elasticity distribution $\gamma = k\,s/(1-s)$, smaller in the poorer market near the baseline, which works against the ranking.

at every pool exactly when the poorer market's cost falls proportionally faster, which is Assumption 1. The uniform distribution is the leading case, with $k = 1$.

Comparative statics in the technology. The technological shocks enter through q, and one exclusion carries them into the displays of the body.

Assumption 2 (Exclusion)**.** *The technology moves the coercion sector only through the pool. The probability q enters neither $\bar{u}(\cdot)$ nor $c(\cdot)$ directly, and both carry the shock only through $L = (1-q)N$.*

The model maintains the same restriction in silence when it moves L exogenously, and stating it gives it content. The safe sector's technology is assumed not to move the prices of the surrounding sectors except through the mass it displaces. The evidence is friendly to the sign, since the wages of the alternative sectors fall where the labor-saving crop spreads and rise where the labor-demanding one does, the direction that congestion through L requires.

Corollary 4 (Comparative Statics in the Technology)**.** *The shock that cuts safe hiring fills the pool, and every response of the model follows it with the signs the pool delivered. Formally, at the stable equilibrium of Proposition C.1, with $L = (1-q)N$ and under Assumption 2, a fall in q raises the coerced share if and only if the cost of coercion falls proportionally faster than the outside option, and total slavery responds as*

$$\frac{d\ln S}{d\ln q} \;=\; -\big(1+\varepsilon\big)\,\frac{q}{1-q}, \qquad \varepsilon \equiv \frac{d\ln s}{d\ln L}.$$

Under the hypotheses of Proposition 3, total slavery is decreasing and strictly convex in q, so a destruction of safe jobs adds more slavery than an equal creation removes. The posted wage rises as q falls exactly when the premium response outruns the decline of the outside option, the condition of Lemma 2.

Proof of Corollary 4. Write $\nu(L) = -\,d\ln\bar{u}/d\ln L$ and $\eta(L) = -\,d\ln c/d\ln L$, the rates at which the outside option and the cost of coercion fall with the pool. In the cutoff $\vartheta^* = \frac{1}{1-s}\,\chi\bar{u}(L)/c(L)$, only $\bar{u}$ and c carry L under Assumption 2, so $\partial\vartheta^*/\partial L = (\vartheta^*/L)\,[\eta(L)-\nu(L)]$. For the share, the chain rule with $dL/dq = -N$ and Lemma C.3 gives

$$\frac{ds}{dq} \;=\; -\,\frac{f(\vartheta^*)\,\vartheta^*}{(1-\gamma)\,(1-q)}\,\big[\eta(L)-\nu(L)\big],$$

using $N/L = 1/(1-q)$, and every factor outside the bracket is positive, so a fall in q raises the share exactly when $\eta > \nu$, the condition of Proposition 1. For total slavery, $d\ln L/d\ln q = (q/L)(dL/dq) = -q/(1-q)$, and $d\ln S/d\ln L = 1+\varepsilon$ by Proposition 2, and the product of the two is the display. For the curvature, L is affine in q, so twice

differentiating $S(q) = L\,s(L)\big|_{L=(1-q)N}$ gives $d^2S/dq^2 = N^2\,d^2[L\,s(L)]/dL^2$, positive under the hypotheses of Proposition 3, and composition with a decreasing affine map preserves convexity and reverses direction, so S is decreasing and strictly convex in q and, for every $\Delta \in (0, \min\{q, 1-q\})$,

$$S(q-\Delta) - S(q) - \big[S(q) - S(q+\Delta)\big] \;=\; \int_0^{\Delta} \big[-S'(q-x) + S'(q+x)\big]\,dx \;>\; 0.$$

For the posted wage, the chain rule with the total derivative in the proof of Lemma 2 gives

$$\frac{dW'_H}{dq} \;=\; -N\left[\left(1 + \tfrac{s}{1-s}\,\chi\right)\bar{u}'(L) \;+\; \frac{\chi\bar{u}(L)}{(1-s)^2}\,\frac{ds}{dL}\right],$$

so the posted wage rises as q falls, $dW'_H/dq < 0$, exactly when $dW'_H/dL > 0$, which is the displayed condition of that lemma. ■

Remark 1 (The Conversion to Measured Employment)**.** *Safe employment is qN, and the employment of at-risk workers that Section 6.3 reads, most of it on the signed-card margin, is the empirical counter available for it, so along that margin $d\ln E = d\ln q$ identically and*

$$\frac{d\ln S}{d\ln E} \;=\; -\big(1+\varepsilon\big)\,\frac{q}{1-q}$$

holds as written, the algebra connecting the model to the response of slavery to at-risk employment. The display carries no parameter value and none is assigned. The model delivers the mechanism and the signs, and magnitudes stay with the empirical work.

Notation. The pre-market stage is written in the notation of the rest of Appendix C. The wage W_A, the vacancy mass J, and the employment probability $q = J/N$ are the objects added by that stage. The population is N, the pool of the body is $L = (1-q)N$, and $\bar{u}(L)$, $c(L)$, χ, $\vartheta_i \sim F$, and the coerced share $s = 1-p$ are as in Section 3.1. The elasticities $\nu(L)$ and $\eta(L)$ of the proof of Corollary 4 are the ν and η of the comparison across markets above, the percentage falls of the outside option and of the coercion cost when the pool grows by one percent. Every comparative-statics display of Section 3.5 carries over evaluated at $L = (1-q)N$, with the chain $dL/dq = -N$ turning each result into a statement in q, and Corollary 4 records the displays.

D Extension: Land Concentration and the Wage

The moderation by market structure of Section 9.1 has a statement in the model, and the extension needs one ingredient, since the cost of coercion can be left alone: concentration enters through the wage. Index the market by its concentration φ and let the wage of free labor carry it, $\bar{u}(L,\varphi)$, with the cost of coercion $c(L)$ free of it. The deception game is otherwise the risky-sector game of Figure 1, and Figure D.1 restates its payoffs: rejection and leaving an honest match pay $\bar{u}(L,\varphi)$, confinement cuts leaving a coercive match to $(1-\chi)\bar{u}(L,\varphi)$, so the coercive firm retains with $W_X = (1-\chi)\bar{u}(L,\varphi)$, and the posted wage of Lemma 2 prices the same deception at the new outside option. The margin of Section 3.3.2 carries over line by line,

$$\pi_X - \pi_H \;=\; \tfrac{1}{p}\,\chi\bar{u}(L,\varphi) - \vartheta_i\, c(L), \qquad \vartheta^*(p,L,\varphi) \;=\; \frac{\frac{1}{p}\,\chi\bar{u}(L,\varphi)}{c(L)},$$

since φ enters the cutoff only through the level of $\bar{u}$, and the equilibrium carries over with it.

Corollary 5 (Equilibrium under Concentration)**.** *Fix φ and let the conditions of Proposition C.1, the two inequalities of (C.1) and the non-decreasing density, hold at $\bar{u}(L,\varphi)$. Then the market has the unique stable equilibrium $s^*(L,\varphi)$ of Proposition C.1, with $\gamma(\varphi) = T'(s^*) < 1$. The proof is Proposition C.1's, which uses only the level of $\bar{u}$ at each belief.*

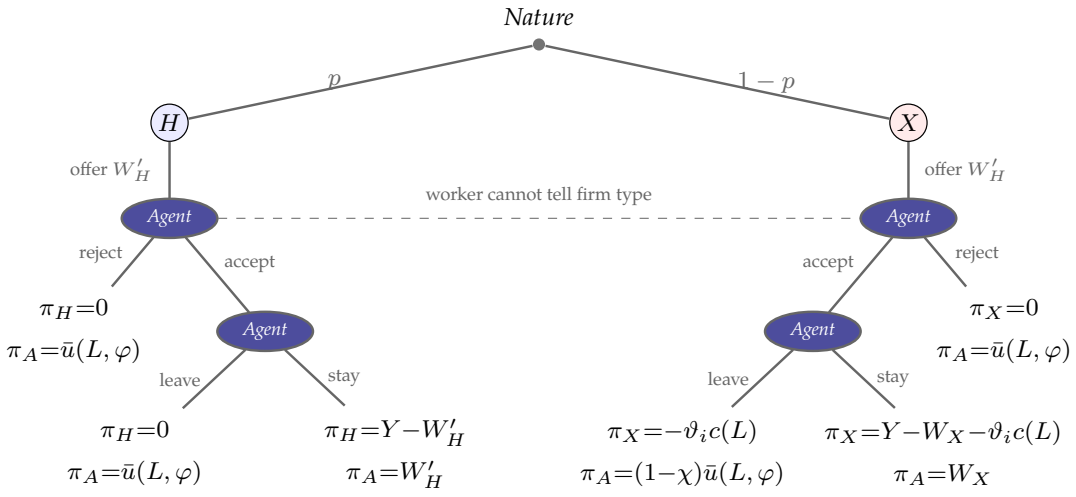


Figure D.1: The deception game under concentration. The risky-sector game of Figure 1 with the wage of free labor carrying the market's concentration, $\bar{u}(L,\varphi)$. Rejecting pays $\bar{u}(L,\varphi)$, leaving a coercive match pays $(1-\chi)\bar{u}(L,\varphi)$, the coercive firm retains with $W_X = (1-\chi)\bar{u}(L,\varphi)$, and the cost of coercion $\vartheta_i c(L)$ does not carry φ.

Assumption 3 (Wage Setting and Concentration)**.** *The wage of free labor responds to the pool more strongly the more concentrated the market,* $\partial\varepsilon_u/\partial\varphi > 0$*, where* $\varepsilon_u(L,\varphi) = -\,\partial \ln \bar{u}/\partial \ln L$ *and* $\varepsilon_c(L) = -\,\partial \ln c/\partial \ln L$ *are the two rates of decline of Proposition 1.*

An employer who sets the wage prices the workers' desperation, so a filled pool passes into the wage directly, and an employer who competes for workers prices their product, which the pool does not move. The assumption writes that contrast as an elasticity rising with concentration and leaves everything else of Section 3 in place.

Proposition 6 (Concentration and the Response)**.** *Under Assumption 3, at the stable equilibrium of Corollary 5 the response of the coerced share to the pool is*

$$\frac{ds}{dL} \;=\; \frac{f(\vartheta^*)}{1-\gamma}\,\frac{\vartheta^*}{L}\,\big[\varepsilon_c(L) - \varepsilon_u(L,\varphi)\big],$$

strictly decreasing in φ *at a fixed equilibrium position, positive exactly while the condition of Proposition 1 holds at* φ*, and zero where concentration closes the gap between the two elasticities.*

Both directions of the shock carry the same bracket, so concentration weakens the response to the inflow and to the outflow alike, which is the shape of Table 6, a response in the dispersed half and none in the concentrated one.

