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The Impact of the Expansion of African Palm Crop on Child Undernutrition in South-West Guatemala

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Abstract

The struggle for water and land use in Guatemala has intensified in the last decade due to the accelerated expansion of the agro-export sector. Particularly, in the south-west region, the recent expansion of african palm crop has taken place at the expense of illegal dredging of rivers, the improper use of water resources and the purchase and forced dispossession of communal and family lands of the indigenous population. This situation not only represents a destructuring of the established order within families and within indigenous communities, but also compromises the nutritional health of the most vulnerable members, such as children and women. This study provides evidence on how the rapid development of this agro-export crop has contributed to increase the probability of children suffering from chronic malnutrition in the region, and particularly those from indigenous mothers, living in urban areas and in households where the head of the family is a man.

Keywords: Child Undernutrition · African Palm · Impact Evaluation
JEL Classification: J13, O12, I15, Q53

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1 Introduction

The agriculture sector in Guatemala has been the key driver of economic growth during the last decade in the country (Sanchez et al., 2016). It is marked by a duality, with a more recent world leading export sector that includes sugar, palm oil, coffee, cardamom and bananas as top 6 export commodities between 2013 and 2015 (United Nations, 2017); and a more traditional one, less productive but more important to indigenous and peasant families, around the production of maize and beans mainly.[1] Guatemala's Agricultural Ministry estimates that nearly 0.8 million households are small-scale commercial and subsistence agriculture producers, cultivating corn and beans in almost one-third of the cultivated agricultural area in Guatemala (Sanchez et al., 2016).

The agro-industrial production of palm oil in Guatemala has been growing since the 1980s. The industry is vertically integrated, with five companies dominating national production, and the yields of palm oil in Guatemala are among the highest in the world, with 7 tons per cultivated hectare compared to a world average that ranges between 3 to 4 (Solomon and Bailis, 2013). With the world's largest growth in exports in the last 20 years, the country has become the fifth world exporter, with palm oil exports representing 1.1% of the international market (CABI, 2017) and 2.7% of national exports in 2015 (United Nations, 2017). African palm is currently being cultivated in 8 departments of the country. In two of them that are located in the south-west region, Quetzaltenango and San Marcos, the expansion that took place between 2007 and 2015 in the share of cultivated hectares with african palm has doubled that of the rest of the country, and it represented 4.08% of the total area of both departments in 2015, compared to only 2.04% in the rest of Guatemala.

In these two departments, the expansion of african palm crop has initially replaced cotton and cattle plantations. However, since 2010, it has involved deforestation, illegal dredging of rivers, the improper use of water resources and the purchase and forced dispossession of communal and family lands of the indigenous population, which not only represents a destructuration of the established order within families and within indigenous communities but also compromises the nutritional health of the most vulnerable members, such as children and women (Castro et al., 2015). Studies such as Ávila-Romero and Albuquerque (2018) and (Sabogal, 2013) provide evidence about the social and environmental effects of the expansion of african palm crop in Brazil, Mexico and Colombia. Sabogal (2013) analyses, through spatial econometric techniques, the relationship between african palm cultivation and forced displacement in areas where the crop has been expanding between 1997 and 2009 in Colombia. More recently, through descriptive data from a fieldwork carried out between 2014 and 2017, Ávila-Romero and Albuquerque (2018) discuss how the agro-industrial production of palm oil in Mexico and Brazil has involved changes in the ownership of agricultural land from communal or individual property to agribusiness; intensive deforestation and forced displacement of population; poor working conditions, incluiding child labour, that contributes to enhance

[1] Indeed, the fundamental basis of food in Guatemala are corn tortillas, which are an institution, and flipped beans.

social and economic marginalization; and dependence on cash crops, at the expense of food crops or local consumption, which raises questions about long-term local food security and possible economic vulnerability.

According to these findings, the means through which the expansion of african palm crop in the Latin American continent is being carried out, is affecting the pre-established order within communities, contributing to increasing social and food security vulnerabilities. The current study is able to provide new evidence on the impact of the recently rapid expansion of african palm crop that is taking place in south-west Guatemala since 2010, on the nutritional health of children under five. It relies on a difference-in-difference empirical strategy that compares the pre-to-post change in nutritional outcomes of the treated sample – children under five years of age living in Quetzaltenango and San Marcos – to the change in nutritional outcomes of the control sample – children under five years of age living in the rest of departments in Guatemala without african palm crop. The outcomes of interest are the standard measures deffined by the World Health Organisation (WHO) of child undernutrition in terms of z-scores ((severe) stunting, (severe) wasting, (severe) underweight).[2] The study uses data from the last four waves of the National Maternal and Children's Health Survey (ENSMI), which enables to build a pre-treatment period for the years 1998/1999, 2002 and 2008/2009, and a post-treatment period for 2014/2015.

