# Not a sweet life: the long-run impacts of agro-terrorism in Brazil*

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**PRELIMINARY VERSION - PLEASE DO NOT CIRCULATE**

**Abstract**

This paper studies the unintended long-run effects of a permanent agricultural shock led by agro-terrorism in Brazil on the education and labor market. We explore the witch broom outbreak in cocoa farms in the world's second most important cocoa production region until 1989, the southeast of Bahia's state in the northeast of Brazil. Although the introduction of the plague had political motivations, it had unintended effects on poor people's lives. To assess the impact of which broom disease, we leverage information about people born in cities affected and not affected by the disease and explore the difference in educational attainments between cohorts older and younger than eighteen years old at the time of the witch broom outbreak. The main results show that the witch broom outbreak negatively affected the long-term education and earnings of individuals living in affected cities. The results are very similar by gender and race. We show a piece of evidence that the increase in child labor may drive our results. The negative effects on young cohorts are consistent with the known relation between child labor and cocoa production and the the literature about the long-term effects of economic shocks.

**Keywords:** Witch Broom, Brazil, Education, Wages.

**JEL Codes:** TBA...

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# 1 Introduction

Terrorism and cyber-terrorism is a well-known concept, and it's part of many governments' and international organizations' agendas. Surprisingly, however, the deliberated action of differing attacks against crops, or agro-terrorism, has received much less attention from scholars and governments. In short, it is defined as "the deliberate introduction of an animal or plant disease/pest for the purpose of generating fear, causing economic loss, or undermining social stability" (USDA, 2018). Therefore, even though the act of agro-terrorism does not threaten people's lives directly, it may affect different aspects of the households, pushing many individuals to unemployment and reducing food security. It is a potentially more dangerous (Foxell, 2001) threat to agriculture than the traditional temporary shocks such as droughts, price fluctuations, floods, and plagues that have been largely studied in economic literature (Baker, Blanchette, and Eriksson, 2019; Kruger, 2007; Padrón and Burger, 2015; Carrillo, 2020; Ager, Herz, and Brueckner, 2020). Yet, it has been used for a while for terrorist groups in African countries[1], moving thousands of people to food insecurity and having long-lasting effects on child development.

This paper studies the long-run effects of a significant agro-terrorism event in cocoa production in Brazil on education and the labor market. We explore the witch broom outbreak in cocoa farms in the world's second most important cocoa production region until 1989, the southeast of Bahia's state in the northeast of Brazil. By 1985, this region, also known as the Ilhéus-Itabuna microregion, produced 80% of Brazilian and 62% of Latin American cocoa (IOCC, 1993). Data and historical documents report that cocoa production reduced by 80% in the first ten years after the disease, pushing almost 250 thousand workers to unemployment.

The context of witch-broom in Bahia is particularly appealing to study the long-run impacts of agro-terrorism for several reasons. First, the municipalities affected by the witch-broom plague had a high dependency on cocoa production. At that time, cocoa was the second most exported product from the Bahia state. In the average affected municipality, cocoa production corresponds to 44% of total agriculture production, reaching more than 80% in some municipalities. It made the region very vulnerable since a negative shock to cocoa production automatically converts into a strong shock on the total income of the municipality. Also, Bahia state has about 15 million inhabitants, comprising an area almost the size of France. It is the most important economy of the nine states in the Northeast of Brazil. Still, a high share of its working population has no jobs or work without any formal contract, and it has the highest percentage of the population receiving the cash transfer program *Bolsa Família*, target to the poorest families in Brazil.

At the time of the outbreak, many different narratives showed up to explain the

[1]See the case of Boko Haram in Nigeria as an example. https://adf-magazine.com/2016/10/when-food-is-a-weapon/.

disease. The first was some unintended accident during the government transport of seeds between the Amazon forest and Ilheus-Itabuna region. The second was the illegal transportation of cocoa plant seedlings from the Amazon forest. Cocoa is an original fruit from the Amazon forest. A third was the main explanatory narrative at that time, based on the belief that it was bio-crime made by coca producers' competitors in the Amazon forest and Ivory Coast. Bio-crime has similar definition to agroterrorism, but in this case there is no political motivation with the attack. However, in 2006 an investigation conducted by the Brazilian Federal Police was made public by an influential national magazine, reinforcing the beliefs that the disease dissemination was intentional and had political motivations.

Brazil was facing the re-democratization period, and there was a tight dispute in the 1989 electoral campaign between the candidates Fernando Color de Melo (right-wing) and Luis Inácio Lula da Silva (left-wing). Besides, some years after the presidential election, Brazil also had municipality elections. Therefore, affecting the landlords economic power would translate in less political power of the elites, increasing the chances of political groups not connected with the military allies in the region. The investigated reported to the police that the disease was deliberated brought from the Amazon forest to destroy the cocoa mono-culture and, consequently, the power of the right-wing landlords.[2] Despite nothing having yet been proved about the responsible and the real motivations, the consensus is that the spread of the fungus was criminal and intentional (Rocha, 2006). Based on the spatial pattern of the infections and the coincidental timing of the first two infections (two different and 100km apart focus sites, both located in the center of the cocoa region) Pereira, De Almeida, and Santos (1996) concluded that the disease was criminally introduced. Finally, it is important to point out that there is no evidence that the plague introduction had the goal of affecting the human capital accumulation in the cocoa region, but instead, the available evidence suggests that the target was the political power of cocoa's landlords.

To assess the impact of which broom disease, we leverage information about people born in cities affected and not affected by the disease and explore the difference in educational attainments between cohorts older and younger than eighteen years old at the time of the witch broom outbreak. We then estimate a difference-in-differences model. The underlying hypothesis is that cohorts older than eighteen had taken most of their educational decisions, while younger cohorts still needed to make many choices. It is a reasonable assumption because of the expected age to conclude the high-school

[2]The militant and his crime partners used to work for CEPLAC, a public institution that provided technical assistance to cocoa production in Brazil. Therefore, they had knowledge about cocoa plagues and its dissemination. In addition, to reinforce the history, it was made public that the owner of first farm affected by the disease (*Conjunto Santana*) was the president of the Democratic Rural Union, a right-wing union supporting Color in the 1989 presidential election, and one of the landlords in the region.

in Brazil is seventeen years old. Besides, at the time of the outbreak, the offer of college, university or vocational education was very limited in the region. Then, we should not expect any difference in educational results between individuals in affected and not affected regions. We use the 2000 and 2010's Brazilian demographic Census coupled with historical information about the timing and severity of the crisis in each city. Our sample contains 7 million individuals who live in one of the nine states of the Brazilian northeast. Our sample is restricted to those born after the witch broom outbreak and had less than 65 years old at each demographic census.

The main results show that the witch broom outbreak negatively affected the education and income of individuals living in affected cities. People below eighteen years old living in cities affected by the witch broom disease have 2.8% less probability of having a high school degree, 3.2% probability of having elementary school, and wages 4.8% lower. Those effects are greater for individuals between zero and twelve years old at the time of the witch broom outbreak. We also show that the impacts are higher in cities with a higher dependency on cocoa production prior to the witch-broom outbreak. We do that by interacting the witch broom covariate with the share of cocoa production in 1989, the year before the outbreak. The effects on high school achievement and wages increase to, respectively 7.6% and 17.4%. Since the outbreak occurred in a staggered fashion between 1990 and 1992, we also used the estimator proposed by Sun and Abraham (2021), showing that our results are not biased by the differences in treatment timing.

Our results are consistent with the luxury axiom in the multi-equilibrium model developed by Basu and Van (1998), where parents choose not to send their children to work when incomes are sufficiently high, and the opposite occurs when the incomes are low. The "luxury axiom" states that families will not send their children to school if the income is sufficiently high. They also assumes that adult and child labor are (not perfect) substitutes, which is in line with Walker (2007). Therefore, shocks change the opportunity cost of schooling, and children are forced to work to help the family income (Baker et al., 2019). The empirical evidence using Brazilian data support the model conclusions. Soares, Kruger, and Berthelon (2012) provides an empirical test of Basu model to the Brazilian context, showing that higher household wealth is associated with lower child labor and higher schooling. However, temporary increases in local economic activity are associated with higher child labor and lower schooling. De Carvalho Filho (2012) showed that families that became eligible to receive rural pensions in Brazil have lower probability of sending their children to work. Duryea, Lam, and Levison (2007) found that when a head of the Brazilian household lost the job, the probability of having a children working increases. There are also empirical evidence from coffee shocks showing that child labor increased during economic booms (Kruger, 2007; Carrillo, 2020). This points out that the relation between shocks and child labor may depend on the

specificities of the labor demand and offer (Manacorda and Rosati, 2011).

We provide evidence that the witch-broom outbreak led to a fall in the GDP per capita, and household incomes of affected municipalities, such as documented in the literature, pushing the southeast region of Bahia to a recession period. We then provide suggestive evidence of the mechanism behind the results. We estimate an event-study regression of the interaction of year dummies with a treatment indicator, where the treatment is being affected by the witch-broom outbreak, and the outcome is the share of children working compared to the total population of children in the municipality.[3] The result suggests that there was an increase in child labor in by 2.5 percentage points in 2000 and 2010 in affected regions compared to non affected regions.

In addition to the fact that the witch broom outbreak had occurred in a very poor area, from 1987 to 1994, Brazil faced the worst inflationary period in its history, with the total annual inflation rate achieving 107,492.07% between February 1986 and November 1989. The inflation rate was controlled only with a pool of macroeconomic policies in 1994, which introduced the current currency, the Real. Therefore, during the which broom outbreak, most of the credit markets in the country were nonexistent, and most of the households had no savings. Furthermore, cocoa production makes intensive use of low-skilled workers, which reduces their mobility to other activities in case of crisis. Households cannot borrow and save pre and during crises in an environment of incomplete (or lack of) capital markets and insurance (Jensen, 2000). Because of their parents' volatile income, reducing children's educational investment is a surviving strategy. Beegle, Dehejia, and Gatti (2006) and Bandara, Dehejia, and Lavie-Rouse (2015) show that access to a bank account mitigates the effect of weather shocks on child labor in Tanzania, for example.