Proof of Proposition 6. The display is Lemma C.3 with $\partial\vartheta^*/\partial L = (\vartheta^*/L)\,(\varepsilon_c - \varepsilon_u)$, which follows from the cutoff above, where only $\bar{u}$ and c carry L. Holding the equilibrium position fixed, φ enters the display only through ε_u, and $\partial\varepsilon_u/\partial\varphi > 0$ makes the bracket, and with it the response, strictly decreasing in φ. The sign and the zero read off the bracket. ■

E Measurement Error in the Detected Outcome

This appendix collects the algebra behind the measurement-model claims in Section 10.1. Let S^*_{jt} denote true forced labor and $S_{jt} = \pi_{jt}\, S^*_{jt}\, e^{u_{jt}}$ the detected count, with $\pi_{jt} \in (0, 1]$ the detection rate and u_{jt} idiosyncratic reporting noise. Writing y_{jt} for the inverse hyperbolic sine of the detected count and y^*_{jt} for the same transform of the truth, the measurement error in the outcome is $\varepsilon_{jt} \equiv y_{jt} - y^*_{jt}$. Detected slavery shares this structure with reported crime, diagnosed disease, and deforestation read from satellites, outcomes observed only through a filter, and our treatment follows the taxonomy of Hyslop and Imbens (2001).

Separability and the absence of bias. A detection process that misses a stable share of a municipality's crime in every year moves y_{jt} by a municipality constant for counts away from zero, and a national detection cycle moves it by a year constant, so we decompose the error into a place component, a time component, and a residual,

$$\varepsilon_{jt} \;=\; \delta_j \;+\; \delta_t \;+\; \xi_{jt}. \tag{E.3}$$

Substituting into the structural relation for the truth, $y^*_{jt} = \alpha^*_j + \alpha^*_t + \beta^{soy}(A^{soy}_j \times Post_t) + \beta^{maize}(A^{maize}_j \times Post_t) + X_j'\gamma_t + \eta_{jt}$, the estimating equation (2) for the detected outcome becomes

$$y_{jt} \;=\; \underbrace{(\alpha^*_j + \delta_j)}_{\alpha_j} + \underbrace{(\alpha^*_t + \delta_t)}_{\alpha_t} + \beta^{soy}(A^{soy}_j \times Post_t) + \beta^{maize}(A^{maize}_j \times Post_t) + X_j'\gamma_t + \big(\eta_{jt} + \xi_{jt}\big). \tag{E.4}$$

The place component of detection is absorbed by α_j and the time component by α_t. If the remaining error ξ_{jt} is uncorrelated with the interacted treatments, it is classical measurement error in the dependent variable, which leaves β^{soy} and β^{maize} unbiased and consistent and inflates only their standard errors (Hyslop and Imbens, 2001). The design neutralizes any detection process that misses a stable share of the crime in a place, however large that share.[48]

The treatment-correlated channel and the sign of the bias. Write the treatment-correlated part of the detection error as a linear projection,

$$\xi_{jt} \;=\; \phi^{soy}\,(A^{soy}_j \times Post_t) \;+\; \phi^{maize}\,(A^{maize}_j \times Post_t) \;+\; \tilde{\xi}_{jt}, \qquad E\big[\tilde{\xi}_{jt}\,(A^c_j \times Post_t)\big] = 0, \tag{E.5}$$

[48] The cell-years at zero sit outside the share reading, and the extensive margin and the levels versions of the estimates carry them (Table 4 and Appendix Table F.7).

where ϕ^c is the response of detection to shock c net of fixed effects. Projecting the detected outcome on the interacted treatments then yields $\widehat{\beta}^c \xrightarrow{p} \beta^c_{\text{true}} + \phi^c$, so the bias has the sign of ϕ^c, as used in (5).

F Additional Tables

F.1 The First Stage: Adoption and Land Use

Table F.1: The First Stage: Technology Adoption and Land Use

	Asinh(Soy area)	**Asinh(Maize area)**	**Asinh(Cropland)**	**Asinh(Pasture)**	**Asinh(Cattle herd)**
	(1)	(2)	(3)	(4)	(5)
Labor-saving	0.4301	−0.0403	−0.0020	0.0049	0.0784
	[0.0717]***	[0.0516]	[0.0021]	[0.0029]*	[0.0568]
Labor-intensive	−0.1178	0.2076	0.0219	−0.0169	−0.1246
	[0.0804]	[0.0669]***	[0.0030]***	[0.0033]***	[0.0555]**
Observations	72,732	72,732	72,713	72,713	7,656
R-squared	0.909	0.796	0.962	0.975	0.970
AMC and Year FE	Yes	Yes	Yes	Yes	Yes

Notes: Estimates of equation (2). Outcomes in inverse hyperbolic sine: soy and maize harvested area (PAM), cropland and pasture (MapBiomas), and the cattle herd (Agricultural Census, 1996 and 2006). Columns (1) and (2) repeat the main-text first stage (Table 1). Columns (3) to (5) add the land-use outcomes. Column (5) is therefore estimated on the two census years, 7,656 observations, a comparison across the two censuses rather than the annual panel of the other columns. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.2 Reweighting Robustness: Alternative At-Risk Profiles

Table F.2: Displacement of At-Risk Workers Under Alternative Profile Definitions

	Asinh(Number of employees)			
	(1)	(2)	(3)	(4)
Labor-saving	−0.0606	−0.1271	−0.1085	−0.0841
	[0.0159]***	[0.0225]***	[0.0231]***	[0.0187]***
Labor-intensive	0.0790	0.1531	0.1305	0.1060
	[0.0178]***	[0.0243]***	[0.0245]***	[0.0204]***
At-risk weights	None	Sex×Age×Educ	Sex×Age×Educ×Race	Educ only
Number of cell-years	546,716	524,222	475,380	546,716
R-squared	0.630	0.624	0.637	0.601
AMC, Year, and Cell FE	Yes	Yes	Yes	Yes
Baseline controls (× Year)	Yes	Yes	Yes	Yes

Notes: Estimates of equation (2) on the census cell panel of Section 6, with the inverse hyperbolic sine of the cell's employee count as the outcome and the cells weighted by alternative definitions of the rescued profile. Column (1) is unweighted. Column (2) uses the baseline weights, the rescued shares over sex, age, and education, and reproduces the at-risk column of Table 3. Column (3) adds the race dimension, recorded for only a third of the rescue records, and column (4) uses education alone. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.3 Robustness: Illegal Mahogany Market Shock

Table F.3: Robustness: Exposure to the Illegal Mahogany Market Shock

	Asinh(Operations w/ slavery)		**Asinh(Enslaved workers)**	
	(1)	(2)	(3)	(4)
Labor-saving	0.0367	0.0139	0.0909	0.0442
	[0.0071]***	[0.0043]***	[0.0155]***	[0.0114]***
Labor-intensive	−0.0230	−0.0056	−0.0518	−0.0159
	[0.0061]***	[0.0043]	[0.0145]***	[0.0118]
1st policy (1999–2000)		0.0911		0.3333
(mahogany 85% suspension)		[0.0443]**		[0.1713]*
2nd policy (2001–2008)		0.5250		1.211
(mahogany full ban)		[0.1240]***		[0.2706]***
3rd policy (2009–2013)		0.5360		1.013
(plus deforestation monitoring)		[0.1201]***		[0.2079]***
Observations	72,732	72,732	72,732	72,732
R-squared	0.374	0.399	0.292	0.305
AMC and Year FE	Yes	Yes	Yes	Yes

Notes: Estimates of equation (2). Columns (2) and (4) add the interaction of an indicator for AMCs with natural mahogany occurrence with the three policy windows of the illegal mahogany market, the 85 percent suspension of extraction in 1999–2000, the full ban from 2001, and the ban combined with satellite deforestation monitoring from 2009 (Chimeli and Soares, 2017). Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.4 Robustness: Alternative Clustering and Spatial Correction

Table F.4: Robustness to Alternative Clustering and Spatial Correction

	Panel A: Asinh(Operations w/ slavery)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Labor-saving	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367	0.0367
	[0.0071]***	[0.0124]***	[0.0077]***	[0.0085]***	[0.0098]***	[0.0109]***	[0.0119]***
Labor-intensive	−0.0230	−0.0230	−0.0230	−0.0230	−0.0230	−0.0230	−0.0230
	[0.0061]***	[0.0104]**	[0.0071]***	[0.0080]***	[0.0093]**	[0.0105]**	[0.0116]**
	Panel B: Asinh(Enslaved workers)						
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Labor-saving	0.0909	0.0909	0.0909	0.0909	0.0909	0.0909	0.0909
	[0.0155]***	[0.0275]***	[0.0175]***	[0.0195]***	[0.0231]***	[0.0255]***	[0.0281]***
Labor-intensive	−0.0518	−0.0518	−0.0518	−0.0518	−0.0518	−0.0518	−0.0518
	[0.0145]***	[0.0242]**	[0.0175]***	[0.0198]***	[0.0234]**	[0.0262]**	[0.0291]*
Observations	72,732	72,732	72,732	72,732	72,732	72,732	72,732
AMC and Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustering	AMC	Micro	Conley	Conley	Conley	Conley	Conley
Distance cutoff			50 km	75 km	100 km	125 km	150 km

Notes: Point estimates of equation (2). Each column recomputes the standard errors, in brackets, with the clustering shown in the bottom rows. Conley standard errors use AMC centroids from the 2010 municipality polygons. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.5 Dose-Group Estimates

Table F.5: Technology and Modern Slavery: Dose-Group Estimates

	Operations w/ detected slavery	Pr(Any slavery)	Enslaved workers
Labor-saving P50–P75 × Post	0.009***	0.008***	0.033***
	[0.003]	[0.002]	[0.009]
Labor-saving P75+ × Post	0.034***	0.018***	0.081***
	[0.008]	[0.004]	[0.019]
Labor-intensive P50–P75 × Post	0.006	0.003	0.015
	[0.004]	[0.002]	[0.010]
Labor-intensive P75+ × Post	−0.015**	−0.006	−0.029*
	[0.007]	[0.004]	[0.017]
Observations	72,732	72,732	72,732
AMC and Year FE	Yes	Yes	Yes
Baseline controls × Year	Yes	Yes	Yes

Notes: Dose-group version of equation (2), following Callaway et al. (2024). Labor-saving is the soy suitability differential and Labor-intensive is the maize differential. Each differential is replaced by indicators for its 50th–75th percentile band and its top quartile, with cutoffs computed on the cross-section of 3,828 AMCs (one observation per AMC) and municipalities below the median as the omitted group. Both treatments enter jointly. Outcomes as in Table 4. All columns include AMC and year fixed effects and the 1991 baseline characteristics interacted with year. The mean soy differential in the 50–75 band exceeds the omitted group's by 0.51 log points, and in the top quartile by 1.01, so the enslaved-workers response per log point rises from 0.064 to 0.080 across the bands and the operations response from 0.018 to 0.034, the rising per-unit effect the convexity of Proposition 3 predicts on the labor-saving side. Standard errors clustered by AMC in brackets. * p<0.10, ** p<0.05, *** p<0.01.