Controlling for a large set of observable characteristics that allow to mitigate concerns of selection bias, the results from the analysis suggest that the accelerated expansion that has taken place in these departments since 2010 and which has involved water pollution and the destructuration of the established order within indigenous communities, has a signifcant impact on deteriorating children's nutritional health in south-west Guatemala.[3] More precisely, the study founds that the probability that a child under five years of age suffers from chronic malnutrition, is significantly increased by 6.1 percentage points (p.p.) – on average – if she/he lives in Quetzaltenango or San Marcos and, thus, is affected by the treatment. The heterogeneity analysis shows that the effect particularly concerns children from indigenous mothers (7.0 p.p.), living in urban areas (15.2 p.p.) and in households where the head of the family is a man (7.6 p.p.). These results are robust when the control sample only considers children living in the other departments from the south-west region where african palm does not grow; when applying matching techniques to reduce heterogeneity among samples; when controlling for the tropical storm Agatha that frapped Guatemala by 2010; when doing falsication tests by modifying the pre/post period; and when modifying the control sample to only consider children living in departments that are suitable for african palm cultivation but where the crop has not yet expanded. Additional analysis also shows that children between two and five years of age are those particularly affected. This suggests that the rapid expansion of african palm crop in Quetzaltenango and San Marcos contributed to a deficient nutritional intake of

[2]Please, refer to the Appendix A for a detailed description of how these measures are calculated.

[3]This result is measuring the impact of the expansion of african palm in Quetzaltenango and San Marcos as a whole, without being able to distinguish the impact of each of the practices through which this expansion has taken place.

children born between 2010 and 2013, increasing their probability of being irreversibly stunted after the age of two.

The article belongs to the stream of literature analyzing the social and environmental effects of agribusiness expansion in Guatemala. For instance, Tomei (2015) analyses the impact on the access to land, labor and legal compliance of ethanol production from sugarcane certified as sustainable by the European Union Renewable Energy Directive (EU RED). The study highlights that the EU Normative does not capture the problems faced by the local population in Guatemala, which endangers rural communities. Alonso-Fradejas et al. (2008) describe well the impact of biofuels production from palm oil and sugarcane in Guatemala as well as the lack of a national regulatory framework used by the state to promote and support these activities. They further highlight the illegal dredging of rivers and the forced displacement of indigenous communities, claiming that the energy crisis is seen as an opportunity for agribusiness in Guatemala, which in turn exacerbates already existing problems for the environment, the poorest and the indigenous population. However, there is no empirical evidence of the effects on food security and the nutritional health of the most vulnerable population, a gap in the literature that this study contributes to fill.

The rest of the paper is organised as follows. Section 2 is dedicated to the context of Guatemala and the analytical framework that hereby applies. Section 3 introduces the empirical and identification strategies that are used in the analysis. Section 4 presents the data and the descriptive statistics of the sample of analysis. Section 5 provides main results from the difference-in-difference estimation and the heterogeneity analysis. Robustness checks are reported in Section 6. Section 7 adds further analysis, and section 8 concludes.

2 Context and Analytical Framework

Palm oil is the new leader in agricultural production in Guatemala. Since 2006, exports to Latin America and Europe have grown at an average annual rate of 20%[4], supplying the growing international demand for biodiesel. Between 2003 and 2015 the number of hectares cultivated with African palm has expanded from 24,209 to 164,049 (INE, 2004, 2016), which represents an annual growth of 17.3% and 4% of the agricultural land in Guatemala in 2015 (CABI, 2017).

Contrary to south-east Asia where over half of the hectares with african palm are cultivated by smallholders – for instance, 44% in Indonesia and 76% in Thailand – (Pirker and Mosnier, 2015), the industry in Guatemala is vertically integrated, with five companies dominating national production (Alonso-Fradejas et al., 2011). According to Global Forest Watch[5], among these five companies only one located in north-east Guatemala is RSPO certified.[6]

[4] Calculations made from UNCOMTRADE data. Please, see Appendix B for a graphical representation on this.