Additionally, this paper makes three contributions to the literature. First, we are the first paper to estimate the causal impact of the witch broom on educational and labor market outcomes. Second, we add to the literature on short and long-run agricultural shocks, but we are the first to explore the effect of an agro-terrorism event. Most of this literature focus on the boll weevil plague in the US Cotton belt (Baker et al., 2019; Ager et al., 2020), coffee shock prices in Latin America (Padrón and Burger, 2015; Carrillo, 2020; Kruger, 2007), desert locust in African countries (Le and Nguyen, 2022) or on the impact of climate events, as droughts (Rocha and Soares, 2015) and floods (Maccini and Yang, 2009). The main difference is that those are temporary shocks, which significantly differ from the witch broom characteristics. Third, we contribute to the literature that relates economic shocks in the agricultural sector to child labor (Kruger, 2007; Cogneau and Jedwab, 2012). Despite the literature suggesting a positive relation, most of papers are

[3] According to the Brazilian statute of children and teenager, any kind of work is strictly prohibited for people younger than fourteen years old in Brazil. See Estatuto Brasileiro da Crianca e do Adolescente - ECA. Law 8.069/1990. http://www.planalto.gov.br/ccivil_03/leis/L8069.htm

not able to empirically prove it (Baker et al., 2019). Besides, we also provide additional empirical evidence of the increase in child labor led by agricultural shocks in Brazil (Soares et al., 2012).

The paper proceeds as follows. In section 2 we present the institutional context of the arrival of the witch-broom in the south of Bahia. Section 3.2 presents both the data and our empirical strategy. In section 4 the main results are presented. Section 4.4 presents robustness checks and discuss the mechanisms behind our baseline results. Finally, section 5 concludes.

# 2 Background

Bahia—a large-sized state with about 15 million inhabitants and whose territory is about the size of France—is one of the poorest states in Brazil.[4] Bahia's labor market has a large share of informal jobs, low-educated workers, and high unemployment rates. According to the 2010 Population Census, informal jobs represented half of the total employment, and half of the workers had at most eight years of educational attainment.[5] In 2019, Bahia had the second-highest unemployment rate in Brazil—17% against the national rate of 11%.

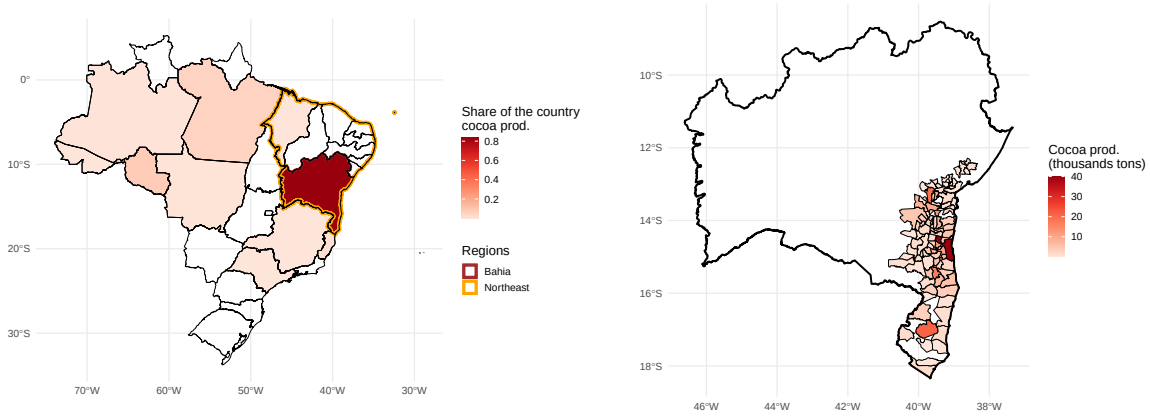
Between 1961 and 1985, Brazil figures out as one of the three biggest cocoa producers globally. In 1985, the Brazilian production was about 448,577 tons of cocoa, representing 70.5% of Ivory Cost production, the biggest producer in the world. The share of Bahia state in the national production was approximately 86%. The southeast of Bahia's state concentrated the cocoa production in Brazil until 1990. Figure 1 shows the map of Bahia state and highlights the municipalities with cocoa production, most known as the Ilhéus-Itabuna microregion. A considerable number of studies, technical reports, and books described the importance of cocoa production for the region, associating cocoa with the development of the agribusiness, to investments in infrastructure and development of local human capital (UESC., 2015; Ceplac, 2009).

The cocoa production in the region was characterized by large farms owned by a few elite families, which led to very high inequality in the region. Besides, because of the high prices of cocoa and the inequality in land ownership, it became a monoculture. Therefore, the region was highly dependent on it, with very low diversification in income generation. Even the development of services in the cities depended on the cocoa economy, with the elite members being the main clients.

[4]Brazil is a three-tiered federation with 26 states, a federal district, and 5,571 municipalities. Bahia state has 417 municipalities.

[5]In 2010, the share of informal workers—defined as those not contributing to social security—was 35.4% in Brazil and 49.4% in Bahia.

**Fig. 1: Spatial distribution of cocoa production in Brazil and Bahia - 1988**




(a) All states (b) Bahia

**Witch Broom**. In may 1989 the Ilhéus-Itabuna microregion fate started to change with the first discovered of the *Miniliophtora perniciosa* in Uruçuca municipality. In October 1989, the Camacan city also reported the presence of the disease. So far, the disease discovers had no technical confirmation, which happened only in 1990, growing to almost all cities with cocoa production by 1992. Figure 2 shows each city with official reports of witch broom disease in Bahia´s state. There is also a large debate on how the witch broom disease landed in Bahia because it is a plague commonly found only in the Amazon forest cocoa.

Because witch broom is one of the most dangerous plagues for cocoa production, many studies try to develop technical procedures to deal with it (IOCC, 1993; Medeiros, Pomella, de Souza, Niella, Valle, Bateman, Fravel, Vinyard, and Hebbar, 2010; Lisboa, Evans, Araújo, Elias, and Barreto, 2020; Scarpari, Meinhardt, Maizzafera, Pomella, Schiavinato, Cascardo, and Pereira, 2005; Fioravanti and Velho, 2011). A remarkable difference from the extensive literature about agricultural shocks is that while price and weather shocks are temporary, the witch broom was permanent. At the outbreak moment in Bahia, there was very little knowledge about how to fight the plague, with the main recommendation being to cut and burn the sick trees. It leads to the destruction of farms and families' sources of income.

This recommendation was proven wrong, but there is still no specific cure or management for the witch broom. Depending on the local climate and cocoa genetics, the treatment is evaluated case by case. These very particular characteristics implied that the peak of contaminated cocoa fruits was in 2000/01 (Ceplac, 2009), ten years after the outbreak. The high level of infected fruits persisted until new agricultural practices started to be implemented, including the use of more resistant genetically modified cocoa species (Medeiros et al., 2010). Finally, it is important to point out that there was no

program created by the governments of the Municipalities, the State or at the Federal level to support the affected families.

At the time of the disease outbreak, the main explanations for the disease were bio-crime conducted by cocoa producers' competitors in the Amazon Forest and in Ivory Coast. Caldas and Perz (2013) provide an extensive narrative and relate different facts to argue that the event was an agro-terrorism. The main event was a Federal Police investigation that interviewed Luiz Henrique Franco Timoteo, a member of the labor democratic party (PDT). He confirmed that he partnered with the other four members of the PDT[6] that worked at the CEPLAC, the agency in the Ministry of Agriculture responsible for the cocoa, decided to contaminate the cocoa production to destroy the power of the cocoa landlord elites to increase the left-wing candidate support in the presidential elections. Besides, reducing their power would also benefit other candidates in the municipality elections in subsequent years.

Because of the witch broom, cocoa production reduced from 448,577 tons in 1985 to only 96000 tons in 1999. The Ilhéus-Itabuna microregion had the highest level of unemployment in its history, with 250 thousand rural workers losing their jobs and the average cocoa revenue reducing from US$ 600 million/year to US$ 200 million/year (Ceplac, 2009). The witch broom disease is one of the most dangerous plagues to the cocoa and chocolate industry, and because of that, many studies have been conducted to understand, control, and avoid the plague (Fioravanti and Velho, 2011; Lisboa et al., 2020; Medeiros et al., 2010; Scarpari et al., 2005). Figure 3 shows the production of cocoa through time. Cocoa production has had a negative trend since 1985 when cocoa prices started to fall. However, it became steeper after the witch broom outbreak, with the lower production levels in 2000, the peak year of cocoa-infected products (Ceplac, 2009).

Panel (a) of figure 4 shows that while the GDP in municipalities exposed to the witch broom fell between 1985 and 1995, it stayed the same in the other municipalities. Panel (b) shows that the fall in the GDP per capita in the period is much higher for exposed municipalities. As mentioned before, from 1987 to 1994, Brazil faced the worst inflationary period in its history, with the total annual inflation rate achieving 107,492.07% between February 1986 and November 1989. Notwithstanding, there is a gap in the GDP data at the municipality level, with 1985 being the last year before the witch broom outbreak and 1995 the first year after the outbreak. Besides, we believe that the positive trend after 1995 is explained by the introduction of the successful macroeconomic reforms and the new currency (Real) that controlled the inflation in Brazil.

