Electoral Accountability After Economic Shocks: Evidence from Mayoral Elections in Brazil*

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Abstract

This paper examines how exogenous economic shocks shape electoral accountability in local elections. We develop a theoretical model in which a sudden increase in household income boosts short-term support for incumbents, even when the shock is unrelated to their actions. Over time, however, voters adapt their expectations, and the incumbent's advantage subsides. We test the model in the context of Brazil's 2003 legalization of genetically engineered soybean seeds, which generated uneven gains in productivity across municipalities due to variation in climate and soil. Leveraging this quasi-natural experiment for the 2000-2020 period, we show that incumbent mayors were more likely to be reelected in municipalities that experienced larger productivity gains, though this effect was short-lived. Our findings highlight how misattribution and voter learning jointly shape the electoral consequences of economic change in developing countries, which are more vulnerable to exogenous shocks due to their structural reliance on commodity exports.

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1 Introduction

Economic voting is an important instrument of democratic accountability: citizens reward or punish incumbents based on economic performance (Duch & Stevenson, 2008). For example, presidential elections in 13 Latin American countries from 1980 to 2003 show that a one percentage point decrease in per capita gross domestic product (GDP) is associated with a 1.7 percentage point decline in the vote share of the incumbent party (Benton, 2005). This principle of economic voting rests on a key assumption: clarity of responsibility. Voters must correctly discern who is responsible for economic outcomes. In practice, however, voters often struggle to disentangle government action from external shocks (Achen & Bartels, 2017). Wars, pandemics, natural disasters, commodity price shocks, global inflationary pressures, and other external events impact the local economy independently of domestic policies, distorting voters' perception of the incumbent's economic performance and undermining electoral accountability.[1] These challenges are particularly acute in developing countries, which are most vulnerable to external shocks due to their heavy reliance on exporting oil, iron ore, soybeans, sugar, coffee, orange juice, and other commodities (Campello & Zucco, 2016).

Much of the literature on economic voting and clarity of responsibility focuses on national-level outcomes (e.g. Campello & Zucco, 2020; Lewis-Beck & Stegmaier, 2000; Lewis-Beck et al., 2008; Nadeau et al., 2013). Building on Novaes and Schiumerini (2022) and Larsen et al. (2019), we examine how exogenous economic shocks affect electoral accountability at the local level. Specifically, we focus on Brazil's 2003 legalization of genetically engineered (GE) soy seeds, a "quasi-natural" experiment that led to uneven increases in agricultural productivity across municipalities due to variation in soil and climate conditions. In soy-producing regions, this technical change improved productivity, reduced labor intensity, promoted industrial growth, and spurred capital accumulation, changes that were largely exogenous to local

[1] Irrelevant events like local college football games (Healy et al., 2010) and shark attacks (Achen & Bartels, 2017) might also affect voting behavior, though recent studies have called both findings into question (Fowler & Hall, 2018; Fowler & Montagnes, 2015).

politics (Bustos et al., 2016, 2020).

We argue that this exogenous shock distorted electoral accountability, particularly in the early years following GE soy seed legalization. Using data on mayoral elections from 2000 to 2020, we show that incumbent mayors were more likely to win reelection in municipalities with higher gains in soy productivity. In these municipalities, voters initially misattributed the resulting economic gains to mayoral policies. Still, this misattribution was short-lived: it peaked in the 2008 election and disappeared thereafter. Our findings suggest that voters temporarily rewarded incumbents for perceived economic improvements, but adjusted their expectations over time. In identifying the potential for misattribution in new democracies like Brazil, our findings also underscore the temporal dynamic of voter learning.

The remainder of the paper is structured as follows. First, we review the rich literature on electoral accountability with a focus on commodity-exporting developing countries, where accountability challenges are more widespread. Second, we develop a theoretical-formal framework to examine how exogenous economic shocks impact the fortunes of incumbents in local elections, deriving testable hypotheses from the main predictions. After describing our case selection and the corresponding data, we present preliminary empirical results that confirm our expectations. We conclude by discussing future strategies to test the proposed mechanism.

2 Electoral Accountability and Commodity Dependence

In democracies, a central challenge to electoral accountability is that voters struggle to connect unexpected events to their global causes (Campello & Zucco, 2020; Lewis-Beck & Stegmaier, 2000; Nadeau et al., 2013). Without reliable information, individuals may mistakenly credit incumbents for economic upturns and provide undue political support or punish incumbents for circumstances outside the control of domestic leadership.

This challenge is particularly acute in developing countries, where economic performance depends on exchange rates, US interest rates, international trade policies, commodity prices, and other factors largely beyond the incumbent's control (Campello & Zucco, 2016). While industrialized nations are susceptible to the same global economic shocks, they tend to have diversified economies, easy access to financial markets, and more robust welfare systems that help them weather difficult times (Wibbels, 2006). In contrast, most developing countries have undiversified economies: they rely on exporting a few commodities, like oil, natural gas, soybeans, sugar, coffee, wheat, and cotton, all of which have volatile prices. When commodity prices are high, incumbents might prioritize short-term policies that bring immediate electoral gains, hoping to receive credit for economic success. Conversely, in times of downturn, even the most qualified and effective leaders might be unfairly blamed and voted out of office.

Even during commodity booms, the improvements voters hope for might not materialize. In Brazil, oil windfalls translate into increased revenue and, consequently, increased reported spending on public goods and services, yet concrete benefits — like educational and health inputs, infrastructure, and household income — increase far less than one would expect, due to corruption and patronage (Caselli & Michaels, 2013). In São Tomé and Príncipe, there is similar evidence that oil discovery announcements increase perceived corruption (Vicente, 2010). Driven by excessive optimism, the electorate might exaggerate the likely revenues (Collier, 2017) and not only reward the wrong political actor, but also do so based on perceived, illusory gains.

Commodity dependence can distort accountability in one additional way: by amplifying institutional features that obscure responsibility and undermine governance. In presidential systems, divided governments (where the executive and the legislative come from different parties) can obscure responsibility (Samuels, 2004). Term limits reduce incentives for good performance during an incumbent's final term, and weak parties rarely discipline their members or offer consistent platforms. In Brazil, Colombia, Mexico, and elsewhere, voters often punish the parties of underperforming incumbents, creating an "incumbency curse:" parties that barely win a mayoral election are more likely to lose in the following cycle (Klašnja & Titiunik, 2017). However, since incumbents can easily switch parties or continue their careers elsewhere, this punishment affects the party, not the individual, and rarely translates into improved governance. This "incumbency curse" — like its counterpart, the "incumbency blessing" — is particularly prevalent in rural areas, which Novaes and Schiumerini (2022) attribute to commodity dependence. Sanctioning parties, not individuals, further weakens the link between performance and accountability. When external shocks cloud citizens' ability to hold leaders responsible for economic performance, the result is political volatility and frequent turnover that can weaken democratic institutions, particularly in contexts where such institutions are weak to begin with.

3 The Argument

We study a dynamic electoral environment in which municipalities r hold mayoral elections at discrete dates $t \in \{-1, 0, 1, 2, \ldots\}$. Each municipality contains a unit continuum of risk-neutral voters indexed by $i \in [0, 1]$. Politicians are *ex-ante* identical, so elections function solely as a mechanism for retrospective accountability rather than for selecting among heterogeneous types (Ashworth, 2012).

At $t = 0$, municipality r receives an exogenous, positive income windfall $\Delta A_r > 0$ that we treat as permanent for analytical convenience, even though, in reality, it may simply be long-lasting. Such a shock might result from the adoption of new extraction technologies, an expansion of arable land, the introduction of high-yield crop varieties, or the discovery of natural resources. The windfall is realized before the $t = 0$ election, so voters' income at that period already includes the shock.

3.1 Income, Exposure, and Expectations

Voters do not directly observe policy effort or quality. Instead, following the logic of retrospective voting (Fearon, 1999; Wolfers, 2007), they use their own material outcomes — particularly income — as a proxy for performance. Two dimensions of household-level heterogeneity shape how income responds to shocks.

First, individuals differ in their exposure to the regional windfall. Let $\theta_{i,r} \in [\eta, 1]$ denote the exposure of voter i in municipality r, where $0 < \eta < 1$ is the lowest spillover any resident receives. Households directly involved in commodity-related activities — production or extraction, transport, or processing — obtain the full benefit, $\theta_{i,r} = 1$; all others receive only the baseline spillover, potentially capturing general equilibrium impacts, $\theta_{i,r} = \eta$. Exposure is taken as exogenous and time-invariant, with the cumulative distribution $F_r(\theta)$ as common knowledge. Thus, we have that:

$$\theta_{i,r} = \begin{cases} 1, & \text{if } i \text{ is directly employed in the commodity sector in region } r, \\ \eta, & \text{otherwise} \end{cases}$$

Second, voters differ in their baseline income levels. Let $\mu_{i,r}$ denote the pre-shock income of individual i in municipality r, capturing heterogeneity unrelated to the commodity windfall. Each period, income is further affected by an idiosyncratic zero-mean shock $\varepsilon_{i,r,t} \sim \mathcal{N}(0, \sigma_\varepsilon^2)$, which we assume is independent across individuals, municipalities, and time. The variables $\mu_{i,r}$, $\theta_{i,r}$, and $\varepsilon_{i,r,t}$ are mutually independent; $\theta_{i,r}$ is drawn once — prior to $t = -1$ — and remains fixed thereafter. Consequently, the observed income of voter i in municipality r at date t is given by:

$$y_{i,r,t} = \mu_{i,r} + \theta_{i,r}\mathbb{I}_{\{t\geq 0\}}\Delta A_r + \varepsilon_{i,r,t} \tag{1}$$

where $\mathbb{I}_{\{t\geq 0\}}$ is an indicator function that equals 1 from $t = 0$ onward and 0 beforehand.