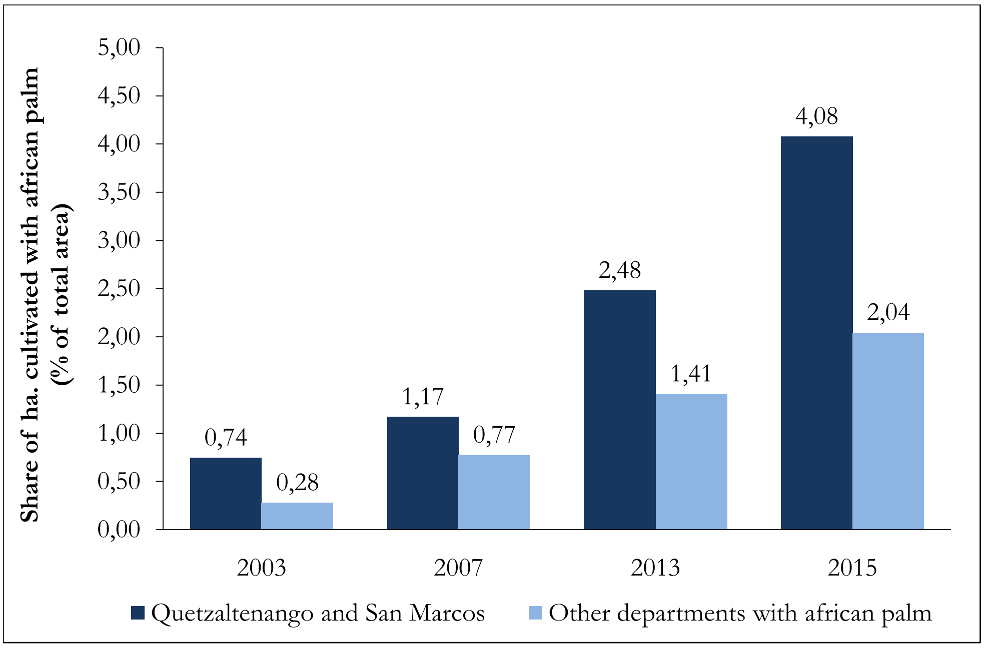
[5] www.globalforestwatch.org

[6] The Roundatable Sustainable Palm Oil (RSPO) was established in 2004 by the agro-industries of Malaysia and Indonesia in order to promote the production of sustainable palm oil, providing an answer to environmental

To date, african palm is being developed in eight departments of the country. In two of them that are located in the south-west region, Quetzaltenango and San Marcos, the percentage of hectares cultivated with african palm has increased much more over the last decade and represents a larger share of the total area of both departments, compared to what is observed in the rest of Guatemala. Figure 1 shows that the share of land cultivated with african palm in Quetzaltenango and San Marcos has increased almost 3 percentage points (p.p.) between 2007 and 2015 and, by that year, represented 4.08% of the total area. Meanwhile, the percentage of hectares with african palm crop in other departments has only expanded 1.27 p.p. in the last decade and the share of total land that covered in 2015 was 2.04%.

Moreover, since 2010, the expansion of african palm crop in Quetzaltenango and San Marcos has led to illegal dredging of rivers, inappropriate use of water resources and land grabbing of indigenous peasant communities, compromising food and nutritional security of the most vulnerable population (Castro et al., 2015). Indeed, industrial cropping of african palm in adult age demands a significantly high amount of water that, in times of high temperatures, can range between $42,000$ and $49,000$ liters per day and per hectare[7] (Hortúa, 2014). This leads to these plantations to compete for the use of water resources in the irrigation of traditional crops of staple grains (corn and beans) consumed by the communities.

Figure 1: Share of hectares cultivated with african palm (percentage of total area)



Source: National Agricultural Census 2003 and National Agricultural Survey 2007, 2013 and 2015

Additionally, the cases documented in the study carried out by the Coordination of NGOs and Cooperatives of Guatemala (Castro et al., 2015), point out that wastewater of

and social concerns expressed by NGOs and the global society (Feintrenie, 2012).

[7]Between 300 and 350 liters per african palm tree and considering that one hectare can grow around 140 palm trees.

african palm crop, which has a high content of fertilizers and pesticides, is discharged into the rivers Ocosito and Pacayá (in Quetzaltenango and San Marcos, repectively), jeopardizing regional biodiversity (fauna and flora), reducing the availability of fishes, flooding the agricultural lands of families during the rainy season and exposing the population of urban and rural areas to harmful substances for their health.

The growing model of african palm crop in the two departments of the south-west region of Guatemala also differs from the one developed in south-east Asia. For instance in Indonesia, two schemes within the production of palm oil coexist: one consisting on a contract signed between a company, smallholders, and banks, with the supervision of the government and under the name Nucleus Estates and Smallhoders (NES), where the company plants, manages and collect the crop, giving the landowner a percentage of the revenue; and another where the farmer independently develops its oil palm plantation and sell the fruit to the industry in charge of the oil extraction. Smallholders can thus be organised within cooperatives, learning how to improve their plantations, or included in partnerships with companies, with a strong support of public policies (Feintrenie, 2012).