F.6 Effects by Sector of Activity: Pooled Estimates

Table F.6: Technology and Modern Slavery by Sector of Activity: Pooled Estimates

	Panel A: Asinh(Operations w/ slavery)									
Sector	All		Agriculture		Cattle r.		Crops		Other	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Labor-saving	0.0367	0.0190	0.0291	0.0176	0.0263	0.0182	0.0048	0.0009	0.0130	0.0047
	[0.0071]***	[0.0059]***	[0.0062]***	[0.0051]***	[0.0059]***	[0.0046]***	[0.0017]***	[0.0015]	[0.0030]***	[0.0024]**
Labor-intensive	−0.0230	−0.0148	−0.0199	−0.0148	−0.0192	−0.0156	−0.0025	−0.0007	−0.0071	−0.0030
	[0.0061]***	[0.0055]***	[0.0053]***	[0.0047]***	[0.0050]***	[0.0042]***	[0.0018]	[0.0018]	[0.0026]***	[0.0022]
R-squared	0.374	0.382	0.422	0.427	0.470	0.474	0.145	0.148	0.178	0.187
	Panel B: Asinh(Enslaved workers)									
Sector	All		Agriculture		Cattle r.		Crops		Other	
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Labor-saving	0.0909	0.0455	0.0717	0.0415	0.0626	0.0446	0.0187	0.0036	0.0380	0.0153
	[0.0155]***	[0.0148]***	[0.0140]***	[0.0131]***	[0.0131]***	[0.0112]***	[0.0058]***	[0.0061]	[0.0079]***	[0.0069]**
Labor-intensive	−0.0518	−0.0311	−0.0446	−0.0314	−0.0441	−0.0364	−0.0085	−0.0017	−0.0205	−0.0094
	[0.0145]***	[0.0139]**	[0.0126]***	[0.0121]***	[0.0111]***	[0.0098]***	[0.0065]	[0.0068]	[0.0074]***	[0.0067]
R-squared	0.292	0.299	0.326	0.330	0.432	0.436	0.127	0.129	0.153	0.161
Baseline controls (× Year)	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732
AMC and Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table is the pooled counterpart of Figure 9. The first column of each sector pair estimates equation (2) without controls and the second adds the 1991 baseline controls interacted with year. The All columns aggregate over all sectors and correspond to Table 4. The Agriculture, Cattle r., and Crops columns match the black (agriculture as a whole, which contains the other two), grey, and blue series of the figure, with the year-by-year path of equation (3) replaced by a single average post-period coefficient. Other collects the non-agricultural sectors, not drawn in the figure. With the controls, the crop effects go to zero while the cattle-ranching effects are unchanged. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.7 Main Outcomes in Levels

Table F.7: Technology and Modern Slavery: Outcomes in Levels

	Operations w/ slavery (count)		Enslaved workers (count)	
	(1)	(2)	(3)	(4)
Labor-saving	0.0809	0.0456	1.578	0.849
	[0.0201]***	[0.0141]***	[0.4052]***	[0.3410]**
Labor-intensive	−0.0563	−0.0390	−0.937	−0.594
	[0.0166]***	[0.0130]***	[0.3436]***	[0.3129]*
Mean of dep. var.	0.025	0.025	0.650	0.650
Observations	72,732	72,732	72,732	72,732
R-squared	0.402	0.407	0.194	0.199
AMC and Year FE	Yes	Yes	Yes	Yes
Baseline controls ($\times$ Year)	No	Yes	No	Yes

Notes: Estimates of equation (2) with the outcomes in levels, the untransformed counts of operations with detected slavery and of enslaved workers. Deleting the largest operations leaves the estimates essentially unchanged. The asinh estimates of Table 4 are the baseline, and the two readings bracket the magnitudes in Section 7.4. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.8 The Coercion Rate Under Six Denominators

Table F.8: The Coercion Rate Under Six Denominators

	Panel A: Asinh(Operations w/ slavery per 1,000)					
	(1)	(2)	(3)	(4)	(5)	(6)
Denominator	Population	Interp. pop.	Workforce	At-risk	Formal	Informal
Labor-saving	0.0013	0.0010	0.0190	0.0741	0.0088	0.0223
	[0.0003]***	[0.0002]***	[0.0040]***	[0.0129]***	[0.0024]***	[0.0045]***
Labor-intensive	−0.0007	−0.0006	−0.0090	−0.0384	−0.0039	−0.0106
	[0.0003]**	[0.0003]**	[0.0040]**	[0.0127]***	[0.0022]*	[0.0045]**
R-squared	0.111	0.099	0.179	0.210	0.142	0.170
	Panel B: Asinh(Enslaved workers per 1,000)					
	(7)	(8)	(9)	(10)	(11)	(12)
Denominator	Population	Interp. pop.	Workforce	At-risk	Formal	Informal
Labor-saving	0.0155	0.0128	0.0656	0.1298	0.0415	0.0711
	[0.0031]***	[0.0027]***	[0.0118]***	[0.0218]***	[0.0084]***	[0.0125]***
Labor-intensive	−0.0077	−0.0062	−0.0331	−0.0676	−0.0196	−0.0361
	[0.0031]**	[0.0028]**	[0.0116]***	[0.0215]***	[0.0081]**	[0.0124]***
R-squared	0.135	0.118	0.207	0.227	0.188	0.203
Observations	72,732	72,732	72,732	72,732	72,731	72,732
AMC and Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Estimates of equation (2) on the full 1995–2013 panel. Outcomes are the inverse hyperbolic sine of operations with detected slavery (Panel A), or of enslaved workers (Panel B), per 1,000 of the denominator shown. The population denominator is the 1991 census municipal population, held fixed. The interpolated-population denominator moves every year, the municipal population log-linearly interpolated between its census and count values of 1991, 1996, 2000, 2007, and 2010, held at the 2010 value afterward. The workforce, at-risk (cells weighted by s_c), and informal denominators are fixed at their census-2000 values, and the formal denominator is annual formal employment from RAIS. A census-year version with contemporaneous denominators points the same way, with less precision. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.9 Heterogeneity by Baseline Outside Options: Detailed Splits

Table F.9: Heterogeneity by Baseline Outside Options: Detailed Splits

	Panel A: Asinh(Operations w/ slavery)											
	Formal jobs		**Unemployment**		**Literacy**		**No education**		**>12 years educ.**		**Years educ.**	
	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Labor-saving	0.0233	0.0160	0.0001	0.0299	0.0243	0.0183	0.0116	0.0280	0.0170	0.0205	0.0243	0.0116
	[0.0098]**	[0.0084]*	[0.0074]	[0.0101]***	[0.0095]**	[0.0082]**	[0.0074]	[0.0101]***	[0.0093]*	[0.0086]**	[0.0097]**	[0.0075]
Labor-intensive	−0.0188	−0.0137	−0.0044	−0.0192	−0.0173	−0.0221	−0.0181	−0.0211	−0.0091	−0.0243	−0.0144	−0.0186
	[0.0088]**	[0.0077]*	[0.0067]	[0.0093]**	[0.0083]**	[0.0086]***	[0.0082]**	[0.0089]**	[0.0075]	[0.0092]***	[0.0081]*	[0.0082]**
Observations	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732
R-squared	0.382	0.382	0.383	0.383	0.384	0.384	0.384	0.384	0.382	0.382	0.384	0.384
	Panel B: Asinh(Enslaved workers)											
	Formal jobs		**Unemployment**		**Literacy**		**No education**		**>12 years educ.**		**Years educ.**	
	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]	<[50th]	>[50th]
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Labor-saving	0.0544	0.0400	−0.0022	0.0725	0.0556	0.0502	0.0326	0.0647	0.0386	0.0518	0.0553	0.0326
	[0.0236]**	[0.0196]**	[0.0168]	[0.0242]***	[0.0228]**	[0.0183]***	[0.0165]**	[0.0240]***	[0.0220]*	[0.0186]***	[0.0228]**	[0.0179]*
Labor-intensive	−0.0389	−0.0308	−0.0061	−0.0405	−0.0351	−0.0540	−0.0428	−0.0445	−0.0156	−0.0565	−0.0275	−0.0453
	[0.0215]*	[0.0195]	[0.0157]	[0.0231]*	[0.0208]*	[0.0200]***	[0.0191]**	[0.0221]**	[0.0187]	[0.0214]***	[0.0196]	[0.0208]**
Observations	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732	72,732
R-squared	0.300	0.300	0.300	0.300	0.301	0.301	0.301	0.301	0.300	0.300	0.301	0.301
AMC and Year FE	Yes											
Baseline controls (× Year)	Yes											

Notes: Detailed version of Table 7 in the main text. Each split reports a single estimation of equation (2) on the full panel with the two treatments, and the post indicator, interacted with an indicator for the municipality's side of the 1991 median of the split variable, computed on the cross-section of 3,828 AMCs. The below- and above-median columns of a split therefore come from the same regression. The splits are the 1991 formal employment share, unemployment rate, literacy rate, share of adults with no schooling, share of adults with more than twelve years of schooling, and mean years of schooling. Columns (1)–(6) and (13)–(18) reproduce Table 7. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.10 Complaints and the Findings Margin

Table F.10: Complaints and the Findings Margin

	Asinh(Local complaints)	**Share w/ findings**	**Pr(Any slavery)**
	(1)	(2)	(3)
Labor-saving	0.0382	0.0189	0.0220
	[0.0078]***	[0.0030]***	[0.0036]***
Labor-intensive	−0.0277	−0.0098	−0.0119
	[0.0071]***	[0.0030]***	[0.0035]***
Observations	72,732	72,732	72,732
R-squared	0.382	0.192	0.258
AMC and Year FE	Yes	Yes	Yes

Notes: Estimates of equation (2) on the full panel. Column (1) is the inverse hyperbolic sine of local complaints (denúncias). Column (2) is the share of inspections in a municipality-year that ended with detected slavery, set to zero when no inspection took place. Column (3) is the indicator for any detected slavery. Labor-saving is the soy suitability differential interacted with $Post_t$. Labor-intensive is the maize differential. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.11 The Smuggling Window and the Legal Period

Table F.11: The Smuggling Window (2001–2002) and the Legal Period (2003–2013)

	Operations w/ detected slavery	**Pr(Any slavery)**	**Enslaved workers**
	(1)	(2)	(3)
Labor-saving × 2001–2002	0.0174***	0.0103***	0.0502***
	(0.0053)	(0.0030)	(0.0155)
Labor-saving × 2003–2013	0.0285***	0.0146***	0.0662***
	(0.0080)	(0.0045)	(0.0187)
Labor-intensive × 2001–2002	−0.0173***	−0.0103***	−0.0493***
	(0.0051)	(0.0030)	(0.0147)
Labor-intensive × 2003–2013	−0.0239***	−0.0108**	−0.0503***
	(0.0076)	(0.0045)	(0.0182)
Observations	72,732	72,732	72,732
AMC and Year FE	Yes	Yes	Yes
Demographic controls (× Year)	Yes	Yes	Yes

Notes: Estimates of equation (2) replacing the single post indicator with separate indicators for the years of informal planting of smuggled seed, 2001–2002 (Bustos et al., 2020), and for the years after legalization, 2003–2013. The specification is otherwise identical to the controlled columns of Table 4. Standard errors in parentheses, clustered at the AMC level. *p≤0.1, **p≤0.05, ***p≤0.01.