Following the adaptive-expectations tradition, voters compare their current income with a moving reference point that adjusts gradually. Let $\lambda \in (0,1)$ denote the speed of adaptation. The reference income evolves according to:

$$\bar{y}_{i,r,t} = (1-\lambda)\,\bar{y}_{i,r,t-1} + \lambda\, y_{i,r,t-1}, \qquad \bar{y}_{i,r,-1} = \mu_{i,r} \tag{2}$$

From Equation (2), voters are therefore initially surprised by the windfall, but as new income realizations arrive, their benchmark converges toward the post-shock level.

Substituting (1) into (2) and iterating forward yields the closed-form path of the reference income:

$$\bar{y}_{i,r,t} = \mu_{i,r} + \big[1-(1-\lambda)^{t+1}\big]\theta_{i,r}\,\mathbb{I}_{\{t\geq 0\}}\Delta A_r + \sum_{s=-1}^{t-1}(1-\lambda)^{t-1-s}\,\varepsilon_{i,r,s} \tag{3}$$

where the first term is the pre-shock baseline, the second captures the gradually internalized income windfall, and the third is a geometrically weighted history of idiosyncratic shocks. Note that $\lim_{t\to\infty}\bar{y}_{i,r,t} = \mu_{i,r} + \theta_{i,r}\Delta A_r$; i.e., the reference point converges to the post-shock steady state.

3.2 Sanctioning Behavior and Support for the Incumbent

Voters sanction the mayor by comparing their *current* income with the *reference* income formed in the previous period. The resulting satisfaction gap for voter i in municipality r at election t is defined as:

$$G_{i,r,t} \equiv y_{i,r,t} - \bar{y}_{i,r,t} \tag{4}$$

Using (1) and (3), and focusing on the post-shock years $t \geq 0$, we obtain

$$G_{i,r,t} = \theta_{i,r}\Delta A_r\gamma(t) + \varepsilon_{i,r,t} - \sum_{s=-1}^{t-1}(1-\lambda)^{t-1-s}\varepsilon_{i,r,s} \tag{5}$$

where the decay factor $\gamma(t) = (1-\lambda)^{t+1}$ captures the diminishing surprise from the income windfall as voters' expectations adjust.

Importantly, heterogeneity in baseline income $\mu_{i,r}$ does not affect the satisfaction gap, implying that voting behavior is governed solely by a voter's exposure to the regional windfall and the history of idiosyncratic shocks.

We assume a voter retains the incumbent if, and only if, her satisfaction gap is non-negative. From equation (5) we know that $G_{i,r,t}$ is the sum of independent normal shocks; conditional on exposure $\theta_{i,r}$, the satisfaction gap is therefore normally distributed with mean $\theta_{i,r}\,\Delta A_r\,\gamma(t)$ and variance σ_ε^2. Hence the probability that voter i supports the incumbent at date t is given by:

$$\Pr\big[G_{i,r,t} \geq 0 \mid \theta_{i,r}\big] \;=\; \Phi\!\left(\frac{\theta_{i,r}\,\Delta A_r\,\gamma(t)}{\sigma_\varepsilon}\right) \tag{6}$$

where $\Phi(\cdot)$ denotes the cumulative distribution function of the standard normal.

Aggregating over the continuum of voters with exposure distribution $F_r(\theta)$ yields the share of municipality r's electorate that backs the incumbent in election t:

$$S_r(t) \;=\; \int_\eta^1 \Phi\!\left(\frac{\theta\,\Delta A_r\,\gamma(t)}{\sigma_\varepsilon}\right)\, dF_r(\theta) \tag{7}$$

A particularly transparent case arises when within-region individual shock exposure takes only two values. Suppose a fraction $p \in (0,1)$ of the electorate is fully exposed ($\theta = 1$), while the remaining $1-p$ receive only the baseline spillover ($\theta = \eta$). Equation (7) then reduces to:

$$S_r(t) \;=\; p\,\Phi\!\left(\frac{\Delta A_r\,\gamma(t)}{\sigma_\varepsilon}\right) \;+\; (1-p)\,\Phi\!\left(\frac{\eta\,\Delta A_r\,\gamma(t)}{\sigma_\varepsilon}\right) \tag{8}$$

a weighted average of the approval probabilities of the two voter groups. We adopt this two-type specification for the remainder of the paper.

Elections are decided by simple majority rule,[2] so the incumbent is re-elected in period t if and only if $S_r(t) > \frac{1}{2}$.

[2]Following Alesina and Rodrik (1994), we impose simple majority to focus on aggregate support rather than vote margins or strategic turnout.

3.3 Income Windfall and Incumbency

Let $V_r(t) = \Pr\left(S_r(t) > \frac{1}{2}\right)$ denote the likelihood of reelection for the incumbent in region r at election t, as governed by model parameters. Our simple theoretical-formal framework model yields three transparent comparative-static results.

Proposition 1 (Windfall Effect on Reelection)**.** *For every post-shock electoral period, the probability of reelection is strictly increasing in the magnitude of the regional income windfall.*

Proof. Differentiating Equation (7) with respect to ΔA_r gives

$$\frac{\partial S_r(t)}{\partial \Delta A_r} \;=\; \int_{\eta}^{1} \phi\Bigl(\tfrac{\theta\,\Delta A_r\,\gamma(t)}{\sigma_\varepsilon}\Bigr)\frac{\theta\,\gamma(t)}{\sigma_\varepsilon}\,dF_r(\theta) \;>\; 0$$

because the standard-normal density $\phi(\cdot)$ is strictly positive and all other factors are non-negative. Under simple-majority rule the incumbent wins whenever $S_r(t) > \frac{1}{2}$; thus $V_r(t) \equiv \Pr[S_r(t) > \frac{1}{2}]$ is a non-decreasing transformation of $S_r(t)$ that is strictly increasing on the interior of $(0, 1)$. Consequently

$$\frac{\partial V_r(t)}{\partial \Delta A_r} \;>\; 0, \qquad \forall\, t \geq 0 \qquad \square$$

Proposition 2 (Decay of Windfall Advantage)**.** *The marginal electoral benefit of the regional income windfall diminishes over time.*

Proof. For any $t \geq 0$, the windfall enters each voter's satisfaction gap through the term $\theta_{i,r}\,\Delta A_r\,\gamma(t)$, with $\gamma(t) = (1-\lambda)^{t+1}$ and $\gamma'(t) < 0$. From Proposition 1 we have:

$$\frac{\partial S_r(t)}{\partial \Delta A_r} \;=\; \int_{\eta}^{1} \phi\Bigl(\tfrac{\theta\,\Delta A_r\,\gamma(t)}{\sigma_\varepsilon}\Bigr)\frac{\theta\,\gamma(t)}{\sigma_\varepsilon}\,dF_r(\theta) \;>\; 0.$$

Differentiating this expression with respect to t multiplies the integrand by $\gamma'(t) < 0$, yielding:

$$\frac{\partial^2 S_r(t)}{\partial \Delta A_r\,\partial t} \;<\; 0$$

Because the reelection probability $V_r(t) = \Pr[S_r(t) > \frac{1}{2}]$ is monotonically increasing in $S_r(t)$, the same sign carries over:

$$\frac{\partial^2 V_r(t)}{\partial \Delta A_r \, \partial t} \; < \; 0 \qquad \square$$

Proposition 3 (Exposure and Spillover)**.** *In the two-type case, the share of voters supporting the incumbent is strictly increasing in both the fraction of fully exposed individuals and the magnitude of spillovers.*

Proof. With two exposure types, aggregate support is given by:

$$S_r(t) \;=\; p\,\Phi\big(k\big) + (1-p)\,\Phi\big(\eta\,k\big)$$

with $k \;\equiv\; \frac{\Delta A_r\,\gamma(t)}{\sigma_\varepsilon} \;>\; 0$. Because $S_r(t)$ is linear in p, it follows that:

$$\frac{\partial S_r(t)}{\partial p} \;=\; \Phi\big(k\big) - \Phi\big(\eta\,k\big)$$