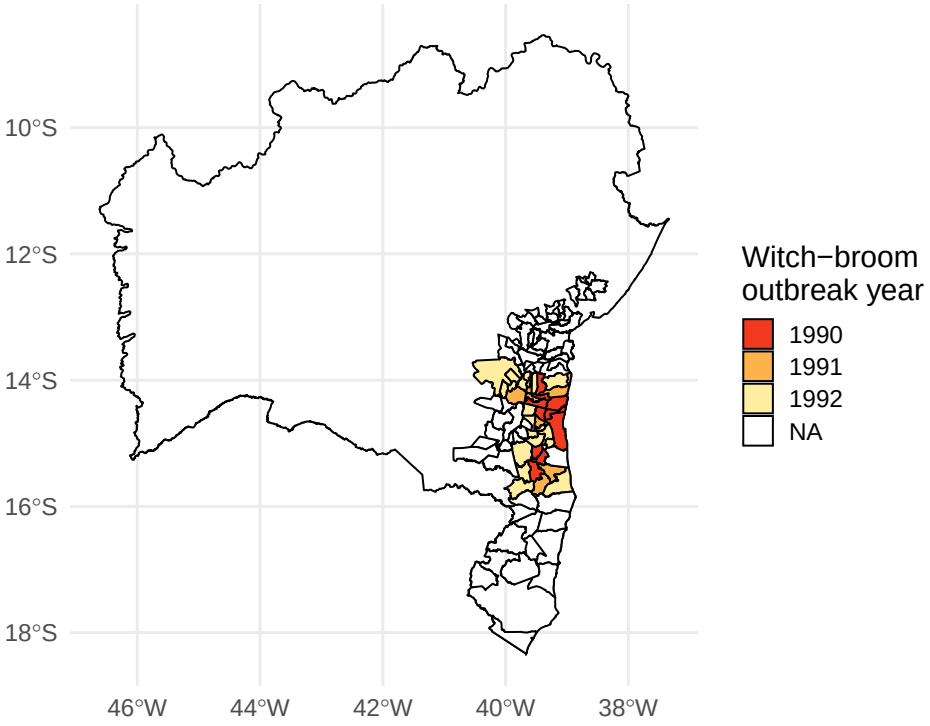
Although these graphs strongly suggest the impact of the witch broom disease, the GDP data at the municipality level before 2002 faces methodological problems[7] and

[6]It is important to point out that PDT is not Lula's political party. Lula is a member of the Labor Party (PT).

[7]Brazilian municipalities only started to calculate GDP using the same methodology in 2002, developed

the fact that there is a gap between 1985 and 1995, we use the Brazilian Census data to recover the income at the municipality level and estimate an event-study regression to complement the previous evidence about the impact of the witch broom at the aggregate level. The Census has a centralized organization and data collection by the IBGE. Figure 5 show the short term impacts of the disease. The municipalities income felt between 25 to 38 per cent between 1991 and 2000 because of the witch broom.

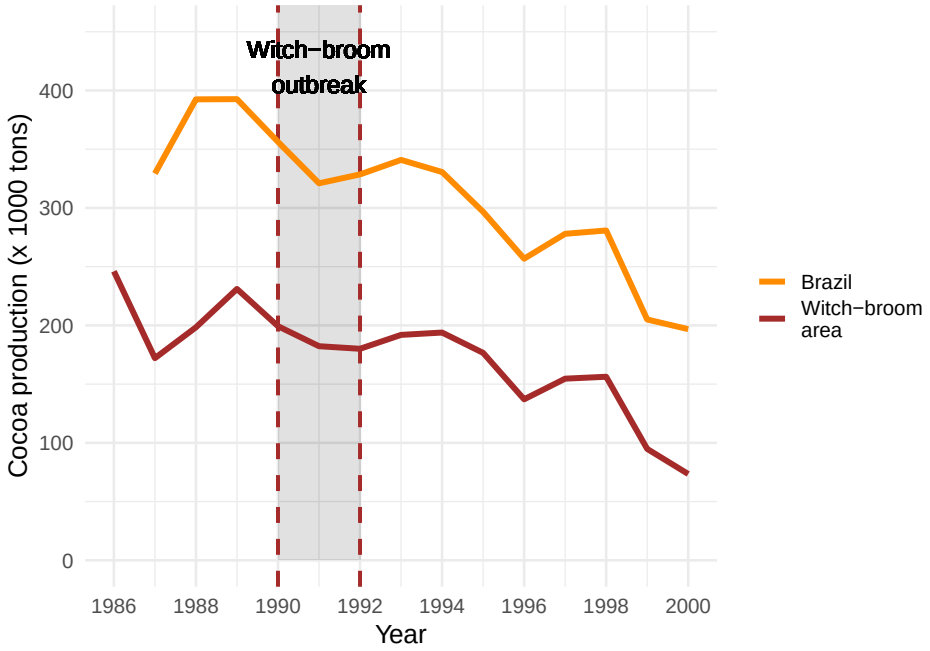
**Fig. 2: Witch broom outbreak by municipalities and year**




*Notes. Based on Lisboa et al. (2020)*

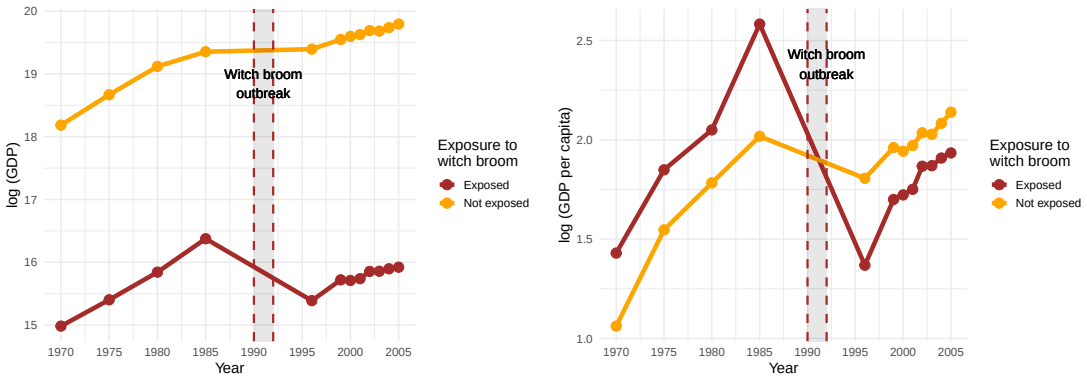
by the Brazilian Bureau of Statistics – IBGE. The municipality's GDP before 2002 was recovered through a methodology developed by Eustáquio et al. (2005). Another important limitation is that the series before and after 1990 are calculated using different methodologies. Therefore, because of measurement errors, it is not recommended to use it for estimation procedures.

**Fig. 3: Trends in Cocoa production 1986 to 2000**




*Notes.* Authors elaboration based on Ipeadata.

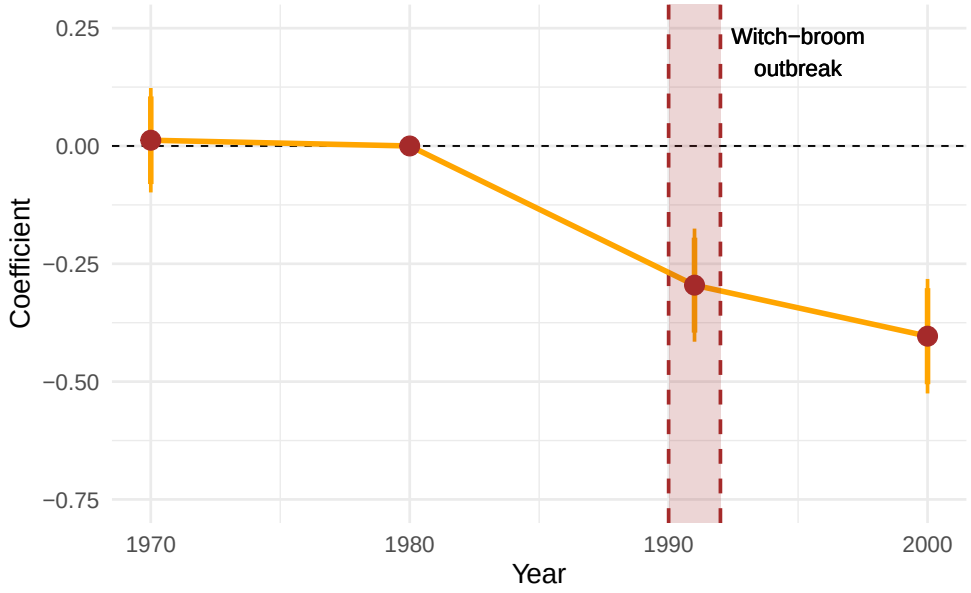
**Fig. 4: GDP and GDP per capita by regions exposed and not exposed to the witch broom**




(a) GDP (b) GDP per capita

*Notes. This figure show the evolution of the municipality GDP (panel (a)), and municipality GDP per capita (panel (b)) between treated and control municipalities.*

**Fig. 5: The short term effect of Witch-broom outbreak on average earnings**




*Notes.* The figure displays estimated coefficients of an event-study regression of the interaction of year dummies with a treatment indicator, where the treatment is being affected by the witch-broom outbreak, on the average earnings in municipalities on the Northeast of Brazil. Data is from 1970, 1980, 1991 and 2000 censuses.

The witch broom disease has two important features for our study. The first one is that there is an incubation period between the disease inoculation and the signals that make it possible to identify sick trees. Only after the incubation period it is possible to identify the sick trees because the appearance of very specific mushrooms. The second is that there is no specific cure or preventive manipulation to avoid completely the disease development and dissemination (Alves, Pomella, Aitken, and Bergamin Filho, 2006; Scarpari et al., 2005). The sick trees with the disease in a initial stage are difficult to spot and if the mushrooms are not correctly destroyed it can disseminate the disease to other threes after small pieces of it are taken by the wind and land in another tree. Figures A.1, A.2 and A.3 illustrate a healthy cocoa fruit, a fruit contaminated with the witch broom and the witch broom mushroom that indicates that tree is contaminated and with the plague.