F.12 The Smuggling Window in the First Stage

Table F.12: The Smuggling Window (2001–2002) and the Legal Period (2003–2013): Adoption

	Asinh(Soy area)	**Asinh(Maize area)**
	(1)	(2)
Labor-saving × 2001–2002	0.1499***	0.0594
	(0.0467)	(0.0522)
Labor-saving × 2003–2013	0.4810***	−0.0585
	(0.0799)	(0.0565)
Labor-intensive × 2001–2002	−0.0124	0.3036***
	(0.0537)	(0.0774)
Labor-intensive × 2003–2013	−0.1370	0.1902***
	(0.0892)	(0.0726)
Observations	72,732	72,732
AMC and Year FE	Yes	Yes

Notes: The specification of Table 1 with the single post indicator replaced by separate indicators for the years of informal planting of smuggled seed, 2001–2002 (Bustos et al., 2020), and for the years after legalization, 2003–2013. Outcomes are the inverse hyperbolic sine of soy and maize harvested area (PAM). Standard errors in parentheses, clustered at the AMC level. *p≤0.1, **p≤0.05, ***p≤0.01.

F.13 Net Migration

Table F.13: Net Migration and the Two Technology Shocks

	Net migration rate			
	(1)	(2)	(3)	(4)
Labor-saving	−0.0215	−0.0122	0.0204	−0.0194
	[0.0057]***	[0.0063]*	[0.0052]***	[0.0050]***
Labor-intensive	0.0314	0.0233	−0.0006	0.0245
	[0.0059]***	[0.0062]***	[0.0058]	[0.0053]***
Design	DiD	DiD	Cross-section	Cross-section
Observations	7,656	7,656	3,828	3,828
AMC and Period FE	Yes	Yes	No	No
Baseline controls	No	Yes	No	Yes

Notes: Net migration rates by AMC and census decade, which we construct from the 1991, 2000, and 2010 census microdata with the cohort average method (Shryock et al., 1980) used by Bustos et al. (2016). The method compares each age cohort's population in a census with the population its survival would predict from the census before, using the national survival rate for that cohort, and divides net migrants, summed over ages 10 to 60, by the area's total initial population. Columns (1) and (2) stack the 1991–2000 and 2000–2010 rates and estimate equation (2), with the 2000–2010 decade as the post period and standard errors clustered at the AMC level. In column (2) the 1991 baseline controls are interacted with the period. Columns (3) and (4) are cross-sections of the 2000–2010 rate with robust standard errors. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.14 Spatial Spillovers

Table F.14: Spatial Spillovers: Exposure to the Neighbors' Shocks

	Asinh(Operations w/ slavery)			**Asinh(Enslaved workers)**		
	Baseline	$\delta = 1$	$\delta = 3$	Baseline	$\delta = 1$	$\delta = 3$
	(1)	(2)	(3)	(4)	(5)	(6)
Labor-saving	0.0367	0.0457	0.0637	0.0909	0.1020	0.1082
	[0.0071]***	[0.0120]***	[0.0246]***	[0.0155]***	[0.0261]***	[0.0461]**
Neighbors' soy exposure		−0.0510	−0.0360		−0.0710	−0.0261
		[0.0263]*	[0.0247]		[0.0599]	[0.0464]
Labor-intensive	−0.0230	−0.0390	−0.0600	−0.0518	−0.0810	−0.0987
	[0.0061]***	[0.0118]***	[0.0241]**	[0.0145]***	[0.0263]***	[0.0466]**
Neighbors' maize exposure		0.1151	0.0548		0.2338	0.0783
		[0.0371]***	[0.0267]**		[0.0856]***	[0.0529]
Observations	72,732	72,732	72,732	72,732	72,732	72,732
AMC and Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Estimates of equation (2). Columns (2)–(3) and (5)–(6) add, following the logic of Adao et al. (2019), the neighbors' exposures of equation (6), the averages of the other AMCs' suitability differentials weighted by centroid distance with decay $d^{-\delta}$, interacted with $Post_t$. A flatter decay averages suitability over a broader region. Standard errors in brackets, clustered at the AMC level. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

F.15 Farm-Size Composition in Cattle Ranching

Table F.15: Farm-Size Composition in Cattle Ranching: Shares of Establishments

	Share small (< 10 ha)	**Share medium** (10–100 ha)	**Share large** (> 100 ha)
Soy Diff. $\times$ Post	0.025**	-0.004	-0.007
	[0.010]	[0.010]	[0.006]
Maize Diff. $\times$ Post	-0.045***	0.022**	-0.002
	[0.013]	[0.011]	[0.006]
Baseline share (1996)	0.331	0.468	0.198
Observations	7,601	7,601	7,601
AMC and Census FE	Yes	Yes	Yes

Notes: Difference-in-differences estimates on the 1996 and 2006 Censuses of Agriculture for establishments whose main activity is livestock ("Pecuária" in the 1995–96 census, and the CNAE livestock group in 2006). Outcomes are the shares of the sector's establishments in each size class. The panel is AMC by census year, restricted to cells with at least one livestock establishment. Both treatments enter jointly with AMC and census fixed effects. Standard errors clustered by AMC in brackets. * p<0.10, ** p<0.05, *** p<0.01.

F.16 Slavery in Cattle Ranching, Conditional on the Sector's Scale

Table F.16: Slavery in Cattle Ranching, Holding the Sector's Scale Fixed

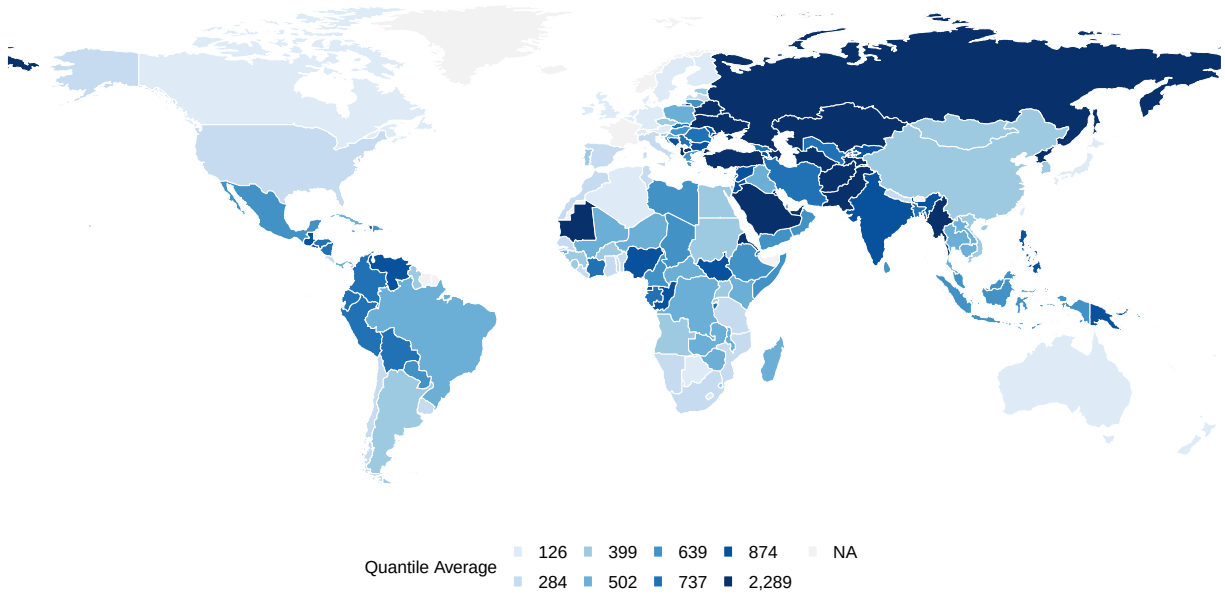
	(1)	(2)	(3)	(4)
Panel A. Asinh(Operations w/ slavery, cattle ranching)				
Labor-saving × Post	0.026***	0.026***	0.027***	0.017***
	[0.006]	[0.006]	[0.006]	[0.004]
Labor-intensive × Post	−0.019***	−0.019***	−0.020***	−0.014***
	[0.005]	[0.005]	[0.005]	[0.004]
R^2	0.494	0.495	0.496	0.500
Panel B. Asinh(Enslaved workers, cattle ranching)				
Labor-saving × Post	0.060***	0.060***	0.063***	0.041***
	[0.013]	[0.013]	[0.013]	[0.011]
Labor-intensive × Post	−0.042***	−0.042***	−0.044***	−0.033***
	[0.011]	[0.011]	[0.011]	[0.009]
R^2	0.455	0.455	0.456	0.460
Herd (asinh, contemporaneous)	No	Yes	Yes	Yes
Pasture (asinh, contemporaneous)	No	No	Yes	Yes
Baseline controls × year	No	No	No	Yes
Observations	68,904	68,904	68,886	68,886

Notes: Estimates of equation (2) on the 1996–2013 annual panel, with the inverse hyperbolic sine of operations with detected slavery (Panel A) and of enslaved workers (Panel B) at establishments whose activity is cattle ranching. Columns (2) to (4) add the inverse hyperbolic sine of the municipality's contemporaneous cattle herd (PPM) and pasture area (MapBiomas cover share converted to hectares) as controls, so the estimates hold the scale of the sector fixed. A response that ran through the sector growing or contracting would be absorbed by these controls. Standard errors clustered by AMC in brackets. * p<0.10, ** p<0.05, *** p<0.01.