Since $0 < \eta < 1$ and the standard-normal c.d.f. Φ is strictly increasing, the difference is positive. That is:

$$\frac{\partial S_r(t)}{\partial p} > 0$$

Furthermore, only the second term of the $S_r(t)$ depends on η, so we have:

$$\frac{\partial S_r(t)}{\partial \eta} \;=\; (1-p)\,\phi\big(\eta\,k\big)\,k$$

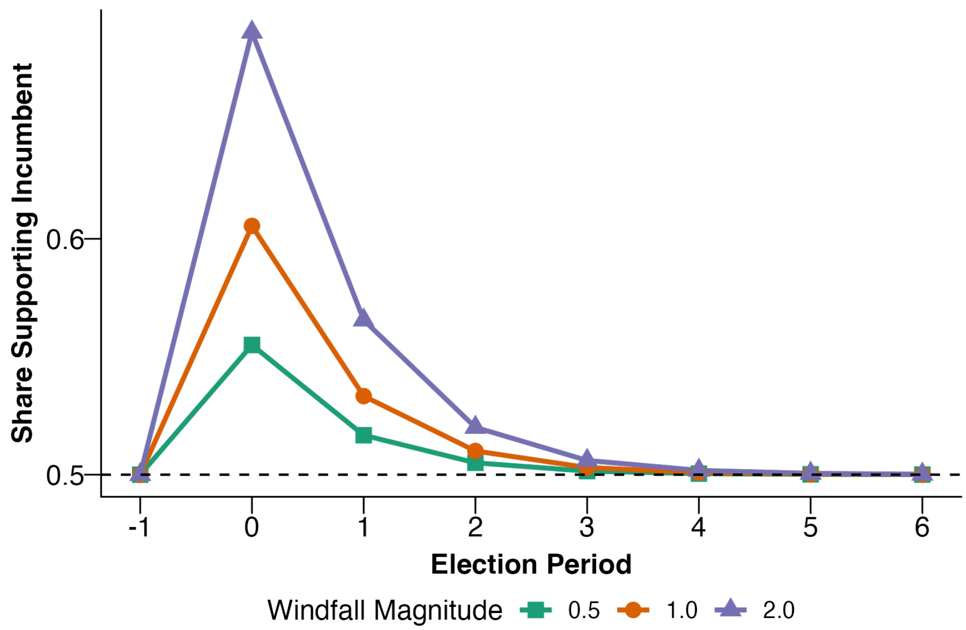
Because $k > 0,\ 1-p > 0$, and $\phi(\cdot) > 0$, the derivative is strictly positive. $\square$

3.4 Simulations

To visualize the dynamic logic of the model, we simulate the aggregate support function $S_r(t)$ under varying parameter configurations. Each exercise isolates a key mechanism: (i) the magnitude of the windfall ΔA_r, (ii) the speed of expectation adjustment λ, and (iii) the structure of exposure — namely, the share of voters fully exposed to the shock p and the intensity of spillovers η.

We begin by illustrating the result in Proposition 1. Holding the speed of adjustment fixed at $\lambda = 0.7$, we assume that 10% of voters are fully exposed to the income windfall, while the remaining 90% receive a spillover of 20%. Figure 1 plots support dynamics across different windfall magnitudes. As expected, larger shocks generate sharper initial gains in support, reflecting a greater satisfaction gap. However, these gains diminish over time as expectations adjust, even though incomes remain permanently higher.

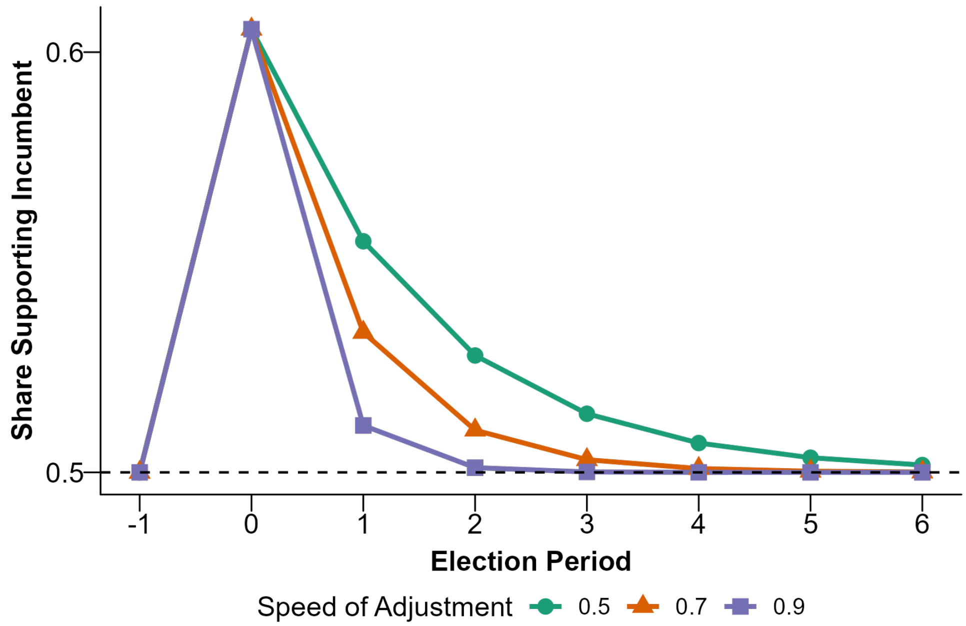
Figure 1: Windfall Effects on Share Supporting the Incumbent



Next, we turn to the role of expectation adjustment, following Proposition 2. Using the same exposure structure and an intermediate windfall level, Figure 2 shows how the speed of learning affects the persistence of political gains. When adaptation is slower ($\lambda = 0.5$), the satisfaction gap — and thus support — remains elevated for longer. Faster adaptation compresses this window, causing support to revert more quickly toward baseline levels.

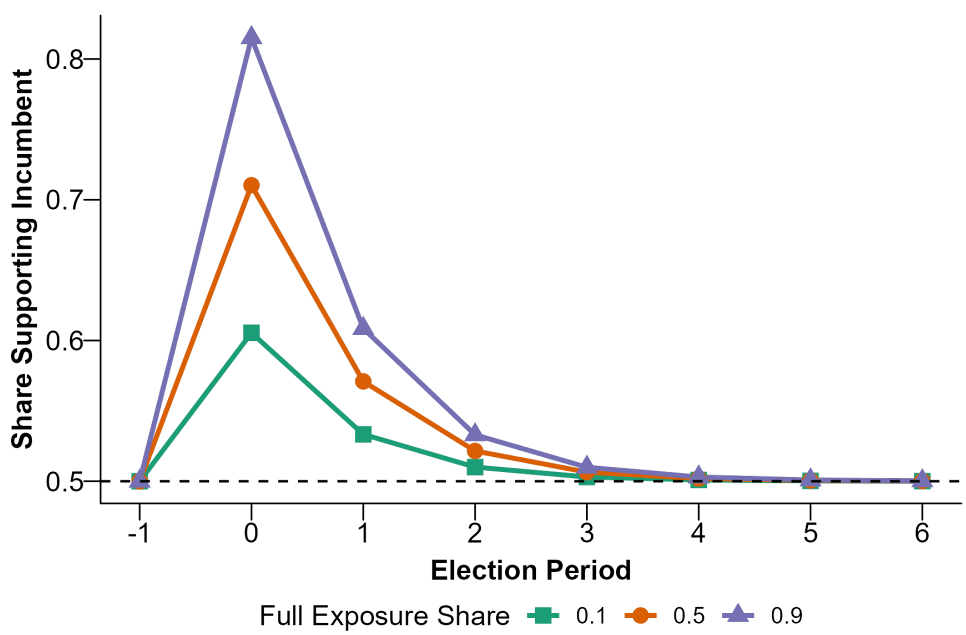
We then explore the role of exposure heterogeneity, in line with Proposition 3. Figure 3 examines how aggregate support varies with the share of voters fully exposed to the shock.

Figure 2: Adjustment Speed and the Persistence of Support



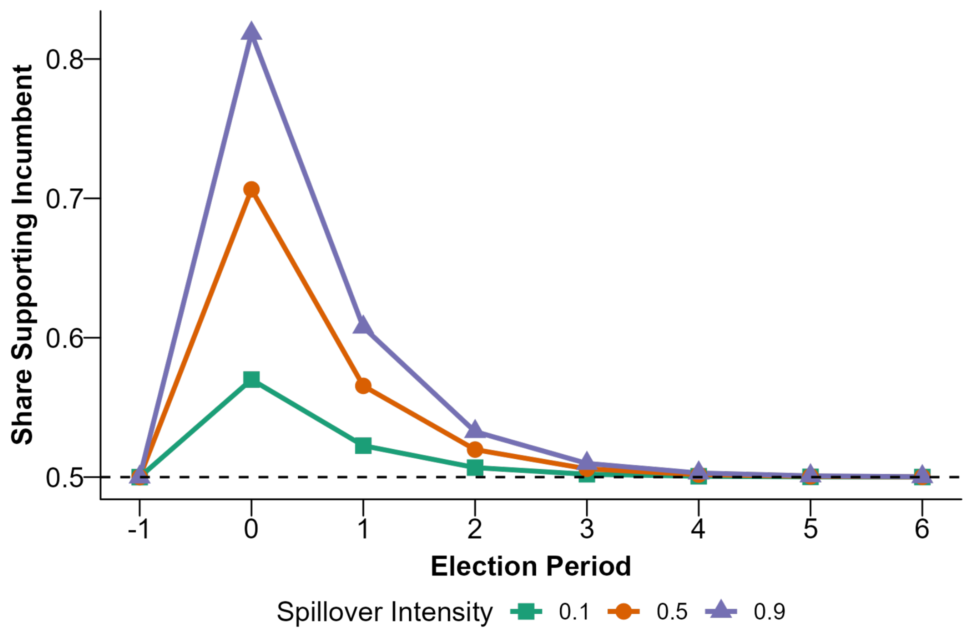
Holding other parameters constant, a larger value of p strengthens and extends the boost in support, while a lower value (i.e., more indirect exposure) dampens the aggregate response due to weaker income gains.

Figure 3: Share of Fully Exposed Population and Incumbent Support



Finally, Figure 4 highlights the role of spillover intensity η, again holding other parameters fixed. When indirect exposure is low, the benefits — and thus support — are narrowly concentrated among the directly exposed minority. As η increases, the windfall reaches a broader segment of the population, amplifying and prolonging political support.