# 3 Data and Empirical Strategy

## 3.1 Data

To assess the long-run effects of the Witch-broom outbreak we use the 2000 and 2010 waves of Brazilian census. The census have detailed information on education and labor market outcomes, like occupation and wages. Since the 2000's and 2010's census do not ask individuals the municipality of birth, we keep on the sample only individuals

that declared to be born on the municipality of residence and use this information as a proxy to the municipality of residence at the time of the shock. We only consider municipalities on the northeast region, and excluded from the sample individuals with more than 65 years old. To improve the comparability of age cohorts, we restricted the sample only to individuals with 0 to 35 years old at the time of the witch-broom outbreak. For municipalities not affected by the witch-broom, we consider the individuals with 0 to 35 years by 1990, the first year of the plague. Finally, the witch-broom outbreak dates for each municipality were collected using data from Pereira et al. (1996).

## 3.2 Empirical Strategy

We are interested in the effect of the witch broom disease outbreak on the probability of completing high school and wages in the long run. Thus, first we estimate the equation 1 that represent a difference-in-difference identification strategy exploiting the differential timing of the year of the witch broom outbreak across municipalities. The estimated parameters must be interpreted as an intention to treat effect because not everyone in the municipality affected by the plague below eighteen years old were direct affected by the shock.

$$Y_{im} = \beta_k WB_{im} * A_{age \leq 18} + \gamma X_i + \rho_m + a_{2010} + \epsilon_{im} \tag{1}$$

$X_i$ is a vector of socioeconomic characteristics, and $\rho_m$ a municipality fixed effect. Equation 2 is an event-study version of previous equation to examine the witch broom disease impacts on education and wages by comparing adjacent birth cohorts. In this case, individuals are grouped in eight cohorts $WB_c$, and we add a cohort fixed effect $\theta_c$. The cohorts below 18 years old living in cities affected by the witch broom outbreak are the treated group because they did not finish their schooling decisions, while the cohorts above 18 years old at the time of the outbreak are the control group, because they had already taken most of their educational decisions. More specifically, we are looking to the probability of having high school.

The interpretation of these estimates assumes that individuals between the ages of 19 and 35 when the witch broom shocks in their municipality of residence do not alter their educational decisions. There are two reasons to expect that. The first is that the offer of technical and college education was very scarce in this region before 2000 (OECD, 2021). Therefore, young adults had very limited option to choose between work and study after age of eighteen. The second is that the typical age for finishing elementary education is 14, while the typical age to finish high school is 17. Therefore, only a very strong belief would refuse these two assumptions together.

$$Y_{icm} = \sum_{k=0}^{8} \beta_k * 1\{19 \leq WB_c - K \leq 18\} + \gamma X_i + \theta_c + \rho_m + a_{2010} + \epsilon_{icm} \quad (2)$$

We believe that there are three potential mechanisms that explains the results. The first one is the increase in child labor, which is consistent with the luxury axiom in Basu and Van (1998); Soares et al. (2012). In section 4.3 we estimate an event study regression that confirm that child labor may explain the findings. The second is the potential impacts of the income drop on health outcomes, which is also well established in the literature (Rocha and Soares, 2015) , and the third is that the which broom shock may have led to reduction in education inputs in the affected municipalities, such as school closure due to the drop in municipality revenues. Unfortunately, however, there are no available data in Brazil at the municipality level before the shock to test the educational and health hypothesis. Regarding education, most of the spending on education at the municipality level in Brazil is led by transfers from the Federal government and not by municipality tax collection. Therefore, there is no reason to expect a sharp drop in educational spending or school closure.

Finally, because of differential timing of the outbreak across municipalities, section 4.4 presents the Sun and Abraham (2021) estimator for a DiD with staggered adoption. The main results do not change, eliminating potential bias arising from the OLS estimation. Another potential concern it that migration could biases our results. Affected families may had chosen to migrate to other municipalities to find better employment opportunities. To overcome that we also estimate a model in a restrict sample composed of individuals that reported that were born and always lived in the city $c$. Section 4.4 shows that migration do not seems to driven our results. Besides, section 4.4 also explain that there is some sparse evidence of an internal migration within cities in the Ilhéus-Itabuna region, but not about people leaving the micro-region. Finally, in section 4.4 we provide evidence that the effects are not driven by some municipality idiosyncratic characteristic, by assuming that there was some shock in the same municipalities in 1970 or 1980.

# 4 Results

In this section, we present the results of the empirical strategy described in 3.2. We split the section into three parts. First, we present the main results for all cohorts. Second, we present the results by sex. Finally, we present a bunch of robustness checks and placebo analyses.

## 4.1 Baseline results

Columns (1) and (2) of table 1 show the impact of the witch broom disease on the probability of having completed at least a high school degree using equation 1. Cohorts younger than eighteen years old at the time of the witch broom disease exposure have 2.8% lower probability of having at least a completed high school degree. Columns (3) and (4) show a slightly stronger result for the probability of completing elementary school. Columns (5) and (6) show that cohorts exposed to the witch broom have wages -5.4% lower than cohorts not exposed to the witch broom.

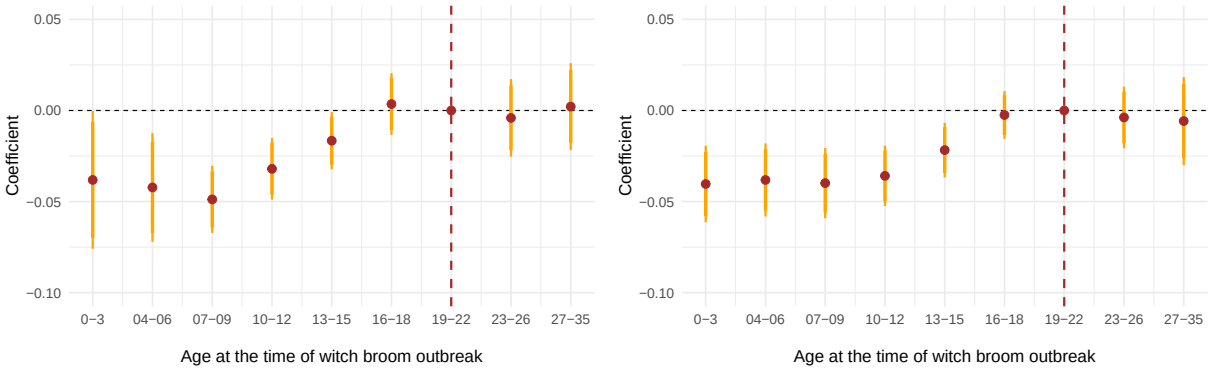
Figures 7 and A.5 add by showing the long-term witch-broom effects for different cohorts estimated using the equation 2. These figures present two main messages. First, the results are stronger for cohorts younger than 12 years old, both for education and wages. Second, the results are not statistically significant for cohorts between 16 and 18 years old at the time of the shock.

**Table 1: Long Run effect of witch broom on exposed cohorts**

| | High School | | Elementary School | | log(wages) | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Childhood exposure | -0.028*** | -0.028*** | -0.032*** | -0.032*** | -0.056*** | -0.048** |
| | (0.008) | (0.008) | (0.010) | (0.010) | (0.022) | (0.022) |
| $R^2$ | 0.075 | 0.079 | 0.101 | 0.107 | 0.207 | 0.227 |
| Observations | 4,647,460 | 4,625,295 | 4,647,460 | 4,625,295 | 1,884,097 | 1,877,702 |
| Municipality FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Birth-year FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Census wave FE | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ind. Controls | | ✓ | | ✓ | | ✓ |

*Notes.* The Table displays the regression results of the estimation of equation 1 and also alternative specifications. The dependent variable in columns (1) and (2) is a dummy that equals one if the individual completed high school. In columns (3) and (4) the dependent variable is an indicator variable that equals one if the individual completed elementary school. Finally, in columns (5) and (6), the dependent variable is the log of wages. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (1)—. Standard errors are clustered at the municipality level.

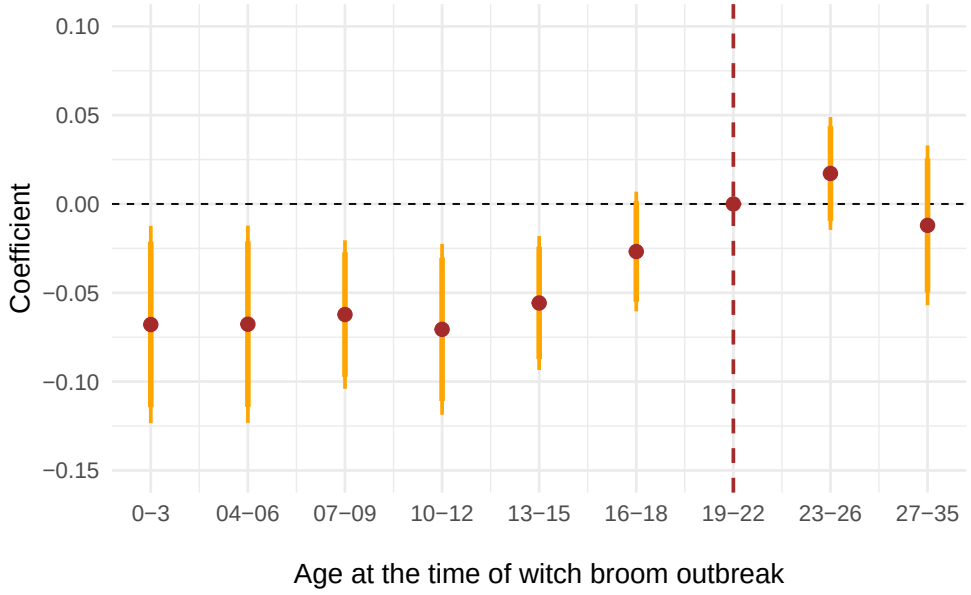
**Fig. 6: Long run consequences of witch broom outbreak on education**




(a) Elementary School (b) High School

*Notes.* The figure displays the baseline results for the probability of having completed elementary and high school up to 20 years after the witch broom outbreak. The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (2)—. Standard errors are clustered at the municipality level. Confidence intervals: 95% and 90%.