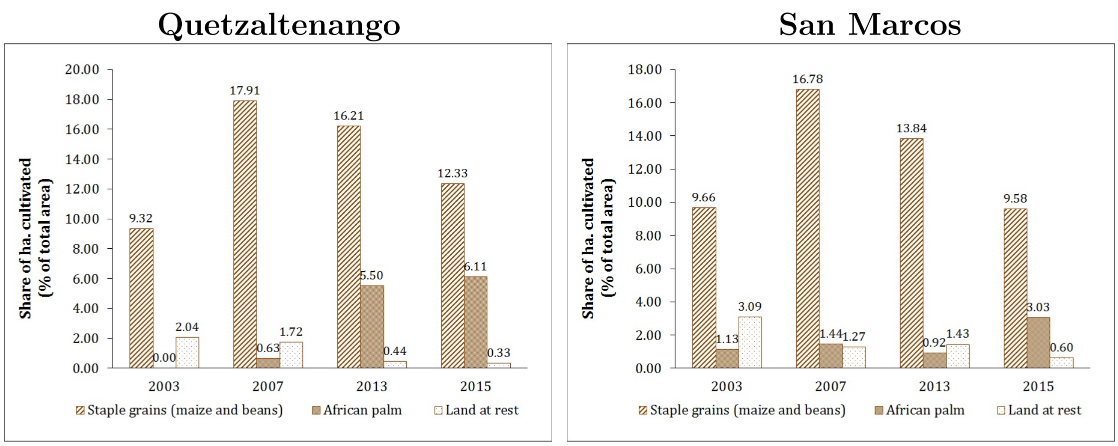
In the south-west region of Guatemala, african palm has initially replaced the cultivation of cotton and occupied lands that were previously used for cattle grazing. Nontheless, in the recent years, the expansion of this monoculture has also involved deforestation and purchase and forced dispossession of communal and family lands of the indigenous population (Castro et al., 2015). Indeed, in order to expand the plantations, companies seek to buy the agricultural land of the farmers. If the landowner refuses to sell, the company uses other mechanisms such as immediate money supply in amounts greater than the local price of land, or threats, coercion and violence. It is also frequent that the company gradually purchases plots of land, closing the access to roads and water resources to the peasants, surrounding the landowner and forcing him or her to sell (Hurtado, 2008). Other strategies used by companies is the offer of employment in oil palm farms. The study done in Castro et al. (2015) documents that most of the hired employees are men under 40 years of age, but also highlights the substantial presence of women and child labour, which represents around 25% and 11% respectively. As a result, the affected families not only become dependent on the income received from this activity and the labor conditions imposed to them, but additionally, they have less access to food due to the total or partial loss of their farmland.

In addition, the dispossession of family and communal agricultural lands, as well as the excessive and poorly paid work hours of male household heads in african palm plantations, implies an increase and lengthening of daily working hours for women (Castro et al., 2015). Consequently, women are not only in charge of the unpaid reproductive and domestic tasks in the household, but they also need to take care of other activities that the partner used to previously carried out - for instance, look for firewood or buy corn. However, in most cases, women are also forced to work in the oil palm industry or migrate to urban areas in search of complementary jobs that allow them to complete family income. This situation not only represents a destructuration of the established order within families and within indigenous communities but also compromises the nutritional health of the most vulnerable members, such as children and women.

Indeed, the expansion of african palm plantations in the south-west region of Guatemala seems to have contributed to the considerable loss of hectareas that were previously dedicated to the production of staple food. When the companies acquire the land, the small and medium farmers stop producing food that was used for their own family consumption, but also products that could be sold in the internal market – such as staple grains (rice, maize and beans), dairy products, and meat. Moreover, some of these farmers also used to rent part of their agricultural lands to other peasants families, that did not have access to land, for the production of staple grains. The acquisition of these lands by the companies, thus contributes to not only reduce the availability of food in the internal market but also confronts these landless families to migrate and relocate themselves in a more precarious way in some other place (Hurtado, 2008).

Using data from the National Agricultural Census 2003 and the three last waves of the National Agricultural Survey (2007, 2013 and 2015), I show in Figure 2 the evolution of the share of hectares cultivated with staple grains (maize and beans), african palm and the share of land that is set to rest, as percentage of total area in Quetzaltenango and San Marcos between 2003 and 2015. It is noteworthy that the percentage of land dedicated to staple grains in Quetzaltenango has decreased 5.6 p.p between 2007 and 2015, whereas the share of cultivated land with african palm has increased 5.5 p.p. In San Marcos the increase in african palm cultivation is lower – around 2 p.p. – than the decrease in the staple grains – around 7 p.p.. It is not possible to withdraw conclusions from this figure but it is just used here as to observe that part of the expansion of african palm crop in the two departments of the south-west region of Guatemala might have taken place at the expense of less land to cultivate staple grains used for the consumption of peasant families.