G Additional Figures

G.1 Global Prevalence of Modern Slavery

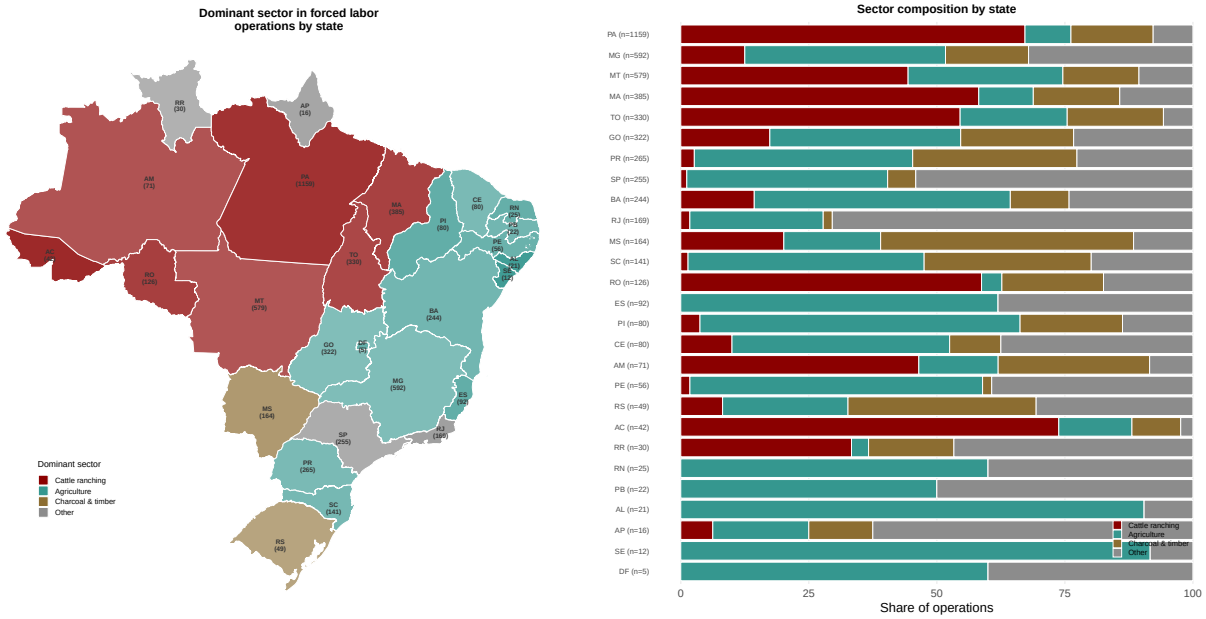
Figure G.1: Estimated Prevalence of Modern Slavery Across Countries, 2022



Notes: The map shades countries by the estimated number of people in modern slavery per 100,000 inhabitants in 2021. The estimated global total is 50 million. *Source*: Walk Free Global Slavery Index (Walk, 2023).

G.2 Forced-Labor Operations by Sector

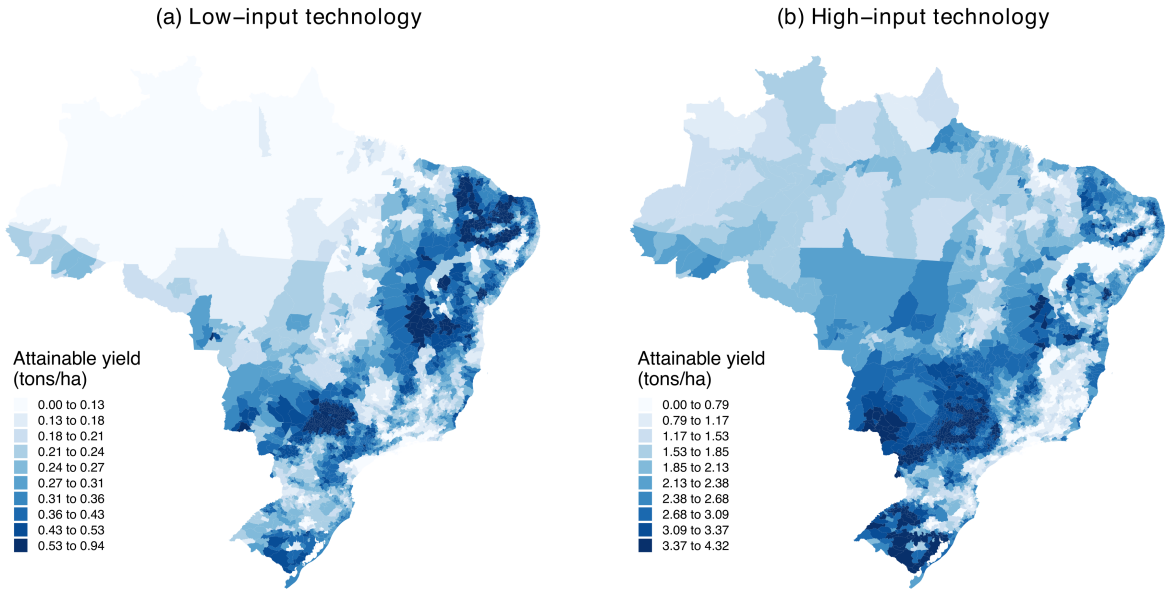
Figure G.2: Forced-Labor Operations by Sector



Notes: The left panel maps the dominant sector of forced-labor operations by state. The right panel shows each state's sector composition of operations. *Source*: Ministry of Labor inspection records.

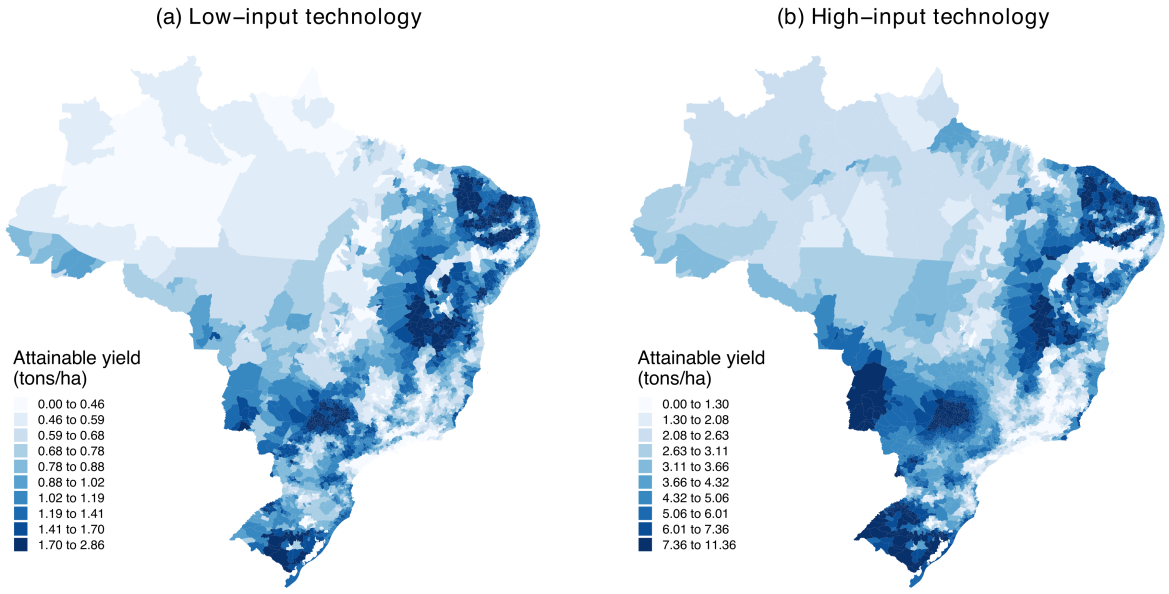
G.3 Attainable Yields Under the Two Input Packages

Figure G.3: FAO-GAEZ Attainable Soy Yields, Low- and High-Input Technology



Notes: The maps shade AMCs by the FAO-GAEZ attainable soy yield, in tons per hectare, under the low-input package in panel (a), rain-fed and worked with traditional practices and manual labor, and under the high-input package in panel (b), with mechanization, improved varieties, and chemical inputs. Each panel is binned by its own deciles, so the two color scales are independent and each map shows the geography of its own surface. The log difference of the two surfaces is the treatment of equation (1).

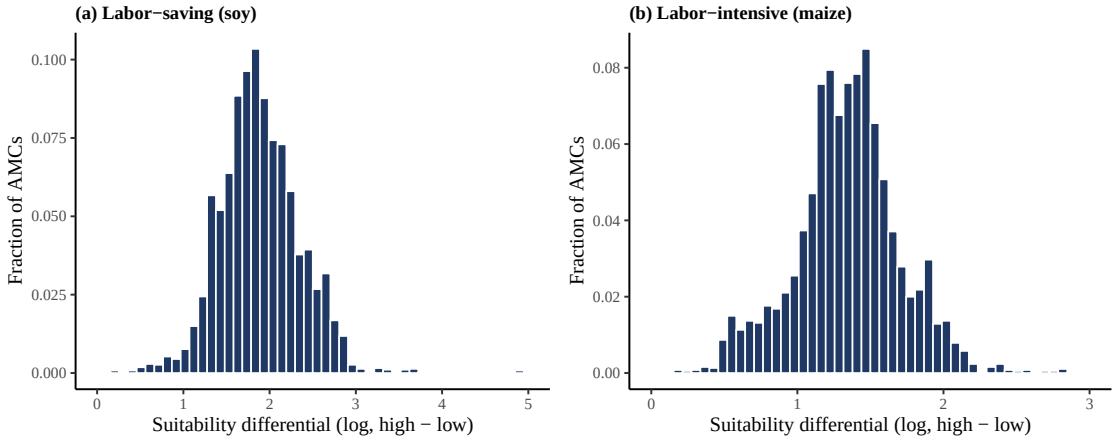
Figure G.4: FAO-GAEZ Attainable Maize Yields, Low- and High-Input Technology



Notes: The maps shade AMCs by the FAO-GAEZ attainable maize yield, in tons per hectare, under the low-input package in panel (a) and the high-input package in panel (b), each panel binned by its own deciles with independent color scales. The log difference of the two surfaces is the treatment of equation (1).

G.4 Cross-Sectional Variation in Exposure to the Technologies

Figure G.5: Cross-Sectional Variation in Exposure to the New Technologies

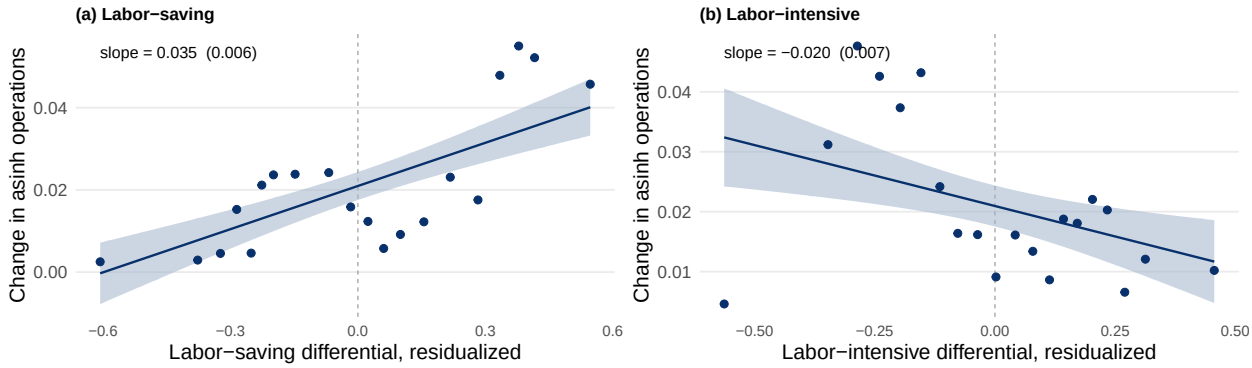


Notes: The figure plots the distribution of productivity gains for soy and maize. Gains are measured as the log difference between attainable yields under high-input and low-input conditions, following Bustos et al. (2020). Data are from FAO-GAEZ.