**Fig. 7: Long run consequences of witch broom outbreak on wages**




*Notes.* The figure displays the baseline results for the probability of having high school up to 20 years after the witch broom outbreak. The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (2)—. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

As explained before, cocoa production in Bahia was a monoculture with low diversification. Many cities' economic systems were dependent on it. Figure A.4 shows the share of cocoa production in relation to the total agriculture production in each city affected

by the witch broom. The average share of cocoa on the total agricultural production was 40%, achieving about of 80% in some cities. Table 2 show the estimation results after interacting the witch broom exposure with the cocoa share of the total agricultural production in the city in 1989, one year before the shock. The results suggest that the effect increase three times, from –2.8% to –7.6% for the probability of having high-school and from –5.6% to –17.4% for wages.

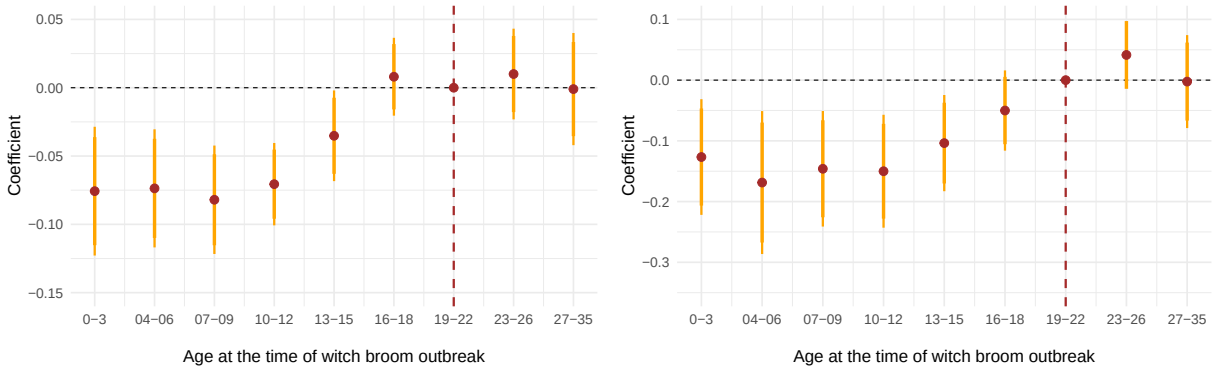
Therefore, different from the boll weeviel evidence (Baker et al., 2019), the introduction of the witch broom did not reshape the pervasive poverty and inequality in the Ilhéus-Itabuna region. The fact that this was a poor area totally dependent of the cocoa economy made the economic restructuring difficult. The arrival of the witch broom, thus, was not followed by reductions in the most negative aspects of the cocoa economy.

**Table 2: Long Run effect of witch broom on exposed cohorts by intensity of cocoa dependence**

| | High_School | | log(wages) | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Childhood exposure | -0.028*** | | -0.056*** | |
| | (0.008) | | (0.022) | |
| Childhood exposure * Cocoa share | | -0.076*** | | -0.174*** |
| | | (0.021) | | (0.065) |
| $R^2$ | 0.075 | 0.075 | 0.207 | 0.207 |
| Observations | 4,647,460 | 4,647,460 | 1,884,097 | 1,884,097 |
| Municipality FE | ✓ | ✓ | ✓ | ✓ |
| Birth-year FE | ✓ | ✓ | ✓ | ✓ |
| Census wave FE | ✓ | ✓ | ✓ | ✓ |

*Notes.* The Table displays the baseline regression results of the estimation of equation 1 and also results for the interaction of the childhood exposure dummy with the share of cocoa production in each municipality over the total agriculture production, as a proxy for cocoa dependence. The dependent variable in columns (1) and (2) is a dummy that equals one if the individual completed high school. Finally, in columns (3) and (4), the dependent variable is the log of wages. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (1)—. Standard errors are clustered at the municipality level.

**Fig. 8: Long run consequences of witch broom outbreak by intensity of exposure**




(a) High School

(b) Wages

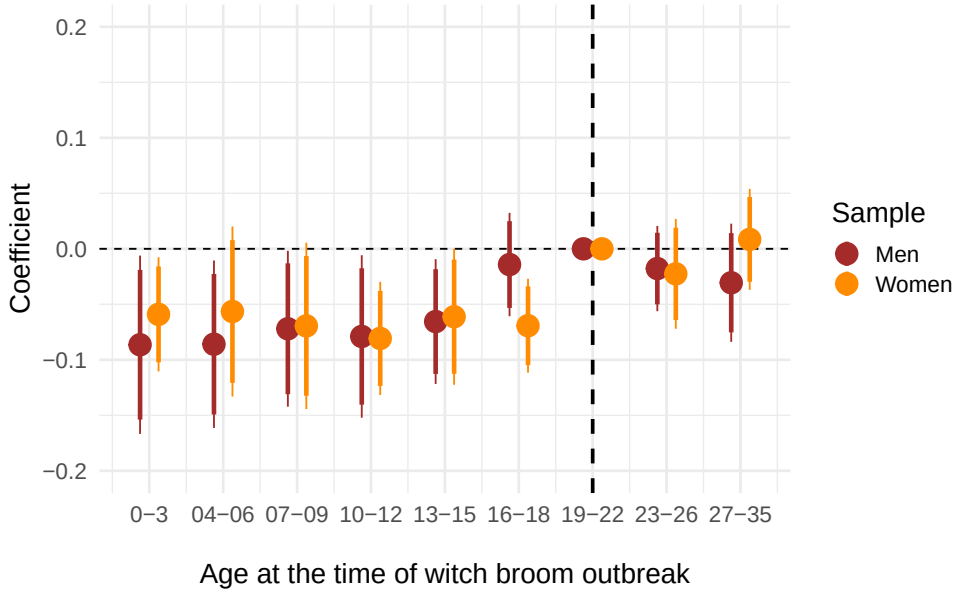
*Notes.* The figure displays the baseline results for the probability of having completed elementary and high school up to 20 years after the witch broom outbreak. The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (1)—. Standard errors are clustered at the municipality level. Confidence intervals: 95% and 90%.

## 4.2 Heterogeneous effects

Although child labor is a remarkable characteristic in Brazilian agriculture, Manacorda and Rosati (2011) suggested using the Brazilian census that it is more intense on girls labor than boys. Cogneau and Jedwab (2012) provide descriptive evidence that boys in the agricultural sector in the Ivory Coast present higher enrollment and lower probability of working than girls. Besides, they also show that this difference is higher in cocoa production areas than in non-cocoa production areas.

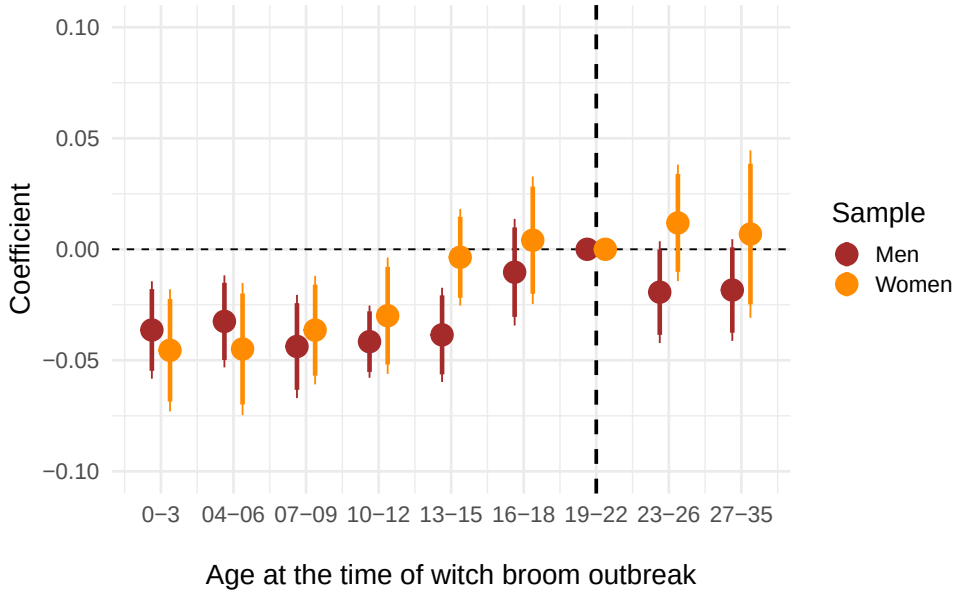
We explore the heterogeneous effects of the witch broom outbreak by sex. Figures 9 and 10 show that witch-broom outbreak affected both groups equally. Therefore, despite historical documents (Walker, 2007) and the above descriptive evidence of the cocoa production in using girls more than in other crops production, the effect of the witch broom was homogeneous across sex.