Figure 4: Spillover Intensity and the Breadth of Political Gains



Taken together, these simulations underscore a core insight of the model: even long-lasting income shocks generate only temporary electoral gains. The size, duration, and distribution of support depend crucially on the structure of exposure and the speed at which expectations adapt. Our theoretical-formal framework thus offers clear predictions about the temporal and spatial heterogeneity of political responses to commodity-related income windfalls.

3.5 Discussion

This theoretical-formal framework formalizes a retrospective mechanism through which long-lasting, exogenous income shocks — such as those associated with commodity-based windfalls — translate into potentially short-lived electoral rewards for incumbents. In the immediate aftermath of the shock, household income rises abruptly while expectations, shaped by past experiences, remain anchored in pre-shock conditions. This divergence creates a transitory satisfaction gap that increases the likelihood of incumbent support.

Over time, voters gradually revise their benchmarks through a simple adaptive process, allowing reference income to catch up to the new income level. As a result, the perceived benefit of the shock diminishes, although income remains permanently higher. The incumbent's electoral advantage therefore decays geometrically, at a rate determined by the speed of expectation adjustment, captured by λ.

Importantly, the mechanism is fully retrospective: voters do not evaluate incumbents based on policy quality or effort, but infer performance from personal economic outcomes. Political returns to a windfall, therefore, reflect the psychology of adaptation rather than actual competence.

A key implication of the framework is that it isolates the role of exposure in shaping electoral responses. Baseline income heterogeneity, $\mu_{i,r}$, is absorbed by the adaptive benchmark and does not enter the satisfaction gap. Instead, what drives incumbent support is the interaction of individual exposure, $\theta_{i,r}$, and the size of the regional windfall, ΔA_r. This combination generates a temporary surge in support that peaks in the first post-shock election and fades over time, even though income remains permanently higher.

Together, these dynamics yield a clear empirical prediction: exogenous income shocks should produce a temporary rise in incumbent support, concentrated in the first post-shock election. In the next section, we test this prediction using data on a large-scale agricultural transformation that generated uneven windfalls across municipalities in a commodity-dependent economy.

4 Agricultural Transformation in Brazil

4.1 Case Selection

Brazil is a good case to test the relationship of interest due to its global economic integration and local-level variation in commodity dependence. In June 2003, the government of Brazil authorized the cultivation and sale of genetically engineered (GE) soy seeds for the 2003/2004 harvest season.[3] Six months later, the temporary authorization was extended to the 2004/2005 season.[4] In March 2005, the government established a lasting regulatory framework, creating a National Technical Commission on Biosafety and authorizing genetically modified organisms on a lasting basis.[5] The decision was a win for biotech companies like Monsanto, but also for farmers who were already smuggling GE seeds from neighboring Argentina since 2001. The appeal of GE soy seeds is evident: they are much more resistant to herbicides than their traditional counterparts. Instead of extensively preparing the soil to weed out unwanted plants, GE seeds allow farmers to use herbicides that eliminate weeds while safeguarding the soy plants. This requires less labor to yield the same output, allowing for an expansion of soy production into areas where traditional seeds would not be viable.

As Figure 5 shows, there was a pronounced increase in the area devoted to soy production — and, as a consequence, in total production — after 2003, coinciding with the adoption of GE seeds (as the dotted vertical lines indicate). By both metrics, Brazil is the world's largest soy producer as of 2023 (FAOSTAT). Relatedly, Figure 6 shows the area planted per worker and output per worker (or labor productivity). While these metrics have increased consistently since the 1990s, their slope and level increased noticeably after 2003.

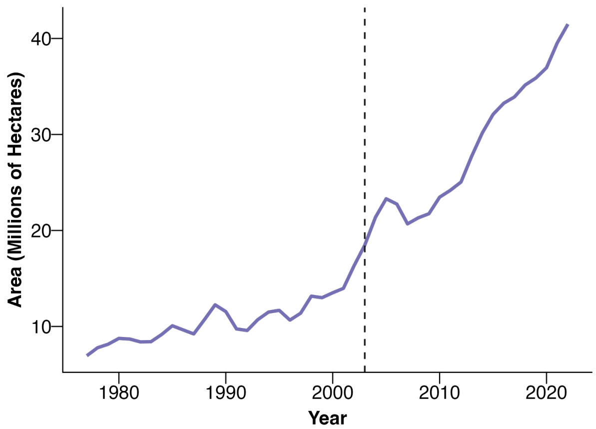
As Figures 5 and 6 indicate, GE seeds coincided with a surge in productivity that translated into higher revenues, job creation, and improved infrastructure. It also increased savings and available credit, driving capital investment in soy-producing municipalities (Bustos

[3] Lei 10688, https://www.planalto.gov.br/ccivil_03/leis/2003/l10.688.htm

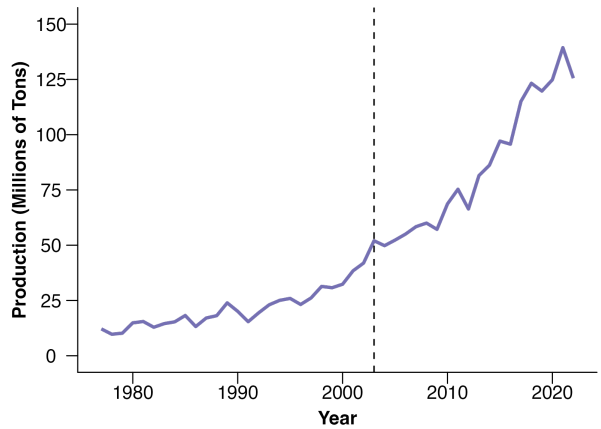
[4] Lei 10814, https://www.planalto.gov.br/ccivil_03/leis/2003/l10.814.htm

[5] Lei 11105, https://www.planalto.gov.br/ccivil_03/_ato2004-2006/2005/lei/l11105.htm

Figure 5: Soybean Productivity: 1976-2022



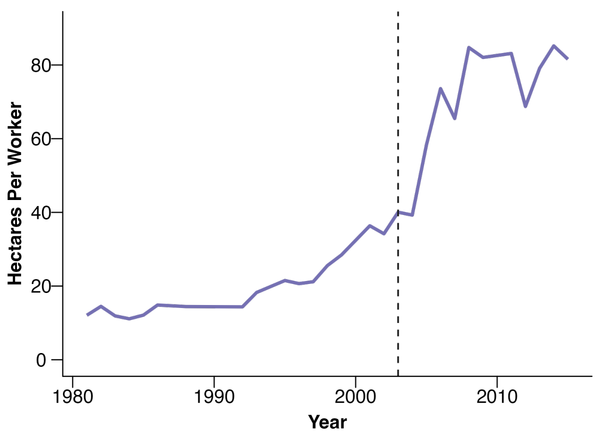
(a) Area Planted



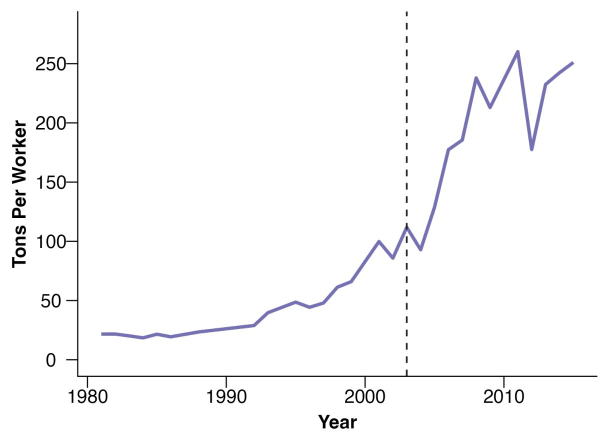
(b) Total Production

This figure shows the soybean productivity, in area planted (millions of hectares, left) and output (millions of tons, right). The dotted vertical line indicates the adoption of GE soybean seeds in 2003. Source: Brazilian Ministry of Agriculture, computed by *Companhia Nacional de Abastecimento* (CONAB). Adapted from Bustos et al. (2016).

Figure 6: Soybean Productivity Per Worker: 1980-2015



(a) Area Planted Per Worker



(b) Output Per Worker

This figure shows the soybean productivity per worker, in area planted (hectares per worker, left) and output (tons per worker, right). The dotted vertical line indicates the adoption of GE soybean seeds in 2003. Source: Brazilian Ministry of Agriculture, computed by *Companhia Nacional de Abastecimento* (CONAB); *Pesquisa Nacional por Amostra de Domicílios* (PNAD), implemented by the Brazilian Institute of Geography and Statistics. Adapted from Bustos et al. (2016).

et al., 2020). Although mayors were not directly responsible for these gains, many claimed credit for the economic boom. As a result, the adoption of GE soy seeds likely had political consequences, enhancing the reelection prospects of incumbent mayors (Novaes & Schiumerini, 2022).