G.5 The Response Against the Residualized Differentials

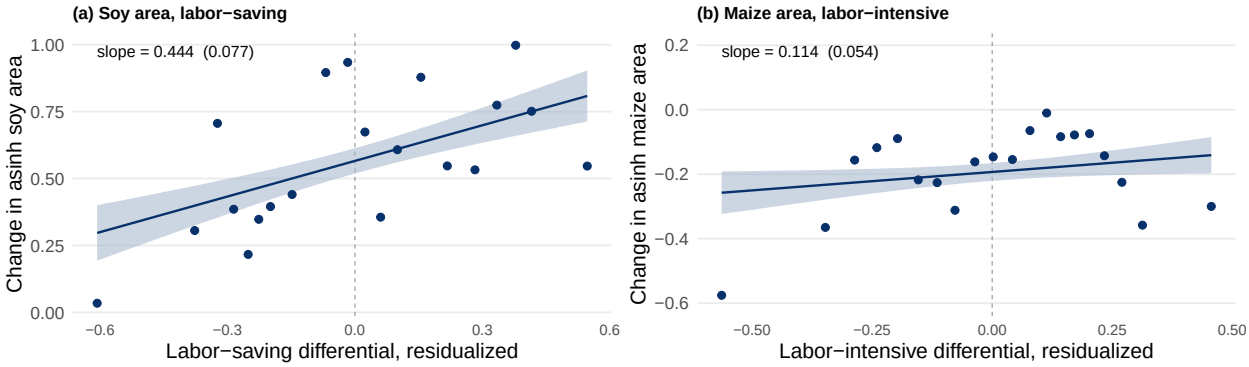
The two differentials are correlated at 0.82 across municipalities, so the joint specification identifies each coefficient from the variation in one differential that remains after conditioning on the other. The figures below plot the outcome and the first stage against that residual variation directly, with the slopes reproducing the panel estimates, and Figure G.8 shows the joint support of the two differentials and the outcome across it. The variation is not regional, since state indicators explain 37 percent of its variance on the labor-saving side and 27 percent on the labor-intensive side, and 17 and 19 of the 27 states hold municipalities on both sides of zero.

Figure G.6: Slavery Against the Residualized Differentials



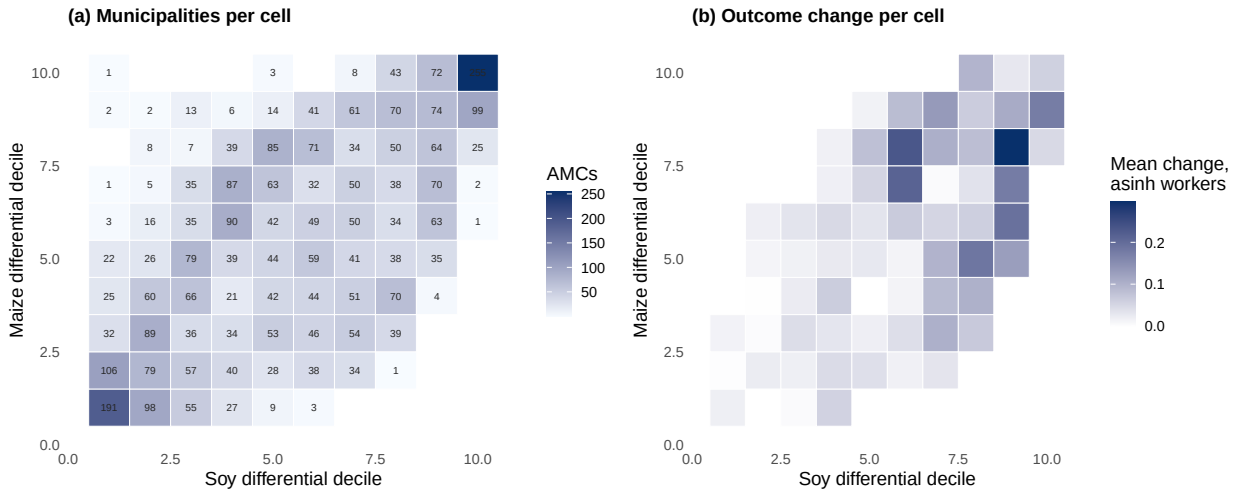
Notes: Binned means over the 3,828 AMCs, twenty bins. The outcome is the change in the inverse hyperbolic sine of operations with detected slavery, the post-period mean minus the pre-period mean. In panel (a) the labor-saving differential is residualized on the labor-intensive one, and in panel (b) the reverse. Lines are fit on the underlying municipalities, and the slopes, 0.037 and −0.023, reproduce the estimates of Table 4.

Figure G.7: The First Stage Against the Residualized Differentials



Notes: Binned means over the 3,828 AMCs, twenty bins. Outcomes are the changes in the inverse hyperbolic sine of soy harvested area, in panel (a) against the residualized labor-saving differential, and of maize harvested area, in panel (b) against the residualized labor-intensive differential. The soy slope, 0.43, reproduces the first stage of Table 1.

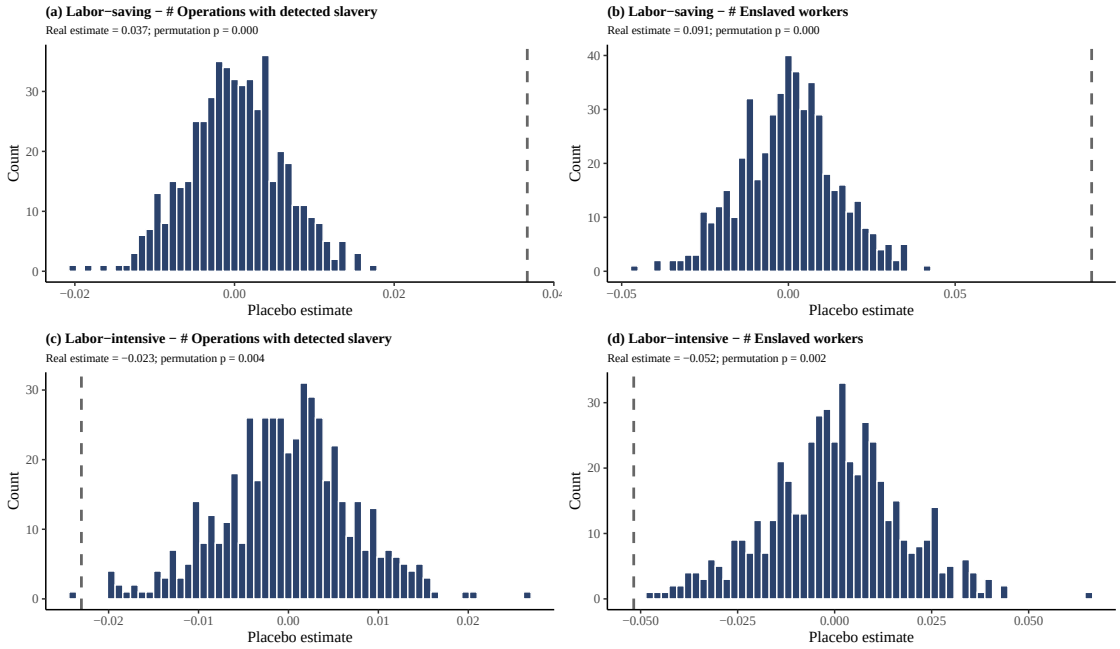
Figure G.8: Support and the Outcome Across the Two Differentials



Notes: Panel (a) counts municipalities in each cell of the soy-by-maize decile grid, the joint support of the two differentials, with the 0.82 correlation visible along the diagonal and the off-diagonal corners nearly empty. Panel (b) shades the cells with ten or more municipalities by the mean change in the inverse hyperbolic sine of enslaved workers, the post-period mean minus the pre-period mean, and the change rises with the soy decile within maize deciles.

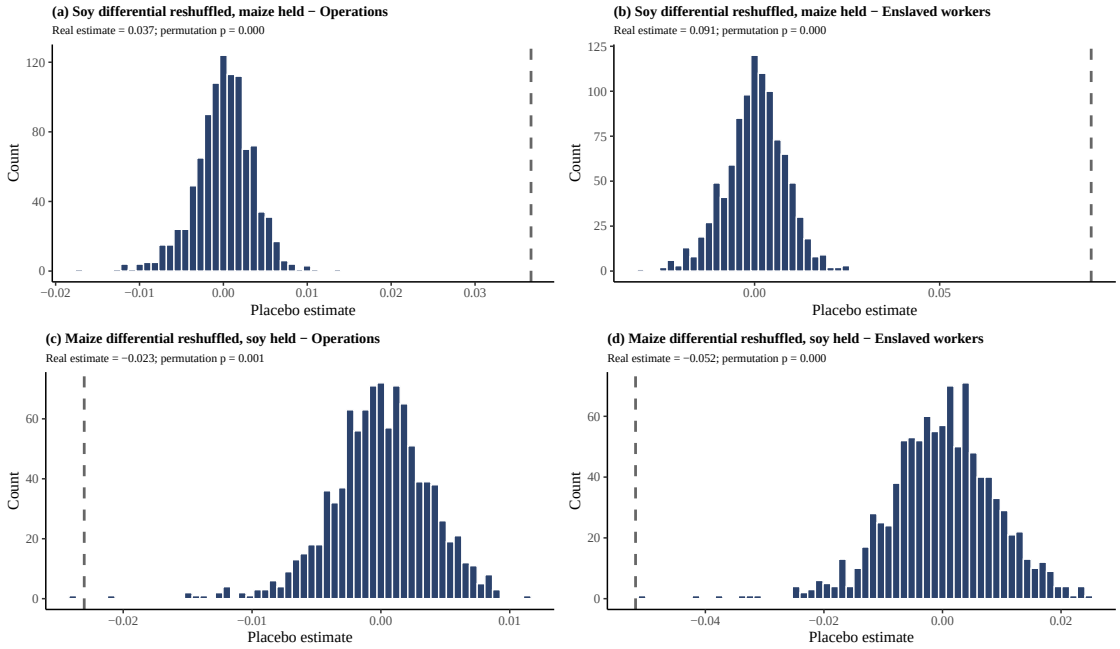
G.6 Permutation Test

Figure G.9: Technological Change and Modern Slavery: Permutation Test



Notes: The figure plots the distribution of placebo coefficients. We randomly reassign the municipality productivity-gain measures and re-estimate the joint specification with the implied placebo treatments. The vertical line marks the true estimate.