**Fig. 9: Long run consequences of witch broom outbreak by gender - Wages**




*Notes.* The figure displays the baseline results for the probability of having high school up to 20 years after the witch broom outbreak. The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (1)—. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

**Fig. 10: Long run consequences of witch broom outbreak by gender - High school.**




*Notes.* The figure displays the baseline results for the probability of having high school up to 20 years after the witch broom outbreak. The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (**??**)—. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

## 4.3 Mechanism

The previous sessions showed that the witch broom impacted the income and GDP per capita of the affected cities, and those impacts translated into long-term effects on human capital accumulation (education) and wages. Our main assumption is that due to the drop in earnings and the lack of savings, families decided to put their children to work to compensate the income loss, which is in line with the main models of child labor (Basu and Van, 1998; Edmonds, 2007).

According to the Brazilian statute of children and teenager[8], any work is strictly prohibited for people younger than fourteen years old in Brazil. Therefore, we aggregate the share of children between ten and thirteen years old working in each city of the Northeast region and estimate an event-study regression of the interaction of year dummies with a treatment indicator, where the treatment is being affected by the witch-broom outbreak, such as the one presented in figure 5, but as the share of children working as the dependent variable.

Figure 11 suggests a strong positive effect of the witch broom outbreak on the probability of child work at the municipality level[9]. The witch broom increased the child labor in affected municipalities in 2.5 percentage points, an increase of 30% compared to the control group average. The effects appears in 2000 and stands until 2010, even though the introduction of the National program against child labor (PETI) in 1996 and its expansion in 2002 when the program was coupled with the Brazilian cash transfer program Bolsa Família. The Brazilian law also specifies stringent rules under which people between fourteen and seventeen can work. The main rule is that they can work short-term as an apprentice and restrict the activities they can do. However, because we cannot disentangle what is child labor and what is apprentice work, we restrict our sample for people below fourteen years old.

The negative result in 1990 is not easy to interpret and would require an additional investigation, but our main hypothesis is that it takes time to families adjust to the economic shock and decide to take their kids out of school and put them to work. Therefore, the observed fall in child labor in 1990 may reflect the fact that this region could have suffered less from the economic shocks of the beginning of the 1980 decade[10] than other regions of the state that are even poorer. This is reasonable because most of the cocoa production was for exportation, not suffering from the internal economic downturn of that period. Therefore, the negative impact of the witch broom outbreak observed in 11

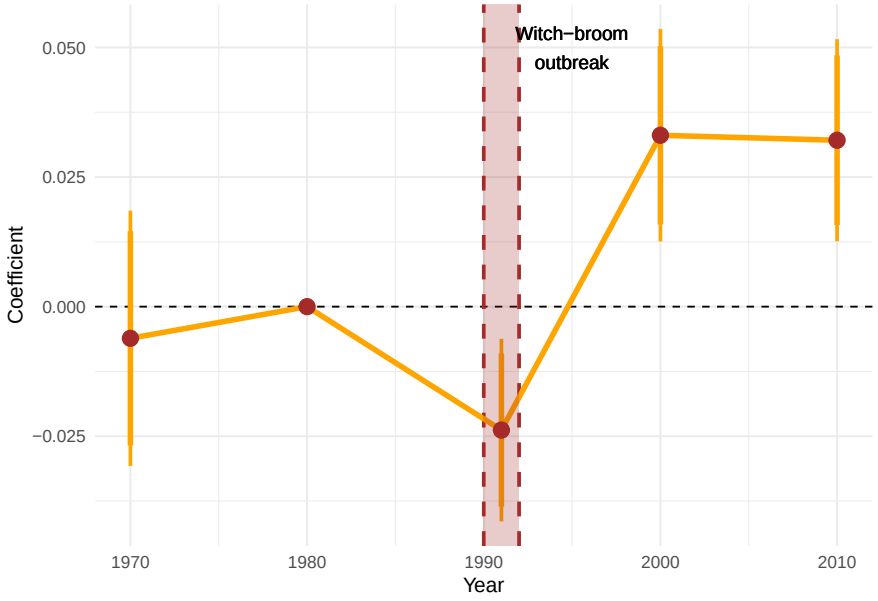
[8]Estatuto Brasileiro da Crianca e do Adolescente - ECA. Law 8.069/1990. http://www.planalto.gov.br/ccivil_03/leis/L8069.htm

[9]In the appendix, we show the same estimation but assuming 1970 as the baseline. The main results do not change

[10]Even though the 1980 is known as the lost decade in Brazil, the worst period was between 1980 and 1983 when the GDP fell by 13%. Between 1984 and 1989 the economy presented a slightly recover, but that was not enough to mitigate the shock in the first four years.

will take time to be translated in the child labor increase.

**Fig. 11: The short term effect of Witch-broom outbreak on the share of working children**




*Notes.* The figure displays estimated coefficients of an event-study regression of the interaction of year dummies with a treatment indicator, where the treatment is being affected by the witch-broom outbreak, on the share of children working in municipalities on the Northeast of Brazil. Data is from 1970, 1980, 1991, 2000 and 2010 censuses.

To provide more evidence that the probable mechanism that led to the long-term impacts on education and health is child labor, we used a yearly national microdata survey called PNAD[11]. We used PNAD 1995 to create table 3, because in 1996 PETI was launched. This table shows in column 2, the share of children that works in cocoa in Bahia's State, compared to the total number of children working in agriculture. Although the interviewed population of Bahia could indicate that they work in 19 different broad agricultural productions at PNAD 1995, which can be disaggregated in almost 375 specific activities, cocoa production responded to 4.3% of all child labor in the agricultural sector of Bahia State in 1995.

Column 3 of table 3 shows the share of young individuals below eighteen years that works in cocoa and reported that they started working at the age $i$, in column 1. The denominator is the share of children that works in any other agricultural production and reported that they started working with age $i$. Thus, in 1995, 18.2% of the individuals below eighteen that reported started working at seven years old, worked in cocoa production. Finally, column 4 shows the average age that individuals started working, per

[11]Pesquisa Nacional por Amostra de Domicílios. It is usually indicated as a "micro census", nationwide representative, and also conducted by the Brazilian Bureal of Statistics - IBGE.

age group, in 1995. It shows that individuals between ten and seventeen started working right after the first years of the witch broom outbreak (1990). Unfortunately, the PNAD only provides information at the state level, and we cannot reproduce this table after 2000 due to changes in the methodology to define the sectors.

**Table 3: Percentage of individuals younger than 18 years old working in the cocoa, compared to other agricultural productions in Bahia state in 1995**

| Age i | # child working - cocoa / # child working in any agr. / | # age child working in cocoa started # age child working in any agr. started | Average starting / working age |
|---|---|---|---|
| 5 | | 9.5% | |
| 6 | | 17.6% | |
| 7 | | 18.2% | |
| 9 | | 3.3% | |
| 10 | 9.4% | 3.1% | 8.33 |
| 11 | 5.1% | 5.9% | 8.50 |
| 12 | 2.2% | 6.1% | 8 |
| 13 | 2.3% | 6.4% | 10 |
| 05-13 | | 5.9% | |
| 10-13 | 4.3% | 4.2% | |
| 14 | 4% | 11.5% | 7.99 |
| 15 | 6% | 27.3% | 10.85 |
| 16 | 6% | 50.0% | 9.8 |
| 17 | 11% | 10.76 | |

*Notes.* The table display in column 1 the age indicator. Column 2 display the share of children working in cocoa in Bahia state (on the total of children working in any agriculture production in the state). This should be interpreted as: 5.1% of all children with eleven years, in 1995, working in Bahia is working at cocoa production. The column 3 should be interpreted as 6.4% of all people below eighteen years old that is working in Bahia in 1995, works in the cocoa production and started working with eleven years old. Finally, the last column shows the average starting working age of children that was working in cocoa production in 1995.

Finally, table 4 adds by showing that in 2000 the percentage of individuals that used to go to school or that never went is much higher in witch broom-affected areas than in not affected areas. Besides, the difference is higher for individuals between eleven and twelve years old. Unfortunately, we cannot recover this information from the 1991 census.

**Table 4: Percentage of individuals younger than 18 years old that are enrolled in school or kindergarten in 2000**

| | Witch broom municipalities | | | | Others | | | |
|---|---|---|---|---|---|---|---|---|
| | Yes, priv. | Yes, Pub. | No, but used to | Never | Yes, priv. | Yes, Pub. | No, but used to | Never |
| 10 | 0.0 | 92.9 | 7.1 | 0.0 | 0.6 | 92.4 | 4.7 | 2.2 |
| 11 | 0.0 | 81.6 | 13.2 | 5.3 | 0.6 | 92.8 | 4.0 | 2.5 |
| 12 | 0.0 | 75.9 | 17.2 | 6.9 | 0.5 | 91.0 | 5.9 | 2.6 |
| 13 | 1.5 | 75.0 | 14.7 | 8.8 | 0.7 | 87.6 | 8.8 | 2.9 |
| 14 | 1.6 | 68.8 | 26.4 | 3.2 | 0.7 | 82.8 | 13.5 | 3.0 |
| 15 | 0.5 | 67.4 | 29.5 | 2.6 | 0.7 | 73.8 | 21.7 | 3.9 |
| 16 | 0.0 | 52.6 | 39.9 | 7.5 | 0.6 | 63.6 | 31.3 | 4.5 |
| 17 | 0.4 | 44.5 | 46.3 | 8.9 | 0.6 | 52.2 | 41.7 | 5.6 |

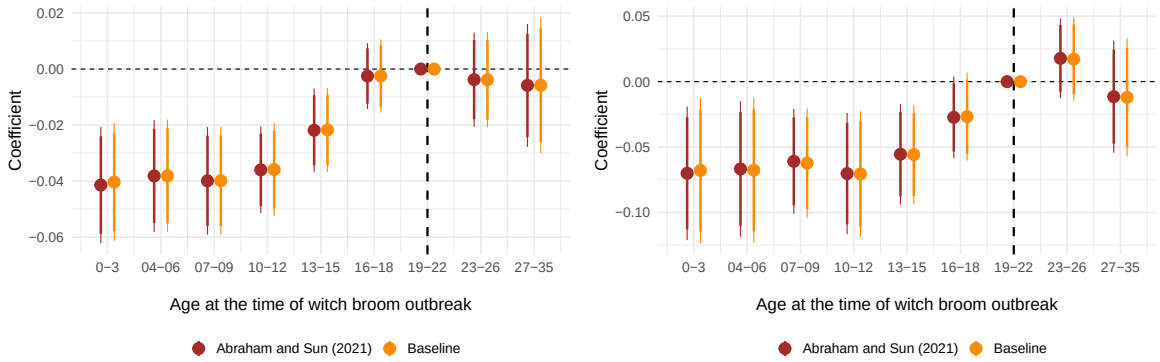
*Notes.* The table display, using the 2000 census, the percentage of individuals younger than 18 years old that are enrolled in school or kindergarten in 2000. They are split into two groups, regions affected and not affected by the witch broom. Yes, priv = yes, she is studying in a private school. Yes, Pub = yes, she is studying in a public school. No, but used to = no, she is not studying, but she used to study. Never = she never ever studied.