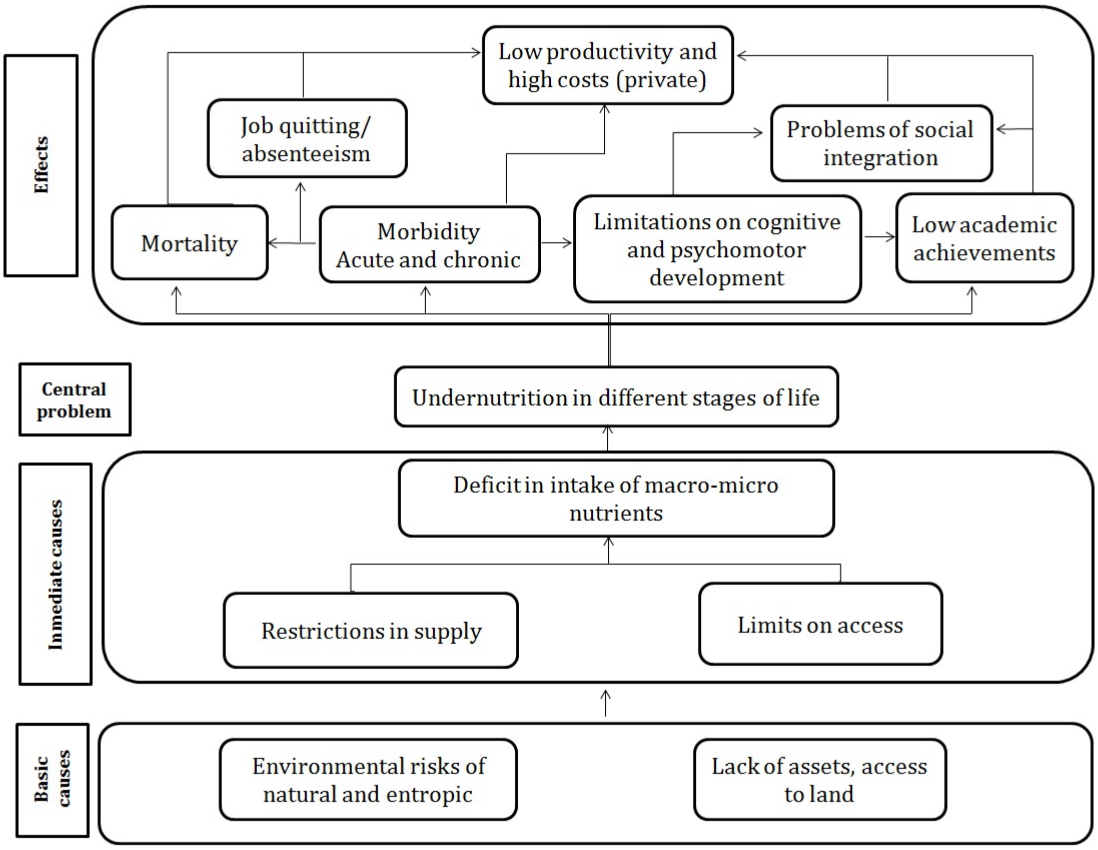
Figure 2: Share of hectares cultivated (percentage of total area) in affected departments



Source: National Agricultural Census 2003 and National Agricultural Survey 2007, 2013 and 2015

Following Martínez and Fernández (2007), this reduction in the availability of staple food caused by entropic factors – water pollution, decrease in the access to water resources and forced restriction in the access to land –, could lead to a deficient intake of nutrients, which, if accumulated in time, might end by causing undernutrition in different stages of life. Figure 3 represents an analytical framework that helps to understand the impact that the means through which the expansion of african palm crop has taken place in Quetzaltenango and San Marcos could have on the nutritional health of the most vulnerable population.

Figure 3: Causes and consequences of undernutrition



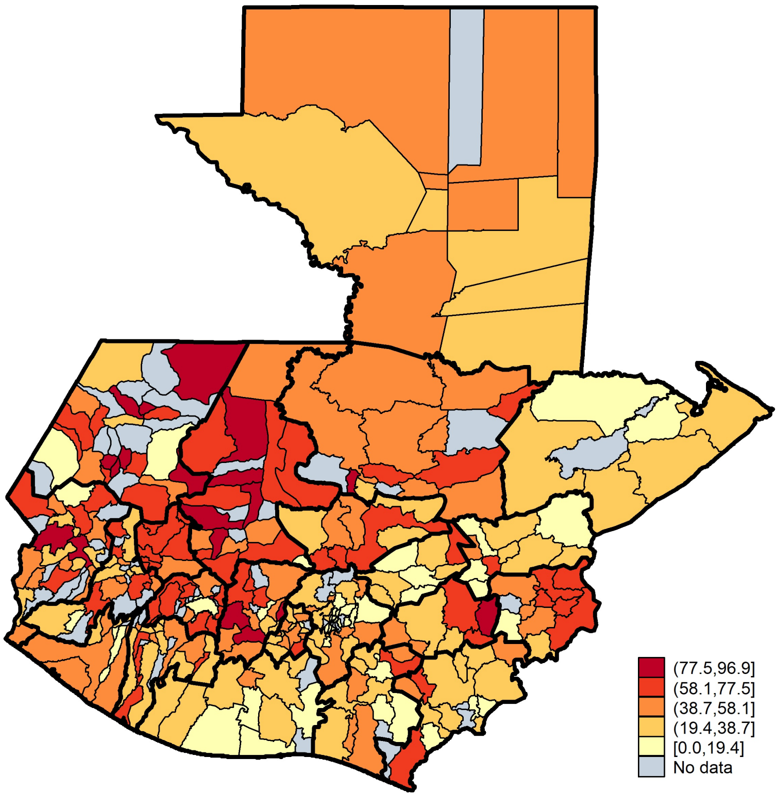
Source: own creation from Martínez and Fernández (2007)

This is particularly relevant in the context of Guatemala since its population is affected by a specific type of undernutrition, which is already structural, and concerns almost one in every two children under five years of age in the country. Indeed, according to the latest data from the National Maternal and Children's Health Survey (ENSMI, 2014/2015), 46.5% of children under five present low height for their age – stunting or chronic malnutrition[8] –, a percentage that increases in the municipalities of the west regions of Guatemala, where most of the indigenous people live. Figure 4 shows that in these regions, the share of children facing low height for their age reaches 60% to 90% in some municipalities, compared to the rest of the country where the average share is not higher than 40%.