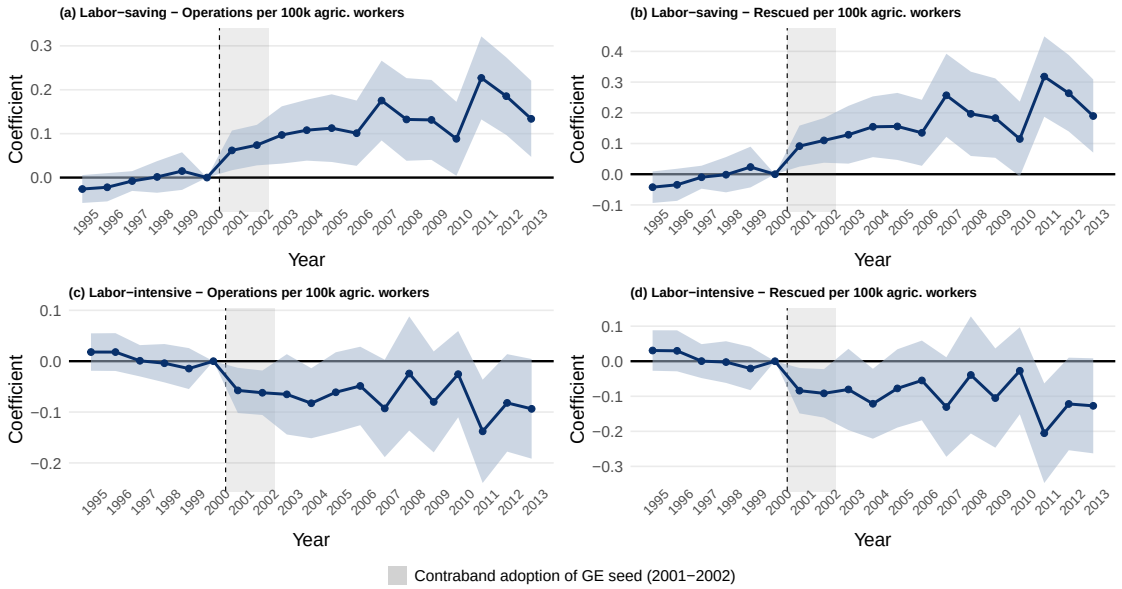
Figure G.10: Permutation Test Reshuffling One Treatment at a Time



Notes: Each panel reshuffles one suitability differential across municipalities while the other differential keeps its true values, and re-estimates the joint specification on 1,000 draws. The histogram plots the placebo coefficients of the reshuffled treatment and the dashed line marks the true estimate, so the test asks whether the residual variation of each treatment, conditional on the other, holds a signal of its own. The permutation p-values are at or below 0.001 in all four panels. Panels (a) and (b) reshuffle the soy differential, panels (c) and (d) the maize differential.

G.7 Slavery Rate per Agricultural Worker

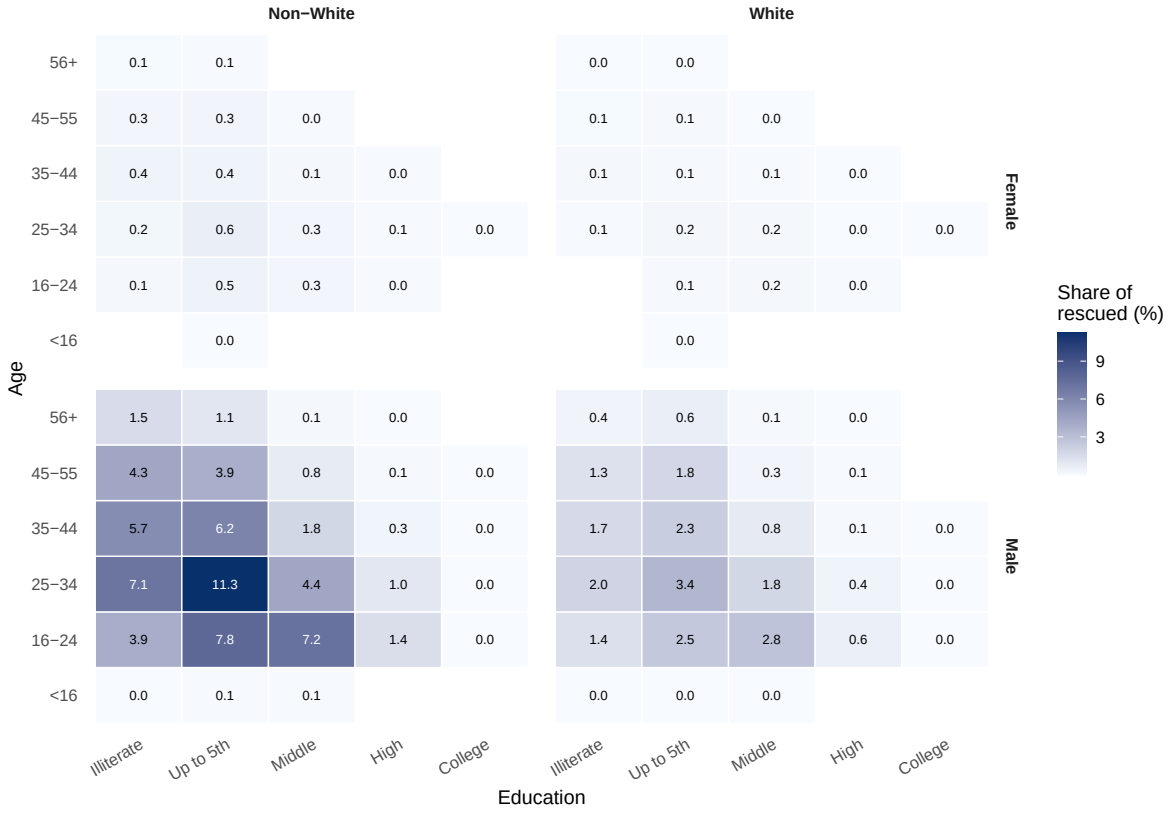
Figure G.11: Local Effects on the Rate of Slavery per Agricultural Worker



Notes: The figure plots coefficients and 95% confidence intervals from the event-study specification of Section 5. The dependent variables are the inverse hyperbolic sine of operations with detected slavery, in panels (a) and (c), and of rescued workers, in panels (b) and (d), per 100,000 formal agricultural workers in RAIS, the denominator the panel labels shorten to agricultural workers. Standard errors are clustered at the AMC level. The main-text composition table (Section 7.2) uses the at-risk employment denominator instead.

G.8 Composition of the Rescued by Race

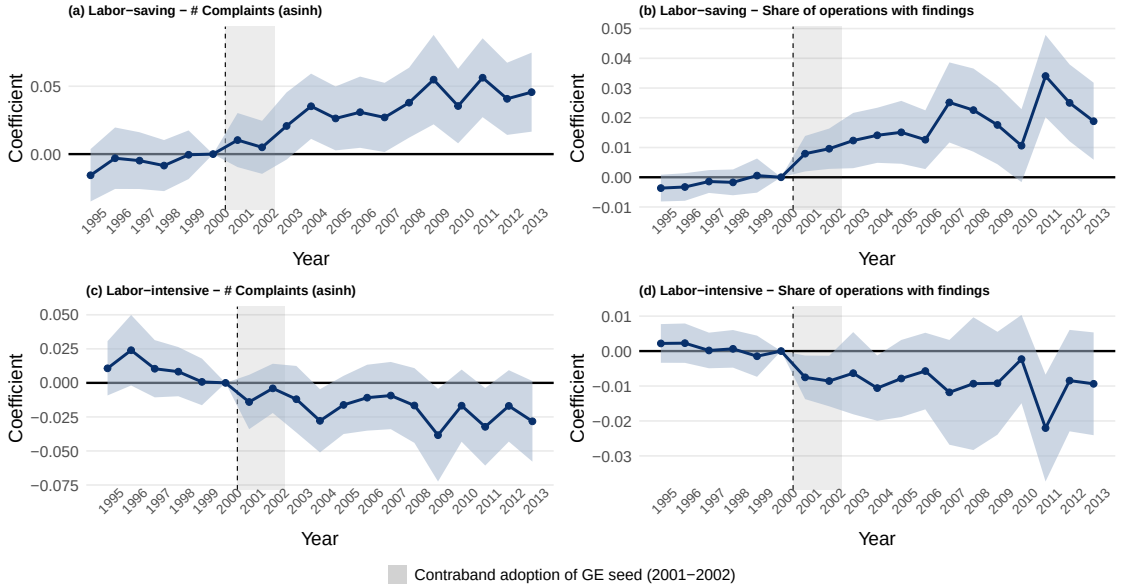
Figure G.12: Composition of Rescued Workers by Demographic Cell, with Race



Notes: Each cell shows the share of rescued workers (percent) in an age band by education by sex by race cell, among the records with race recorded, about a third of the total (Section 4.1). The reweighting weights of Section 6 leave race out and use the full set of records; this figure adds the race dimension for the subset that reports it. *Source*: Ministry of Labor individual rescue records, 2002–2013.

G.9 Alternative Outcomes

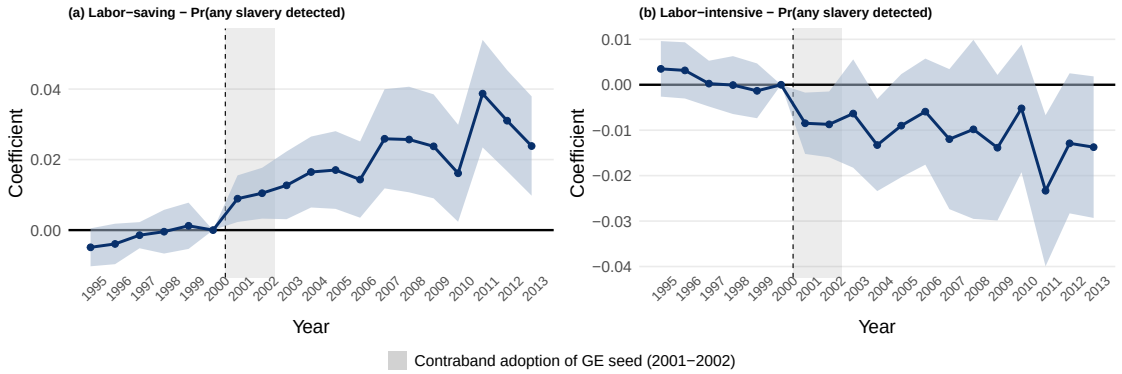
Figure G.13: Technological Change and Modern Slavery: Alternative Measures



Notes: The figure plots coefficients and 95% confidence intervals from the event-study specification of Section 5 for alternative slavery outcomes (complaints and the share of operations with findings). Standard errors are clustered at the AMC level.