## 4.4 Robustness

### 4.4.1 Staggered Difference-in-Differences

Section 2 and Figure 2 explains that the witch broom outbreak had differential timing across municipalities. Therefore, the OLS estimation can be biased (Roth, Sant'Anna, Bilinski, and Poe, 2022). To overcome that, we estimate equation 2 using Sun and Abraham (2021) estimator. Figure 12 suggest that the estimation presented in previous sections are not biased by the staggered outbreak of the disease, since results from baseline are qualitatively identical and quantitatively similar to the estimator proposed by Sun and Abraham (2021). This is somewhat expected, given that we used a large number of never treated cities in the control group and the fact that treatments occurred in a short range interval of time (1990 to 1992), indicating no clear reasons for the treatment effect to vary by treatment groups.

**Fig. 12: Long run consequences of witch broom outbreak: Baseline vs Abraham and Sun (2021) estimator**



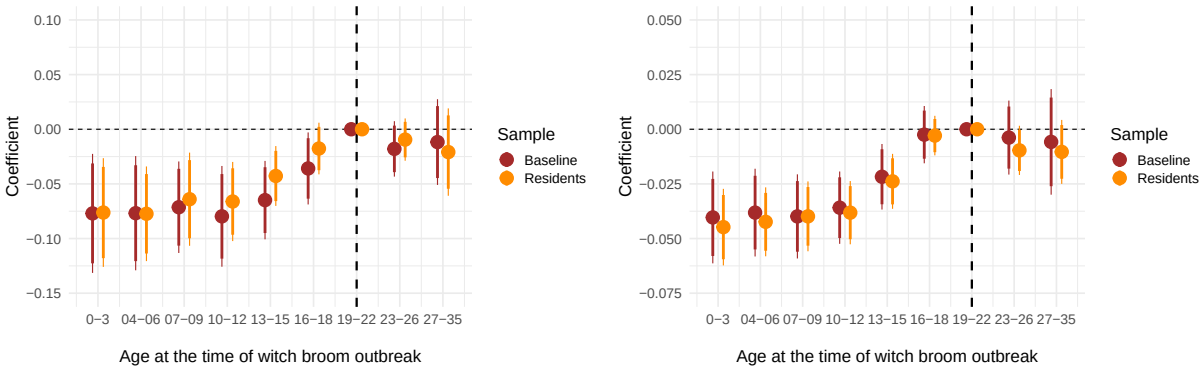

(a) High School (b) Wages

*Notes.* The figure displays the baseline results for the probability of having completed high school and the log of earnings up to 20 years after the witch broom outbreak and results for the estimator proposed by Abraham and Sun (2021) . The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (1)—. Standard errors are clustered at the municipality level. Confidence intervals: 95% and 90%.

### 4.4.2 Migration

A potential concern is that migration could bias our results. Affected families may have chosen to migrate to other municipalities to find better employment opportunities. Since in our main sample we are only considering individuals who were born in the same municipality where they were interviewed in the censuses, migration could lead to biased estimates. To check how much of an impact migration could have on our baseline estimates, Figure 13 compares our baseline results with the ones when considering the municipality of residence as the municipality of birth. As can be seen in Figure 13, results don't change much across both specifications, indicating that if there is some bias due to migration, it is limited. Some historical documents report that there was some migration within Ilhéus-Itabuna micro-region, in which migrants moved to the region's biggest cities, such as Porto Seguro, Ilhéus, and Itabuna, but not to other parts of the state or other states (UESC., 2015; Pereira et al., 1996; Ceplac, 2009; Sergipe and Rocha, 2006).

**Fig. 13: Long run consequences of witch broom outbreak: Baseline vs non-movers**




(a) Income (b) High School

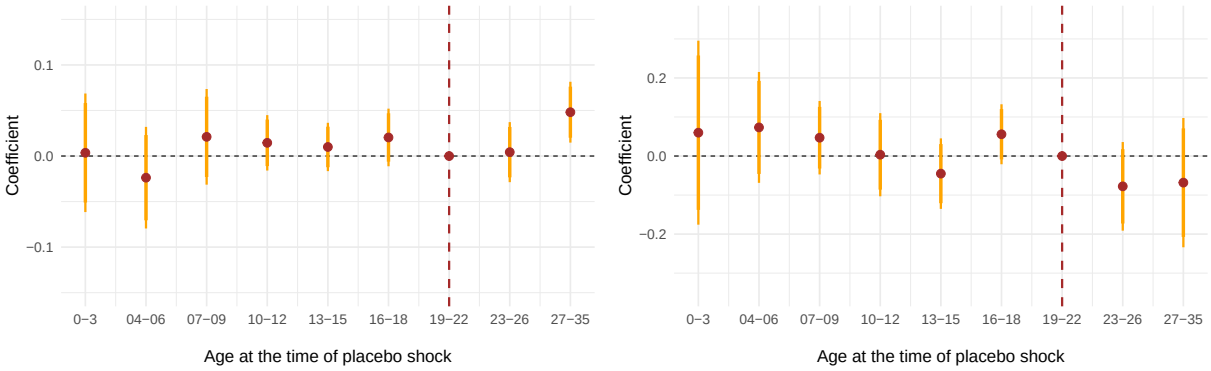
*Notes.* The figure displays the baseline results for the probability of having high school up to 20 years after the witch broom outbreak. The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (**??**)—. Standard errors are clustered at the municipality level. Confidence intervals: 95%.

### 4.4.3 Placebo

So far, we showed how individuals exposed in the childhood to the Witch broom outbreak today have worse labor market and education outcomes than cohorts in municipalities not exposed to the shock. However, it might be the case that younger cohorts in treated municipalities were always worse than the ones in non-treated municipalities because of idiosyncratic characteristics of affected municipalities. To test if that is the case, we estimated equation 2 arbitrarily assigning a placebo shock in 1960 to the same municipalities that, in the future, will be affected by the witch-broom outbreak and look for differences in the same outcomes of individuals on the census of 1970 and 1980.

Due to limitations of the 1970s census, we do not have information on individual wages, and use, instead, the family income as the dependent variable. We measure education using the number of years of schooling, a variable that is compatible between the 1970s and 1980s censuses. The sample is composed only by individuals in the Brazilian Northeast that have 0 to 35 years old in 1960. Figure 14 presents the results of the falsification exercise. As expected, there is no effect.

**Fig. 14: The long run consequences of a Placebo Treatment**




(a) Income (b) Years of schooling

*Notes.* The figure displays the results for a placebo exercise using 1970's and 1980's census data and a fictional shock in 1960 on the municipalities that will be affected by the witch-broom in the future. The horizontal axis shows the age at the moment of the placebo shock. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (2)—. Standard errors are clustered at the municipality level. Confidence intervals: 95% and 90%.

Since the 1970s and 1980s censuses and interviews occurred before the witch-broom outbreak, we should not expect any difference in the labor market and education outcomes of cohorts exposed in childhood to the placebo shock in the 60s. Indeed, as shown in Figure 14, there is no difference in wages or years of schooling between younger and older cohorts exposed and not exposed to the placebo shock, reinforcing the robustness of our baseline estimates.

# 5 Conclusion

This paper studies the long-run effects of a significant agro-terrorism event in cocoa production in Brazil on education and the labor market. We explore the witch broom outbreak in cocoa farms in the world's second most important cocoa production region until 1989, the southeast of Bahia's state in the northeast of Brazil.

Our results show that the witch broom outbreak negatively affected the education and income of individuals living in affected cities. People below eighteen years old living in cities affected by the witch broom disease have 2.8% less probability of having a high school degree, 3.2% probability of having elementary school, and wages 4.8% lower. Those effects are greater for individuals between zero and twelve years old at the time of the witch broom outbreak. We provide suggestive evidence that this long run negative effects on human capital and wages is explained by the aggregated impacts on cocoa production that led to a fall in the GDP per capita, and household incomes, since the

witch broom disease pushed the southeast region of Bahia to a recession period and push children in affected municipalities to start to work early. We also show that the impacts are homogeneous between gender. Finally, we show that the impacts are higher in cities with a higher dependency on cocoa production. The effects on high school achievement and wages increase by 7.6% and 17.4%, respectively.