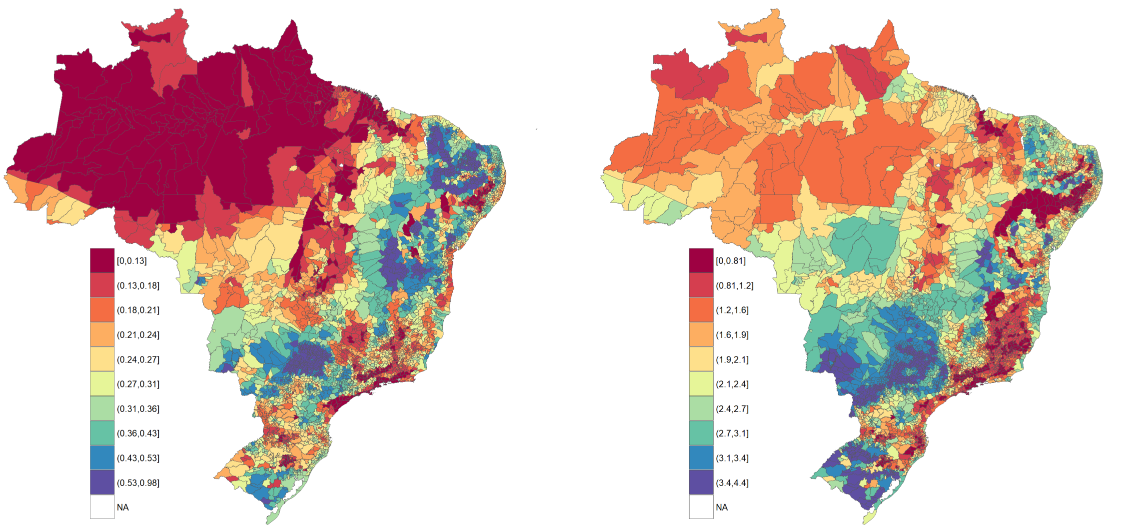
4.2 Productivity Shock

Following Bustos et al. (2016) and Bustos et al. (2020), we leverage the legalization of GE soy seeds in Brazil as a source of temporal variation and the differential impact of this technology across regions as a source of cross-sectional variation. This methodology allows us to disentangle the effects of soybean technological change from other confounding factors that might affect the likelihood of reelection. The legalization of GE soy seeds is not itself an exogenous shock: it may be correlated with specific factors of Brazilian municipalities, individual characteristics of decision-makers, or pressure from farmers following the 1996 approval of GE soy seeds in the US. Yet a municipality's potential yield is arguably exogenous: it is a function of weather and soil characteristics, not actual yields (Bustos et al., 2016).

We use data on potential soy yields from the FAO Global Agro-Ecological Zones (FAO-GAEZ) database to show that the effects of GE seeds adoption were unevenly distributed across municipalities. To calculate these yields, the database incorporates local soil and weather characteristics into an agronomic model that predicts the maximum attainable yield for each crop in a given area, reporting potential yields under different technologies or input combinations. Regions with low input potential yields use traditional production technology, whereas regions with high input potential yields use modern technologies like GE seeds and fertilizers.

Figure 7 presents our measure of the potential yield of soy production, in terms of tons per hectare, under the low and high agricultural technology at the municipality level in Brazil, aggregated into deciles. There is a large variation in production capacity for the municipalities in the top deciles of the distribution: even for the very productive regions ex

Figure 7: Potential Soy Yield Under Low and High Agricultural Technology at the Municipality Level, in Tons Per Hectare (Deciles)



(a) Low

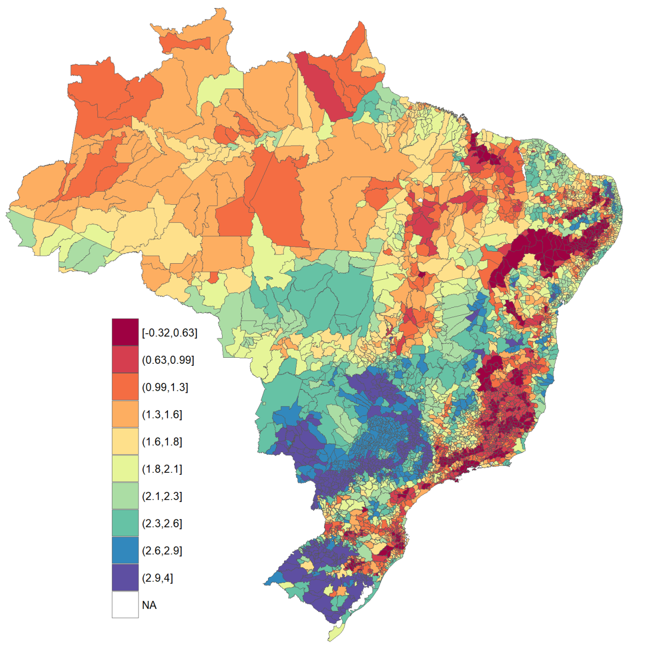
(b) High

This figure shows each municipality's potential soy yield, in tons per hectare, using low and high agricultural technology. Source: FAO-GAEZ.

ante, the potential yield that could be achieved in terms of tons of soy per hectare with the new technology is 3 to 5 times larger.

We construct a measure of local exposure to productivity gains from adopting GE soy seeds in municipality r as ΔA_r^{soy}, the municipal-level *difference* in potential yield in the high and low input scenarios. This difference captures the effect of moving from traditional agriculture to a technology that uses improved seeds and optimum weed control, among other characteristics. Figure 8 illustrates the resulting measure of technical change in soy for the country's 5,570 municipalities. To the extent that GE soy seeds improved mayoral fortunes, they likely did so in municipalities with higher potential yields, where voters were fully exposed to the income windfall and experienced a greater satisfaction gap.

Figure 8: Difference in Potential Soy Yield at the Municipality Level, in Tons Per Hectare (Deciles)



This figure shows each municipality's potential soy yield under the high technology minus its potential soy yield under low technology. Source: FAO-GAEZ.

4.3 Economic Outcomes

Before examining the political effects of the productivity shock, we establish that this shock did not affect all Brazilian municipalities equally. It led to heterogeneity in household incomes, which, we argue, is the key mechanism driving short-term increases in incumbent support in areas most exposed to the shock. We use municipal data from the Brazilian Institute of Geography and Statistics (IBGE) on GDP per capita (in current Brazilian reais) to assess local economic changes. For each municipality, we regress the annual change in GDP per capita on the change in potential soy yield, ΔA_r^{soy}. Table 1 shows that municipalities with greater productivity gains experienced significantly larger increases in income. The economic benefits of the shock were large, but also geographically uneven and concentrated in high-yield areas. Figure 9 visualizes this change.

Table 1: Soy and Income Per Capita

Dependent variable:	Δ GDPpc				Δ log(GDPpc)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔA_r^{soy}	1.069***	0.9278***	0.3287	1.093**	0.2405***	0.2417***	0.1130***	0.1694**
	(0.1668)	(0.2719)	(0.3510)	(0.4953)	(0.0235)	(0.0335)	(0.0359)	(0.0825)
Weighted		✓	✓	✓		✓	✓	✓
State-year fixed effects			✓	✓			✓	✓
Microregion-year fixed effects				✓				✓
Observations	4,255	4,255	4,255	4,255	4,150	4,150	4,150	4,150
R^2	0.013	0.009	0.098	0.386	0.063	0.051	0.267	0.553

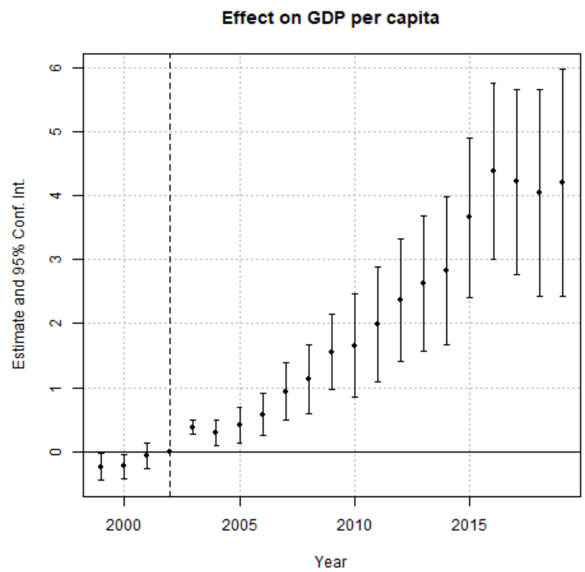
Notes: Unit of analysis r is a municipality. Standard errors (in parentheses) are adjusted for 555 meso-region clusters. In columns 2 and 5, observations are weighted by the population; columns 3 and 5 adds state-year fixed effects; and columns 4 and 6 adds microregion-year fixed effects. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Of course, not every change to the local economy affects voting behavior. For local context to matter, it must be salient in the minds of citizens, in what Larsen et al. (2019) call "context priming." The sharp increase in soy production (Figures 5 and 6) and the associated rise in household income (Table 1) suggest a shock large enough to affect individuals' lived experience. To examine whether this transformation registered in public attitudes (and whether perceptions varied with individual exposure to the productivity shock), we turn to public opinion data from Latinobarómetro, focusing on a question about personal economic well-being: "In general, how would you describe your present economic situation and that of your family? Would you say that it is very good, good, about average, bad, or very bad?"[6]

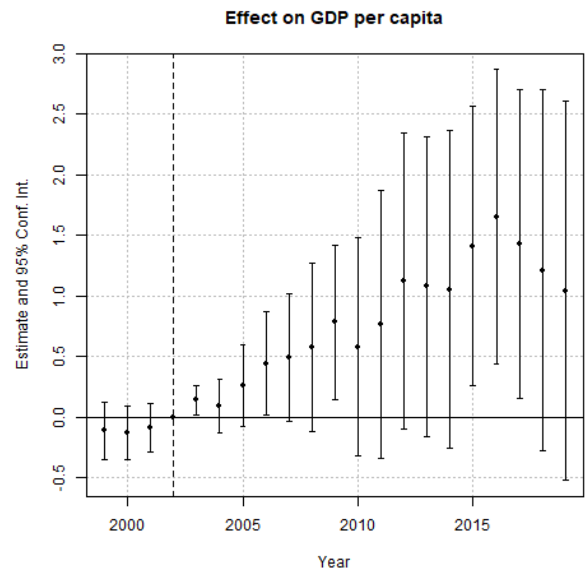
Figure 10 plots the share of respondents who answered "very good" or "good," disaggregated by tertiles of ΔA_r^{soy}, the municipal-level change in potential soy yield. The figure suggests that while *all* respondents expressed greater optimism about their economic situation in the 2006-2010 period, those in areas most affected by the productivity shock (3rd tertile) were more likely to report favorable personal economic evaluations. While the limited sample size (only around 1,000 Brazilians per wave) constrains statistical inference, a one-way ANOVA comparing the mean share of respondents who answered "very good" or "good" reveals a statistically significant difference across tertiles ($p < 0.001$). Households

[6] We exclude survey waves that did not ask this question (2007, 2016, 2017, 2018) or did not provide municipality identifiers (1996, 1997, 2001). Latinobarómetro conducted no surveys in 1999, 2012, and 2014.