G.10 Extensive Margin

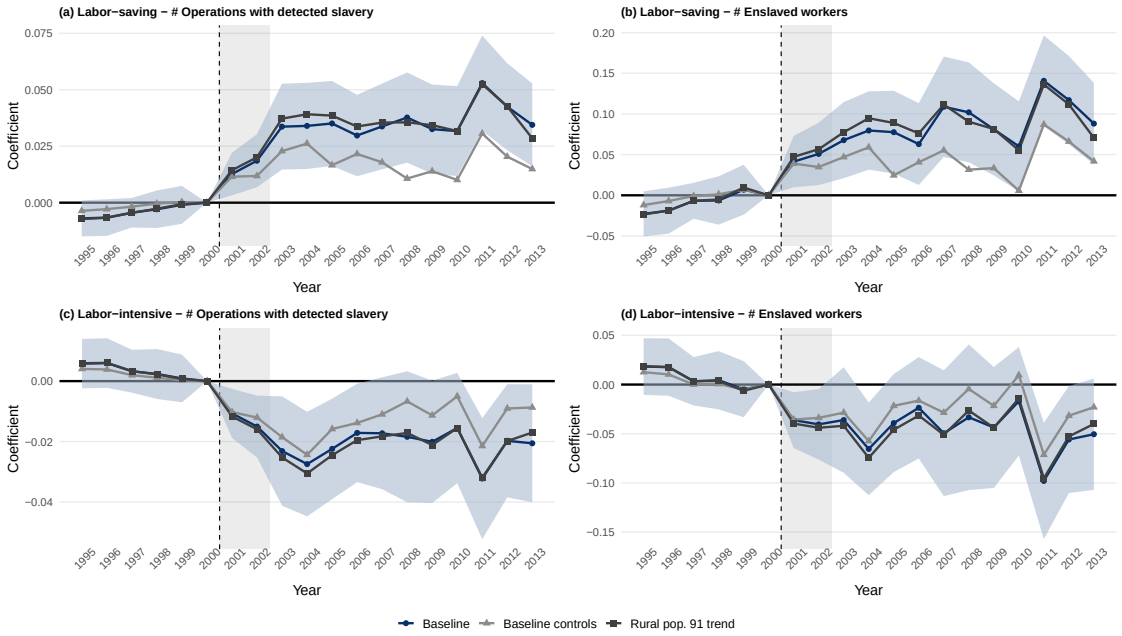
Figure G.14: Technological Change and Modern Slavery: Extensive Margin



Notes: The figure plots coefficients and 95% confidence intervals from the event-study specification of Section 5. The dependent variable is an indicator equal to one if at least one operation found modern slavery. Standard errors are clustered at the AMC level.

G.11 Event Studies Under Alternative Specifications

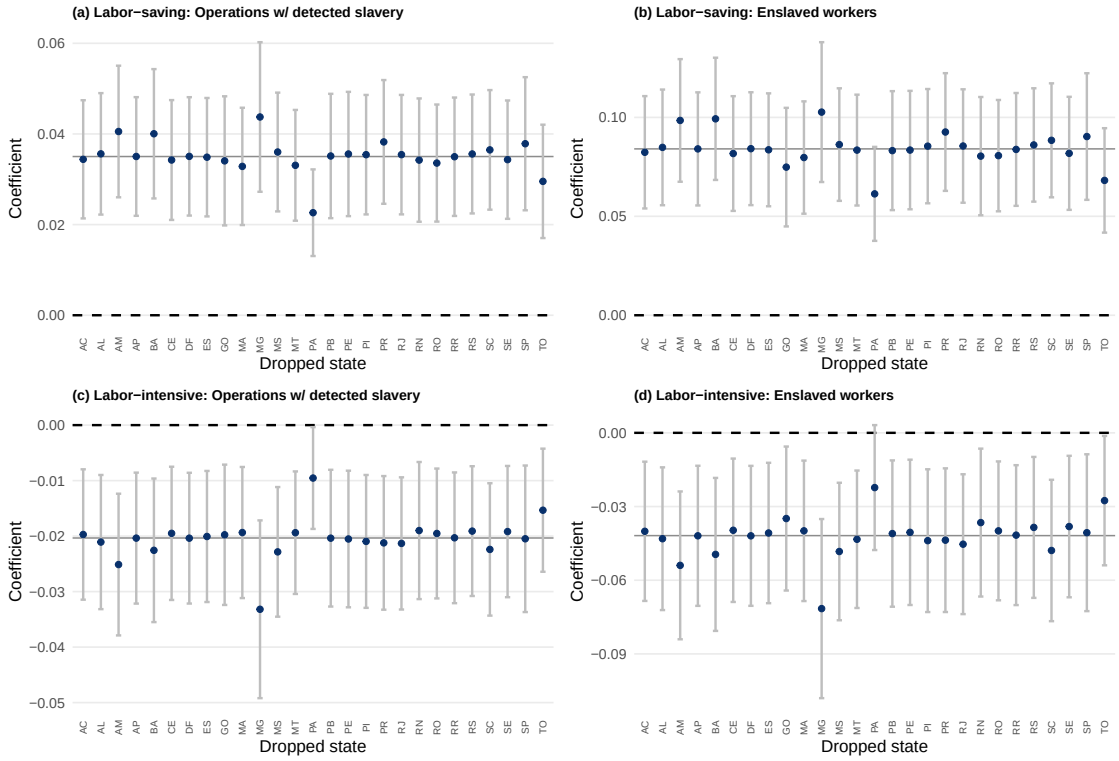
Figure G.15: Event Studies Under Alternative Specifications



Notes: Estimates of equation (3) under three specifications, the baseline with AMC and year fixed effects, in black with its 95 percent confidence interval shaded, the baseline adding the 1991 characteristics interacted with year, in grey, and the baseline adding a trend in the 1991 rural population share, in blue. Panels (a) and (b) plot the coefficients on the soy differential for operations with detected slavery and for enslaved workers. Panels (c) and (d) plot the coefficients on the maize differential. The omitted year is 2000. Standard errors are clustered at the AMC level.

G.12 Leave-One-State-Out

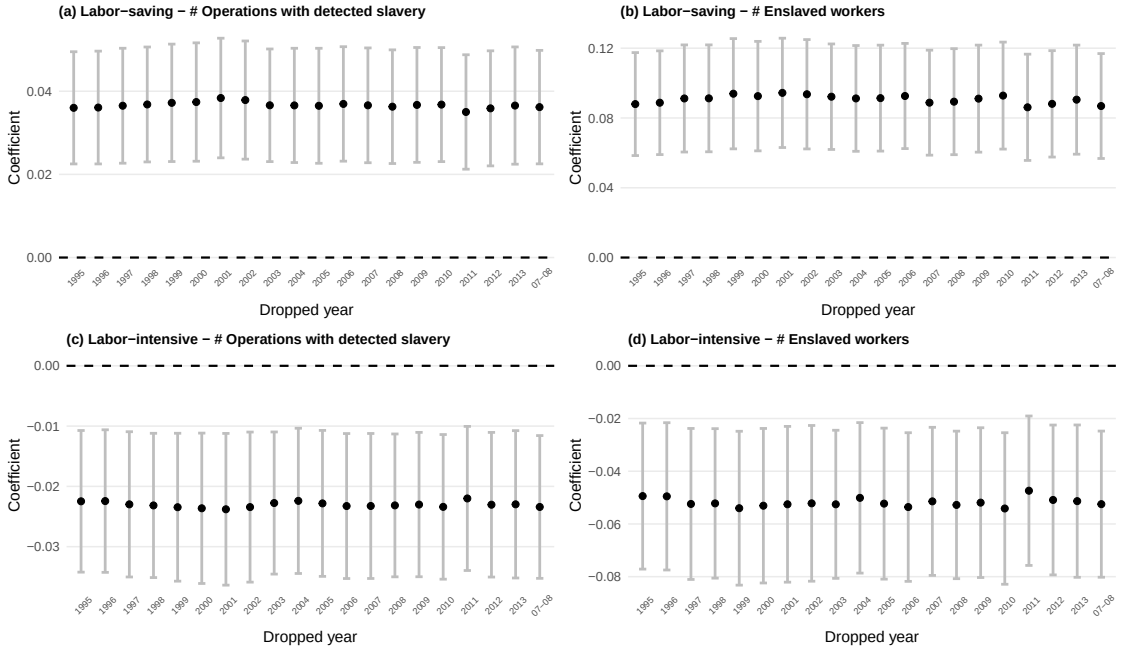
Figure G.16: Leave-One-State-Out Estimates



Notes: Each point re-estimates equation (2) excluding one state at a time. Bars are 95 percent confidence intervals with standard errors clustered at the AMC level, the dashed line marks zero, and the solid grey line marks the full-sample estimate. Panels (a) and (b) plot the coefficient on the soy differential for operations with detected slavery and for enslaved workers. Panels (c) and (d) plot the coefficient on the maize differential.

G.13 Leave-One-Year-Out

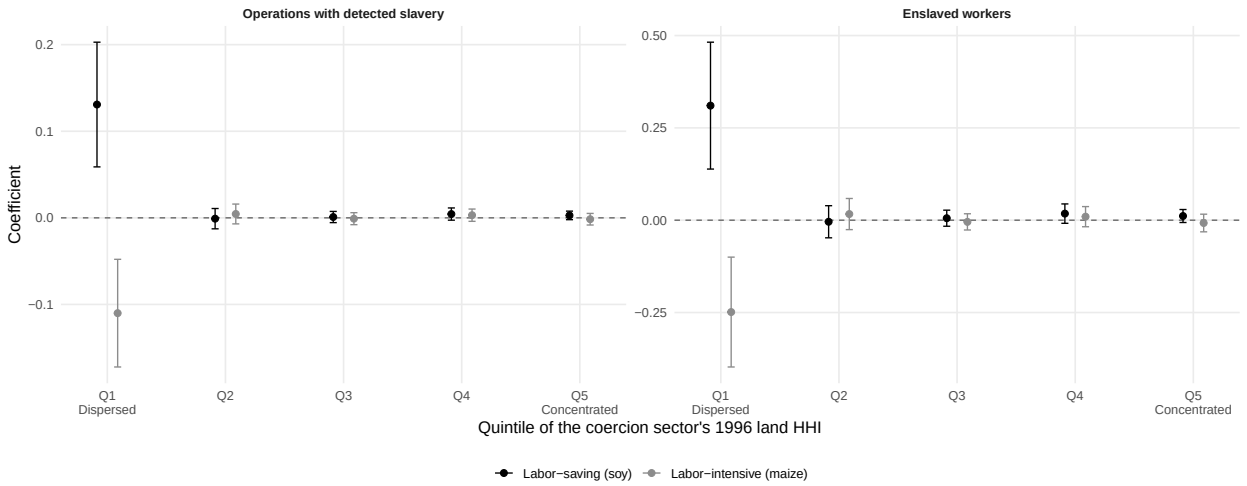
Figure G.17: Leave-One-Year-Out Estimates



Notes: Each point re-estimates equation (2) excluding one year of the panel at a time, with the last entry excluding 2007 and 2008 together, the peak of inspection activity. Bars are 95 percent confidence intervals with standard errors clustered at the AMC level and the dashed line marks zero. Panels (a) and (b) plot the coefficient on the soy differential for operations with detected slavery and for enslaved workers. Panels (c) and (d) plot the coefficient on the maize differential.

G.14 The Response Along the Concentration Distribution

Figure G.18: The Slavery Response by Quintile of the Coercion Sector's Land Concentration



Notes: Each point estimates equation (2), with the baseline controls interacted with year, on the municipalities of one quintile of the coercion sector's 1996 land HHI, the concentration measure of Table 6. Black points are the coefficients on the soy differential and grey points the coefficients on the maize differential, with 95 percent confidence intervals, standard errors clustered at the AMC level. The dashed line marks zero.