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**ONLINE APPENDIX - NOT FOR PUBLICATION**

# Not a sweet life: the unintended long-run impacts of agro-terrorism in Brazil

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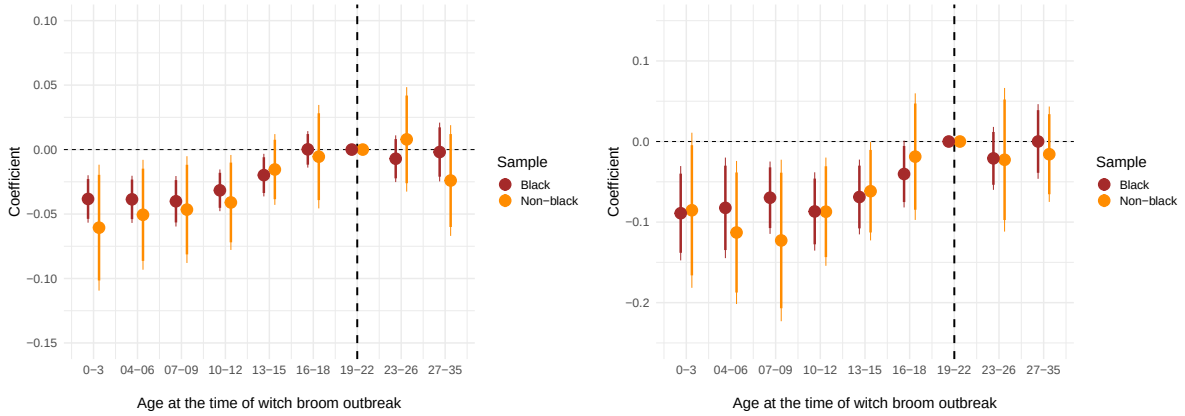
August 2, 2022

# A Appendix: Figures and Tables

**Fig. A.5: Long run consequences of witch broom outbreak by race**




(a) High School (b) Wages

*Notes.* The figure displays the baseline results for the probability of having completed elementary and high school up to 20 years after the witch broom outbreak. The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (1)—. Standard errors are clustered at the municipality level. Confidence intervals: 95% and 90%.

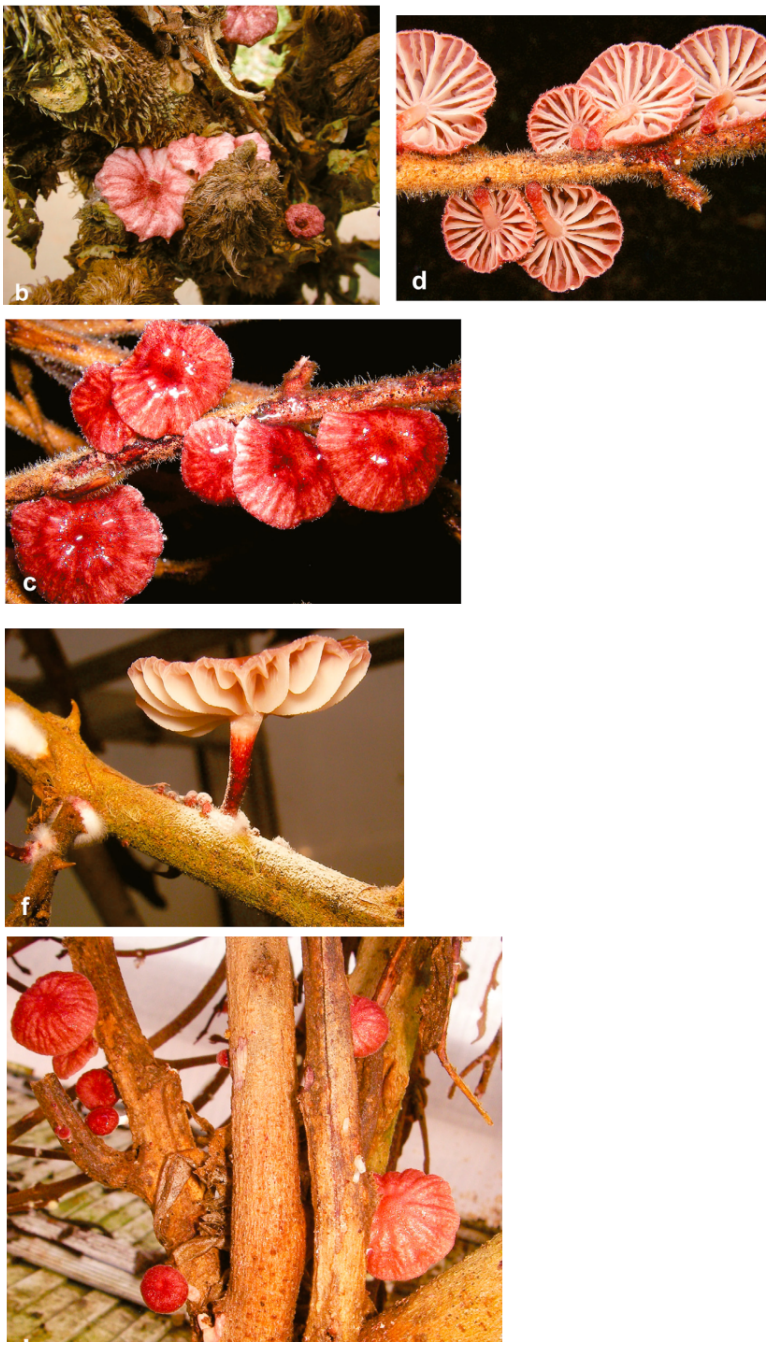
**Fig. A.1: Healthy cocoa**

source: https://agresearchmag.ars.usda.gov/2005/oct/cocoa/

**Fig. A.2: Cocoa with witch broom**

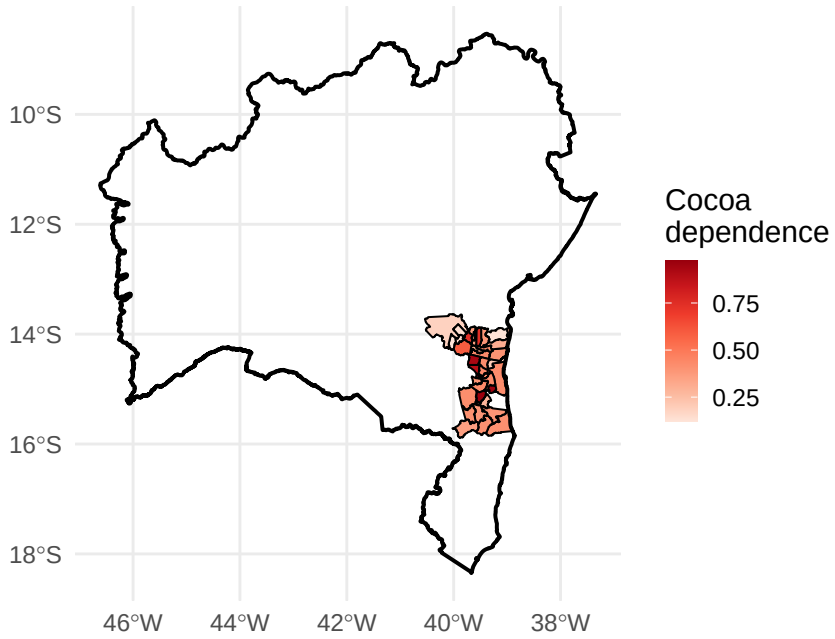
source: https://agresearchmag.ars.usda.gov/2005/oct/cocoa/

**Fig. A.3: Different types of witch broom mushroom**



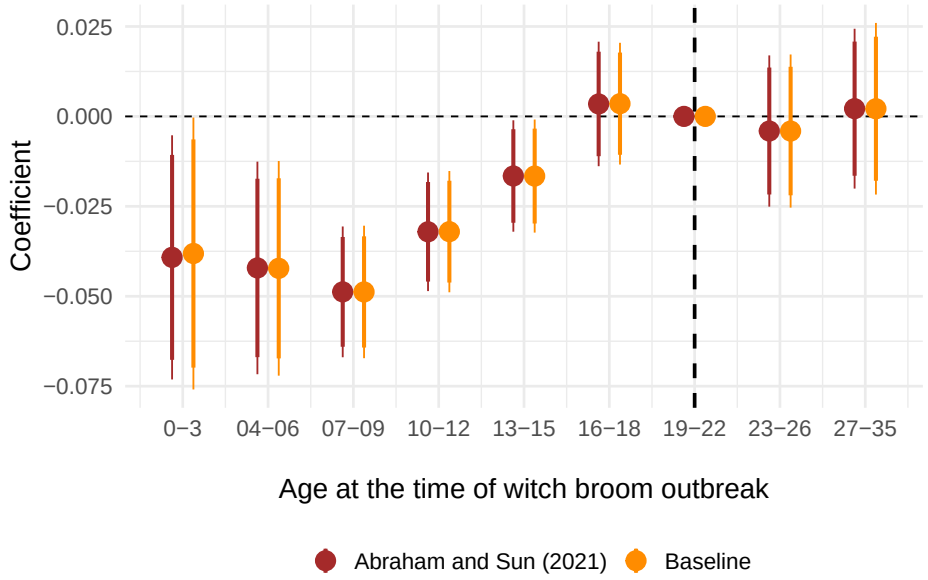

source: Lisboa et al. (2020)

**Fig. A.4: Cocoa dependence in municipalities affected by the witch-broom plague**




*Notes.* The figure plots the spatial distribution of an index of cocoa dependence in municipalities affected by the witch-broom. The index is the share of cocoa production over total agriculture production on the municipality in 1989, a year before the first witch-broom outbreak.

**Fig. A.6: Baseline estimates vs Abraham and Sun (2021) estimator - Elementary school**




*Notes.* The figure displays the baseline results for the probability of having completed elementary school and the log of earnings up to 20 years after the witch broom outbreak and results for the estimator proposed by Abraham and Sun (2021) . The horizontal axis shows the age at the moment of the witch broom outbreak. The estimate corresponds to a ITT effect—to the estimated coefficient of Equation (1)—. Standard errors are clustered at the municipality level. Confidence intervals: 95%.