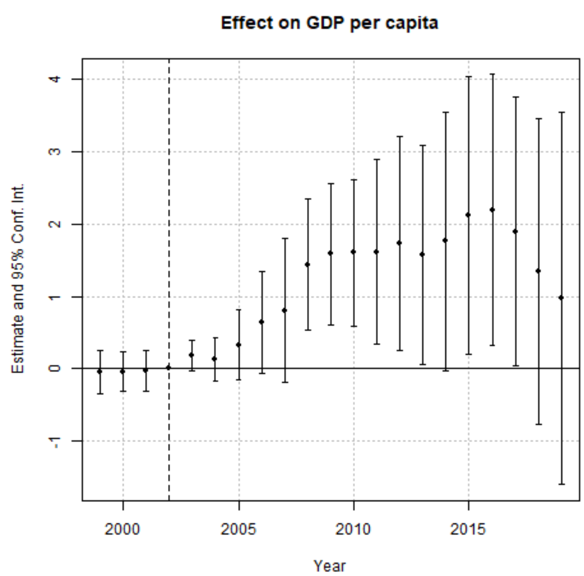
Figure 9: Dynamic Effects of the Soy Shock on Income per Capita



(a) Two-way fixed effects



(b) + State-year fixed effects



(c) + Microregion-year fixed effects

Notes: Each point represents a regression coefficient ($\hat{\beta}$) from estimating Equation (adjust). The dependent variables are regional income per capita in levels (thousands of Brazilian reais) for the years $t = 1999, \ldots, 2019$. All regressions include micro-region and year fixed effects. Standard errors are clustered at the microregion level (555 clusters), and observations are weighted by population.

Figure 10: Share of Latinobarómetro Respondents Who Report Favorable Personal Economic Evaluations, by Potential Soy Yield

For every Latinobarómetro wave, this figure shows the share of respondents who answered the question "In general, how would you describe your present economic situation and that of your family?" with "very good" or "good," disaggregated by tertiles of ΔA_r^{soy}, the municipal-level difference in potential soy yield.

with more exposure to the productivity shock not only *experienced* improved economic conditions (Table 1) but also *perceived* such improvement (Figure 10).[7] This sets the stage for a political response: greater support for the incumbent, at least in the short term.

[7]Ideally, we would use surveys of vote intention or mayoral approval to capture political consequences more directly. However, such data are rarely available for small municipalities across an extended period, hence our indirect measure of personal economic situation, which often shapes electoral behavior.

5 The Political Consequences of a Productivity Shock

5.1 Electoral Context

Brazil elects national and state leaders every four years and municipal leaders in midterm elections.[8] Since 1997, mayors, governors, and the president can serve up to two consecutive four-year terms. Most municipalities elect mayors through a simple majority, except for those with over 200,000 registered voters, where a runoff election is held if no candidate secures an absolute majority in the first round. All municipalities follow a mayor-council form of government and have significant autonomy to manage their own budgets or provide key public services, such as education, health care, and sanitation. This means that Brazilian mayors are powerful figures; their elections are politically consequential and have been widely studied (e.g. Brollo & Nannicini, 2012; Bueno, 2018; De Magalhães, 2015; Johannessen, 2020; Novaes & Schiumerini, 2022).

Following De Magalhães (2015), our unit of analysis is the individual candidate, and our main outcome of interest is a candidate's unconditional *Probability of Winning* (not conditional on the incumbent's probability of rerunning). We retrieve this information, along with each candidate's *Incumbency* status (that is, whether the candidate won the previous mayoral election), from the Superior Electoral Court (*Tribunal Superior Eleitoral*, or TSE) for the 1996, 2000, 2004, 2008, 2012, 2016, and 2020 municipal elections. Because *Incumbency* refers to the previous election, $t-1$, we use 1996 data to construct the lagged independent variable, but restrict our analysis to elections beginning in 2000 and exclude municipalities in which incumbents cannot run in $t+1$ due to term limits (Novaes & Schiumerini, 2022). In additional tests, we also investigate the existence of a *party* incumbency advantage (that is, whether another candidate *of the same party* won an election at $t-1$), recognizing that this might differ from the individual incumbency advantage due to widespread party switching (Desposato, 2006).

[8] The following discussion does not apply to Brasília and Fernando de Noronha, the only two of Brazil's 5,570 municipalities not to hold municipal elections.

5.2 Control Variables

We also collect data about each mayoral candidate's gender and party affiliation. The Brazilian party system is highly fragmented; in 2020, for example, mayoral candidates came from 33 different parties. Partisan attachments are loose and party switching is common, though most switchers choose ideologically proximate parties (Desposato, 2006). We pair this information with Power and Rodrigues-Silveira's (2019) Municipal Ideology Score, which places all mayors on a left-right continuum.

5.3 Empirical Strategy

Our empirical strategy rigorously tests the theoretical predictions developed earlier, specifically focusing on how agricultural productivity shocks influence incumbency advantages in Brazilian municipal elections. To achieve this, we leverage the introduction of genetically engineered (GE) soy seeds, strategically exploiting both the timing of their adoption and geographic variations in productivity gains.

Although GE soy seeds were commercially introduced in the United States in 1996 — a decision exogenous to Brazilian economic conditions — their official adoption in Brazil occurred in 2003, after reports of seed smuggling from neighboring Argentina emerged as early as 2001 (see Section 4). To ensure the exogeneity of our analysis, we begin our sample with mayoral elections in 2000, thus capturing a clear pre-treatment baseline that precedes both the legalization and initial smuggling reports.

As discussed previously, the productivity effects of GE soy technology varied substantially across municipalities due to distinct local soil and weather conditions. We capture this variation through the measure ΔA_r^{soy}, representing the difference in potential soy yields between high and low agricultural technology scenarios.

Our analysis begins with a cross-sectional approach, evaluating incumbency advantages across municipalities with varying exposure levels to the soy productivity shock. Specifically, we estimate the following regression separately for each election cycle t from 2000 to 2020:

$$V_{j,r,t} = \alpha Incumbency_{j,r,t-1} + \beta\left(Incumbency_{j,r,t-1} \times \Delta A_r{}^{soy}\right) + \delta_{r,t} + \varepsilon_{j,r,t} \tag{9}$$

where $V_{j,r,t}$ is the probability of electoral victory for candidate j in municipality r at election year $t \in \{2000, 2004, 2008, 2012, 2016, 2020\}$, $\Delta A_r{}^{soy}$ captures the productivity shock, measured by the potential yield of soy under the high technology minus the potential yield of soy under low technology, $\delta_{r,t}$ are municipality-election fixed effects and $\varepsilon_{j,r,t}$ is an idiosyncratic error term. To ensure robustness, we estimate Equation (9) using both ordinary least squares (OLS, linear probability model) and a Probit specification.

Our primary empirical objective is to test the theoretical prediction regarding how incumbents electorally benefit from exogenous economic shocks. Specifically, we focus on the interaction between incumbency and local productivity shocks, represented by the coefficient β in Equation (9). By evaluating the magnitude, sign, and statistical significance of this coefficient, we can determine whether incumbents in municipalities with greater exposure to productivity shocks experience larger electoral advantages relative to those less exposed. This analysis provides crucial insights into voter perceptions and their attribution of economic outcomes to local politicians.

Beyond our baseline analysis, we enhance the robustness of our empirical strategy by examining the temporal dynamics of incumbency advantages using a difference-in-differences (DiD) design. This approach combines data across multiple electoral cycles, setting the 2004 election—the first election following the legalization of GE soy seeds in Brazil—as the baseline treatment year. Our identification strategy capitalizes on the simultaneous legislative change experienced by all municipalities while leveraging geographical variations in productivity gains associated with GE soy technology. This simultaneous treatment timing circumvents common pitfalls associated with staggered DiD designs, as emphasized in recent methodological discussions (De Chaisemartin & d'Haultfoeuille, 2020; Goodman-Bacon, 2021; Roth et al., 2023). Our canonical DiD model is formalized as:

$$
\begin{aligned}
V_{j,r,t} = \beta_1 \, \text{Incumbency}_{j,r,t-1} + \beta_2 \left(\text{Incumbency}_{j,r,t-1} \times \text{D}_{r,t}\right) + \beta_3 \left(\text{Incumbency}_{j,r,t-1} \times \Delta A_r^{soy}\right) \\
+ \beta_4 \left(\text{D}_{r,t} \times \Delta A_r^{soy}\right) + \beta_5 \left(\text{Incumbency}_{j,r,t-1} \times \text{D}_{r,t} \times \Delta A_r^{soy}\right) + \mu_r + \gamma_t + \delta_{s,t} + \varepsilon_{j,r,t} \quad (10)
\end{aligned}
$$

where $D_{r,t}$ is an indicator variable taking the value of 1 from the first election after the shock (2004 onwards) and 0 otherwise. The terms μ_r and γ_t denote municipality and time fixed effects, respectively, and $\delta_{s,t}$ captures region-by-election-year fixed effects to account for regional temporal heterogeneity (varied for robustness). The triple interaction term, captured by β_5, is central to our analysis as it reflects whether the electoral advantage of incumbents in more exposed municipalities changed significantly following the GE soy legalization.