This type of undernutrition reflects the cumulative effects of deficient diets and infections even before birth, which is an indication of poor environmental conditions that restrict the growth potential of the child in the long term (WHO, 2010). The consequences of chronic

[8]Please, refer to the Appendix A for a detailed description of how these measures are calculated.

Figure 4: Share of children under five with low height-for-age in 2014/2015 in Guatemala



Source: National Maternal and Children's Health Survey (ENSMI) 2014/2015

malnutrition are an increased risk of illness and death, delayed mental development, poor school perfomance and reduced intellectual capacity. These limitations in the development of cognitive and psychomotor abilities translates into problems of social integration during the adult life, which in turn tends to reduce labor productivity and increase public and private costs, affecting the economic development of the society in the long term (Martínez and Fernández, 2007) and implying a greater risk of intergenerational transmission of malnutrition (WHO, 2010).

Undernutrition affects all groups within a community but children are those who are most vulnerable to it since they require higher nutritional intake for their growth and development (Blossner et al., 2005). Therefore, the analysis in this article focuses on the impact that the rapid expansion of african palm crop in the two affected departments of the south-west region of Guatemala has on the nutritional health of children under five years of age.

3 Empirical Strategy and Identification

Following this specific context, the current study seeks to analyse whether the recently rapid expansion of african palm crop that is taking place since 2010 in the two departments of the south-west region of Guatemala – Quetzaltenango and San Marcos – significantly deteriorates the nutritional health of children living in these departments. The treatment is, hence, defined as this accelerated expansion that has taken place in these two departments since 2010 and which has involved water pollution and the destructuring of the established order within indigenous communities. In order to do this, the analysis focuses on comparing children's nutritional outcomes between the treated region – Quetzaltenango and San Marcos – and the control region – rest of the departments of Guatemala, excluding those six where african palm is also cultivated.[9]

Two empirical strategies are used: difference-in-difference regression and propensity score matching with difference-in-difference. Both strategies compare the pre-to-post treatment change in nutritional outcomes of children under five years of age in the region where the treatment takes place – Quetzaltenango and San Marcos – to the change in nutritional outcomes of children under five years of age in the region not affected by the treatment – rest of departments in Guatemala without african palm crop.

To explain this more precisely, let Y_{1idt} be the nutritional outcome of interest – which are the different measures of undernutrition as defined by the World Health Organisation (WHO) ((severe) wasting, (severe) stunting and (severe) underweight[10] – of child i living in department d at period t if the department is affected by the recently rapid expansion of african palm cultivation, and let Y_{0idt} be the nutritional outcome of the child i living in department d at period t if the department is not affected by the recently rapid expansion of african palm cultivation. Ideally, one would like to compare Y_{1idt} with Y_{0idt}, which are the potential outcomes for the same child. However, in practice, we only get to see one or the other, never both. For instance, it is not possible to observe the nutritional outcome of child i after the treatment, had the treatment not taken place, which is called the counterfactual outcome. For this reason, in order to analyse whether the recently rapid expansion of african palm crop in south-west Guatemala has a significant impact in deteriorating nutritional outcomes of children under five years of age, the estimation needs to rely in the comparison of nutritional outcomes between the treated and the non-treated (control) sample.

Additionally, let γ_d be a dummy variable equal to 1 if the child lives in a department d that is affected by the treatment – Quetzaltenango and San Marcos – and equal to 0 if she/he lives in a department d that is not affected by the treatment - the rest of Guatemala not concerned by the african palm cultivation. In this sense, γ_d measures the time-invariant department differences between the treated and control departments that may affect the nutritional status of child i. Let λ_t be a dummy variable equal to 1 if the child is observed and measured in the post-treatment period and equal to 0 if she/he is observed and measured in the pre-treatment period. This variable measures the common temporal trend of both the control and treated departments. Finally, let's denote D_{dt} the dummy variable that measures the treatment a child living in department d receives at period t – whether she/he lives by

[9]Proceeding as such, allows to exclusively focus on the impact of the rapid expansion of african palm in Guatemala, which has implied bad environmental and social practices, and differentiate it from the effect that its cultivation could have in the economy of the country, which is not the scope of this paper.

[10]Wasting (low height-for-weight) or acute malnutrition, stunting (low height-for-age) or chronic malnutrition and underweight (low weight-for-age) or global malnutrition (acute and chronic malnutrition). Please, refer to the Appendix A for a detailed description of how these measures are calculated.

2010 in a department that is characterised by the rapid expansion of african palm crop –, and which is equal to 1 if the child is observed and measured in any of the two departments in the post-treatment period and thus receives the treatment, and 0 otherwise. Accordingly, the observed nutritional outcome of child i living in department d at period t can be written as follows:

$$Y_{idt} = \gamma_d + \lambda_t + \delta D_{dt} + \varepsilon_{idt} \tag{1}$$

where ε_{idt} is the error term assumed of mean 0 – i.e., $E(\varepsilon_{idt}|d,t) = 0$. In the absence of the treatment, the observed average nutritional status can be written as follows:

$$E[Y_{0idt}|d = C, t] = \gamma_d + \lambda_t \tag{2}$$

where C stands for *control*. The pre-to-post treatment change – *first difference* – can be written as follows:

$$E[Y_{0idt}|d = C, t = POST] - E[Y_{0idt}|d = C, t = PRE] = \lambda_{POST} - \lambda_{PRE} \tag{3}$$

In presence of the treatment, the observed average nutritional status can be written as follows:

$$E[Y_{1idt}|d = T, t] = \gamma_d + \lambda_t + \delta \tag{4}$$

where T stands for *treated*. Its pre-to-post treatment change – *second difference* – can be expressed as follows:

$$E[Y_{1idt}|d = T, t = POST] - E[Y_{1idt}|d = T, t = PRE] = \lambda_{POST} - \lambda_{PRE} + \delta \tag{5}$$

Accordingly, the population difference-in-difference can be expressed as:

$$\begin{aligned} E[Y_{idt}|d = T, t = POST] - E[Y_{idt}|d = T, t = PRE] \\ - E[Y_{idt}|d = C, t = POST] - E[Y_{idt}|d = C, t = PRE] \\ = E[Y_{1idt}|d = T, t = POST] - E[Y_{1idt}|d = T, t = PRE] \\ - (E[Y_{0idt}|d = C, POST] - E[Y_{0idt}|d = C, PRE]) \\ = \lambda_{POST} - \lambda_{PRE} + \delta - (\lambda_{POST} - \lambda_{PRE}) = \delta \end{aligned} \tag{6}$$

where δ is the causal effect of interest, thus the effect of the recently rapid expansion of african palm crop, and the means through which it has taken place, on the nutritional outcomes of children under five in the two departments of the south-west region of Guatemala. This can be estimated using the population means from the analysed sample (Angrist and Pischke, 2008).

The four cells in Table 1[11] show, for instance, the average share of children under five stunted (with low height for their age or facing chronic malnutrition) in the treated (Quetzaltenango and San Marcos) and the control (rest of Guatemala not cultivating african palm) departments before and after the rapid expansion of african palm crop in the two departments

[11] Based on Table 5.2.1 of Angrist and Pischke (2008), pp 230.

Table 1: Average share of children under five with low height-for-age in treated and control departments before and after the treatment

Variable	Treated (T)	Control (C)	Difference: (T) - (C)
POST: Average stunting after	52.77	45.57	7.20
	(0.50)	(0.50)	(0.02)
PRE: Average stunting before	52.44	49.08	3.36
	(0.50)	(0.50)	(0.02)
Difference: POST - PRE	0.33	-3.50	**3.84**
	(0.02)	(0.01)	**(0.25)**

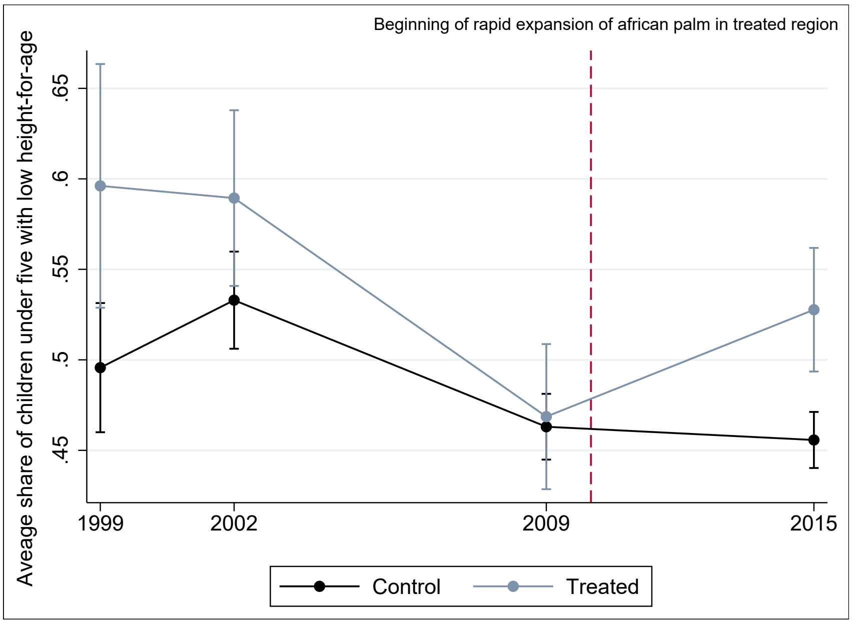
Note: robust standard errors clustered at household level in parentheses. Weighting is according to the weight of the household.
Source: National Maternal and Children's Health Survey (ENSMI)

of south-west Guatemala. The margins show differences between the average incidence of stunting in the treated and control departments for each period, the pre-to-post change in each sample, and the difference-in-difference. The average share of children with low height for their age is higher in the treated departments and in both periods. However, whereas the incidence decreases over time in the control sample, it slightly increases in those departments affected by the rapidly expansion of african palm crop. These two changes produce a positive difference-in-difference, suggesting that the recently rapid expansion of african palm crop, and the means through which it has taken place, has increased the average share of stunted children in the two departments of south-west Guatemala.