To further validate our identification assumptions, particularly the parallel pre-trends condition, we complement our canonical DiD specification with an event-study analysis. The event-study framework explicitly evaluates whether electoral outcomes followed similar trajectories in high- and low-exposure municipalities before the policy intervention. This approach helps verify the credibility of our causal interpretation. The event-study model is specified as follows:

$$
\begin{aligned}
V_{j,r,t} = \sum_{t \neq 2004}^{t} \mathbb{I}\left\{\tau = t\right\} \left[\alpha_t Incumbency_{j,r,t-1} + \beta_t \left(Incumbency_{j,r,t-1} \times \Delta A_r{}^{soy}\right)\right] \\
+ \delta_{r,t} + \varepsilon_{j,r,t} \quad (11)
\end{aligned}
$$

This specification introduces a flexible set of year-specific interaction coefficients β_t, allowing us to assess the evolution of incumbency advantages relative to the productivity shock over time. Under the parallel trends assumption, coefficients for elections prior to treatment should not differ significantly from zero.

Finally, our empirical analyses present results both weighted and unweighted by the number of valid votes cast in each municipality. Applying weights ensures that municipalities with larger populations proportionately influence the estimates, reducing potential biases and heteroskedasticity arising from varying voter populations. Additionally, we consistently cluster standard errors at the micro-region level — geographically contiguous groups of municipalities defined by IBGE — to address spatial and temporal correlation in residuals robustly. This approach accommodates arbitrary correlation structures, accounting for both serial and spatial dependence in electoral outcomes.

5.4 Results

Table 2: Potential Soy Yield and Electoral Victory

Dependent variable:	**Prob. Victory**					
Election Year	2000	2004	2008	2012	2016	2020
	(1)	(2)	(3)	(4)	(5)	(6)
Incumbency	0.3249***	0.2675***	0.3505***	0.2740***	0.1642***	0.4220***
	(0.0385)	(0.0401)	(0.0320)	(0.0415)	(0.0448)	(0.0341)
Incumbency × ΔA_r^{soy}	-0.0260	0.0168	0.0510***	-0.0202	-0.0192	0.0136
	(0.0197)	(0.0205)	(0.0165)	(0.0213)	(0.0218)	(0.0173)
Municipality-year fixed effects	✓	✓	✓	✓	✓	✓
Observations	14,316	15,268	14,387	14,714	14,964	17,277
R^2	0.119	0.106	0.182	0.094	0.095	0.200

Notes: Unit of analysis is a candidate j in municipality r and election t. Standard errors (in parentheses) are adjusted for 555 micro-region clusters. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Potential Soy Yield and Electoral Victory — Probit

Dependent variable:	Prob. Victory					
Election Year	2000	2004	2008	2012	2016	2020
	(1)	(2)	(3)	(4)	(5)	(6)
Incumbency	0.8762***	0.7299***	0.9470***	0.7397***	0.4475***	1.197***
	(0.1069)	(0.1107)	(0.0944)	(0.1131)	(0.1208)	(0.1044)
Incumbency × ΔA_r^{soy}	-0.0682	0.0495	0.1536***	-0.0531	-0.0502	0.0457
	(0.0545)	(0.0571)	(0.0503)	(0.0580)	(0.0587)	(0.0534)
Municipality-year fixed effects	✓	✓	✓	✓	✓	✓
Observations	14,182	15,151	14,145	14,604	14,773	17,109
Squared Correlation	0.10300	0.09173	0.15582	0.08032	0.07285	0.17735
Pseudo R^2	0.08172	0.07376	0.12466	0.06428	0.05844	0.14994
BIC	67,215.4	69,860.9	66,548.1	69,488.3	68,331.4	68,937.9

Notes: Unit of analysis is a candidate j in municipality r and election t. Standard errors (in parentheses) are adjusted for 555 micro-region clusters. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Potential Soy Yield and Electoral Victory DiD

Dependent variable:	**Prob. Victory**		
	(1)	(2)	(3)
Incumbency	0.2981***	0.2991***	0.3019***
	(0.0306)	(0.0307)	(0.0313)
Incumbency × Post-shock	-0.0386	-0.0401	-0.0405
	(0.0309)	(0.0309)	(0.0315)
Incumbency × ΔA_r^{soy}	-0.0221	-0.0226	-0.0232
	(0.0155)	(0.0155)	(0.0158)
Post-shock × ΔA_r^{soy}	-0.0043	-0.0067	-0.0024
	(0.0044)	(0.0044)	(0.0055)
Incumbency × Post-shock × ΔA_r^{soy}	0.0331**	0.0338**	0.0344**
	(0.0158)	(0.0158)	(0.0161)
Municipality fixed effects	✓	✓	✓
Year fixed effects	✓	✓	✓
State-Year fixed effects		✓	✓
Microregion-Year fixed effects			✓
Observations	90,926	90,926	90,926
R^2	0.087	0.088	0.092

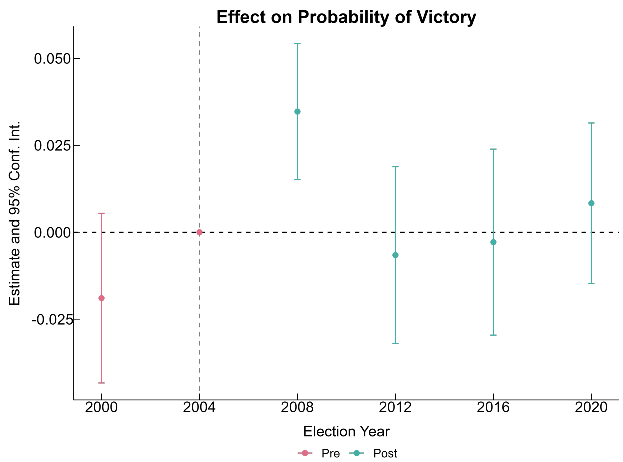
Notes: Unit of analysis is a candidate j in municipality r and election t. Standard errors (in parentheses) are adjusted for 555 micro-region clusters. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Potential Soy Yield and Electoral Victory DiD - Probit

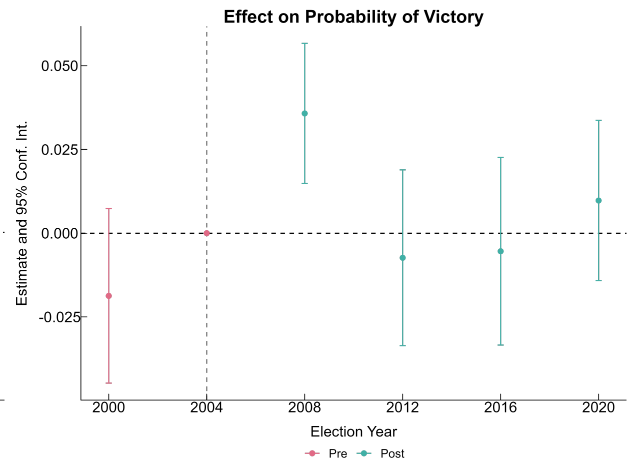
Dependent variable:	**Prob. Victory**		
	(1)	(2)	(3)
Incumbency	0.7867***	0.7895***	0.7997***
	(0.0832)	(0.0837)	(0.0857)
Incumbency × Post-shock	-0.0996	-0.1031	-0.1045
	(0.0839)	(0.0841)	(0.0859)
Incumbency × ΔA_r^{soy}	-0.0582	-0.0593	-0.0613
	(0.0421)	(0.0422)	(0.0432)
Post-shock × ΔA_r^{soy}	-0.0043	-0.0067	-0.0024
	(0.0044)	(0.0044)	(0.0055)
Incumbency × Post-shock × ΔA_r^{soy}	0.0886**	0.0900**	0.0924**
	(0.0428)	(0.0429)	(0.0439)
	(0.0158)	(0.0158)	(0.0161)
Municipality fixed effects	✓	✓	✓
Year fixed effects	✓	✓	✓
State-Year fixed effects		✓	✓
Microregion-Year fixed effects			✓
Observations	90,926	90,926	90,926
Squared Correlation	0.08637	0.08698	0.09085
Pseudo R^2	0.06761	0.06817	0.07152

Notes: Unit of analysis is a candidate j in municipality r and election t. Standard errors (in parentheses) are adjusted for 555 micro-region clusters. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

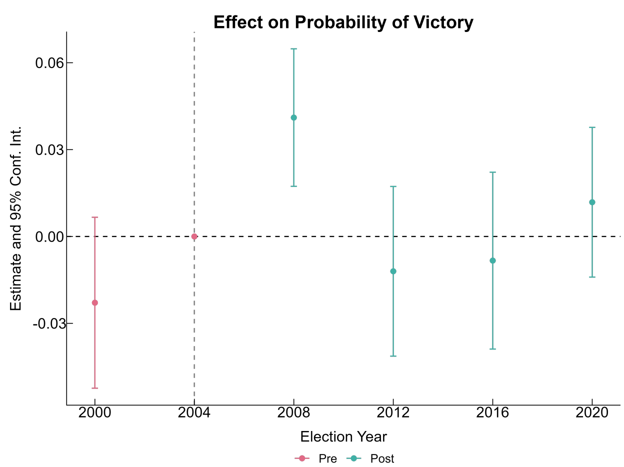
Figure 11: Dynamic Effects of Soy Potential Yield



(a) Two-way fixed effects



(b) + State-year fixed effects



(c) + Microregion-year fixed effects

Notes: Each point represents a regression coefficient ($\hat{\beta}$) from estimating Equation (adjust). The dependent variables are probability of victory of candidate j in municipality r in each election $t = 2000, \ldots, 2020$. All regressions include municipality and year fixed effects. Standard errors are clustered at the micro-region level (555 clusters)

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A Appendix

Table A.1: Potential Soy Yield and Electoral Victory (weighted)

Dependent variable:	Prob. Victory					
Election Year	2000	2004	2008	2012	2016	2020
	(1)	(2)	(3)	(4)	(5)	(6)
Incumbency	0.3985***	0.4647***	0.4085***	0.4229***	0.1721*	0.4997***
	(0.0741)	(0.1177)	(0.0600)	(0.1142)	(0.0964)	(0.0634)
	(0.0385)	(0.0401)	(0.0320)	(0.0415)	(0.0448)	(0.0341)
Incumbency × ΔA_r^{soy}	-0.0124	0.0101	0.1008***	0.0141	0.0163	0.0565**
	(0.0362)	(0.0393)	(0.0324)	(0.0410)	(0.0498)	(0.0282)
Municipality-year fixed effects	✓	✓	✓	✓	✓	✓
Observations	14,316	15,268	14,387	14,714	14,964	17,277
R^2	0.152	0.178	0.283	0.163	0.118	0.298

Notes: Unit of analysis is a candidate j in municipality r and election t. Standard errors (in parentheses) are adjusted for 555 micro-region clusters and observations are weighted by valid votes. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.2: Potential Soy Yield and Electoral Victory — Probit (weighted)

Dependent variable:	Prob. Victory					
Election Year	2000	2004	2008	2012	2016	2020
	(1)	(2)	(3)	(4)	(5)	(6)
Incumbency	1.119***	1.415***	1.097***	1.242***	0.4475***	1.519***
	(0.2278)	(0.4280)	(0.2122)	(0.3856)	(0.1208)	(0.2372)
Incumbency × ΔA_r^{soy}	-0.0248	0.0278	0.3817***	0.0484	-0.0502	0.2233**
	(0.1103)	(0.1336)	(0.1278)	(0.1307)	(0.0587)	(0.1117)
Municipality-year fixed effects	✓	✓	✓	✓	✓	✓
Observations	14,182	15,151	14,145	14,604	14,773	17,109
Squared Correlation	0.09916	0.08420	0.15256	0.07032	0.07285	0.17206
Pseudo R^2	0.12111	0.15572	0.23516	0.13775	0.05844	0.26514

Notes: Unit of analysis is a candidate j in municipality r and election t. Standard errors (in parentheses) are adjusted for 555 micro-region clusters. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.3: Potential Soy Yield and Electoral Victory DiD(weighted)

Dependent variable:	**Prob. Victory**		
	(1)	(2)	(3)
Incumbency	0.3712***	0.3722***	0.3749***
	(0.0643)	(0.0642)	(0.0657)
Incumbency × Post-shock	-0.0217	-0.0230	-0.0216
	(0.0608)	(0.0609)	(0.0630)
Incumbency × ΔA_r^{soy}	-0.0134	-0.0133	-0.0110
	(0.0311)	(0.0311)	(0.0318)
Post-shock × ΔA_r^{soy}	-0.0034	-0.0061	0.0008
	(0.0081)	(0.0076)	(0.0098)
Incumbency × Post-shock × ΔA_r^{soy}	0.0533*	0.0536*	0.0530*
	(0.0300)	(0.0300)	(0.0311)
	(0.0158)	(0.0158)	(0.0161)
Municipality fixed effects	✓	✓	✓
Year fixed effects	✓	✓	✓
State-Year fixed effects		✓	✓
Microregion-Year fixed effects			✓
Observations	90,926	90,926	90,926
R^2	0.162	0.163	0.169

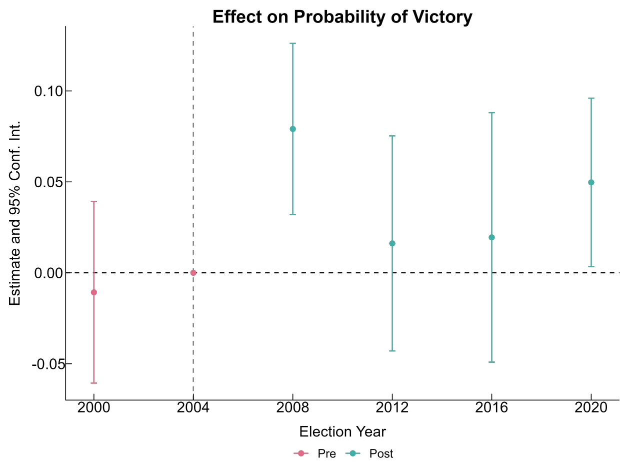
Notes: Unit of analysis is a candidate j in municipality r and election t. Standard errors (in parentheses) are adjusted for 555 micro-region clusters. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4: Potential Soy Yield and Electoral Victory DiD - Probit (weighted)

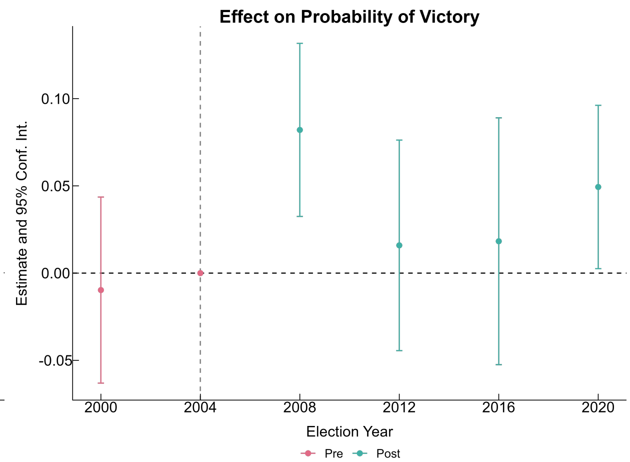
Dependent variable:	**Prob. Victory**		
	(1)	(2)	(3)
Incumbency	1.018***	1.021***	1.035***
	(0.1911)	(0.1922)	(0.1991)
Incumbency × Post-shock	-0.0284	-0.0289	-0.0208
	(0.1787)	(0.1792)	(0.1884)
Incumbency × ΔA_r^{soy}	-0.0145	-0.0226	-0.0077
	(0.0289)	(0.0268)	(0.0341)
Post-shock × ΔA_r^{soy}	-0.0043	-0.0067	-0.0024
	(0.0044)	(0.0044)	(0.0055)
Incumbency × Post-shock × ΔA_r^{soy}	0.1624*	0.1621*	0.1604*
	(0.0894)	(0.0901)	(0.0950)
Municipality fixed effects	✓	✓	✓
Year fixed effects	✓	✓	✓
State-Year fixed effects		✓	✓
Microregion-Year fixed effects			✓
Observations	90,926	90,926	90,926
Squared Correlation	0.08156	0.08168	0.08344
Pseudo R^2	0.13863	0.13962	0.14619

Notes: Unit of analysis is a candidate j in municipality r and election t. Standard errors (in parentheses) are adjusted for 555 micro-region clusters. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

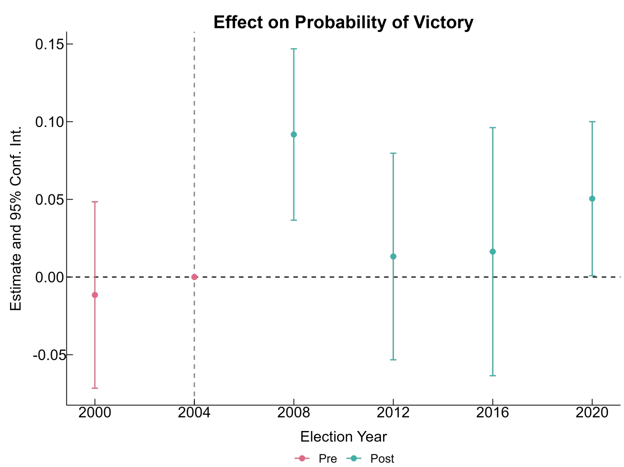
Figure A.1: Dynamic Effects of Soy Potential Yield (weighted)



(a) Two-way fixed effects



(b) + State-year fixed effects



(c) + Microregion-year fixed effects

Notes: Each point represents a regression coefficient ($\hat{\beta}$) from estimating Equation (adjust). The dependent variables are probability of victory of candidate j in municipality r in each election $t = 2000, \ldots, 2020$. All regressions include municipality and year fixed effects. Standard errors are clustered at the micro-region level (555 clusters) and observations are weighted by valid votes.