In order to claim the validity of this evidence, both groups – the treated and the control – need to be comparable. This means that the trend of the average incidence of stunted children would be the same in both groups in the absence of the treament, so that the increase in the percentage of stunted children in the treated group, once the treatment is in place, can exclusively be attributed to the treatment (Angrist and Pischke, 2008). Indeed, as previously noted, because it is not possible to observe the nutritional outcome of child i after the treatment had the treatment not taken place, the analysis need to rely in the comparison of nutritional outomes between treated and non-treated children. However, by doing so, equation 6 might add a term called *selection bias* measuring the potential differences among groups that may help explain why children living in Quetzaltenango and San Marcos received the treatment, whereas those living in the rest of Guatemala (excluding the other departments where african palm is also cultivated) did not. When these differences are not significantly different from zero, the assignment of the treatment is said to be independent of the health status of the children and hence, there is nothing that could explain significant differences in the nutritional outcomes of children during the pre-treatment period. In this case, it would be possible to observe a *common trend* in the average incidence of low height-for-age among treated and control samples during the pre-treatment period.

Figure 5 plots the likelihood of children under five facing a situation of low height for their age in the treated and control departments of Guatemala between 1999 and 2015. The vertical bar is for 2010, when the rapid expansion of african palm began in Quetzaltenango and San Marcos. The share of stunted children is always higher in the treated departments, although the trend is decreasing during the pre-treatment period. In the control departments, despite a slight increase between 1999 and 2002, the average incidence of stunting decreases during the whole period. The 95% confidence intervals show that the difference of low height-for-age between samples is not statistically significant during the pre-treatment period, whereas once the treatment is in place, a statistically significant higher incidence of stunting among children under five is found in the treated departments. This figure provides visual evidence of a *common trend* characterising the evolution of the share of stunted children in both treatment and control departments during the pre-treatment period, and a treatment effect that seems to induce a deviation from it.

Figure 5: Average share of children under five with low height-for-age in treated and control departments



Note: weighting is according to the weight of the household. Confidence intervals at 95% confidence level.
Source: National Maternal and Children's Health Survey (ENSMI).

However, the slight differences in the trend between samples during the pre-treatment period might hint significant differences among treated and control departments that could help explain the assignment of the treatment. In this sense, the causal effect of interest from equation 6 might thus be masked by a *selection bias* term. Indeed, table 1 shows that the difference-in-difference, although positive, is not statistically significant. When the treatment D_{dt} is randomly assigned, Angrist and Pischke (2008) suggest that the selection bias term disappears making the treated and control groups comparable. In this case, a simple regression of Y_{idt} on γ_d, λ_t and δD_{dt} – like in equation 1 – would thus give the average causal effect of the rapid expansion of african palm crop on those children who live in the treated departments. Nonetheless, when this is not the case, one solution is to include in the regression a variety of control variables X_{it} that could help explain the difference in nutritional outcomes between treated and non-treated children. That is, to account for those relevant observable characteristics that could help explain what causes a child to live in Quetzaltenango or San Marcos and, hence, be affected by the rapid expansion of african palm and the means through which it has taken place.

This lead to the *Conditional Independence Assumption* (CIA) or what it is also called *selection on observables* because these variables X_{it} that might help explain the selection of a child to receive the treatment are assumed to be known and observed (Angrist and Pischke, 2008). The CIA is a core assumption that tells that, conditional on the observed characteristics X_{it}, the selection bias disappears and hence, the comparison of average nutritional outcomes across treated and non-treated children has a causal interpretation. Formally, the CIA can be written as:

$$\{Y_{0idt}, Y_{1idt}\} \perp D_{dt} | X_{it} \tag{7}$$

which means that, conditional on the observable variables X_{it}, the potential nutritional outcomes of treated and non-treated children are independent of the treatment assignment and, thus, both groups can be indeed compared[12] so that δ would represent the causal effect of interest. Accordingly, equation 1 can be re-written as follows:

$$Y_{idt} = \gamma_d + \lambda_t + \delta D_{dt} + X'_{it}\zeta + \varepsilon_{idt} \tag{8}$$

In practice, the regression that is estimated in the main analysis is a linear probability model for child i that lives in the department d in the year t and is specified as follows:

$$Y_{idt} = \alpha_1 Treat_d + \alpha_2 After_t + \underbrace{\delta}_{\text{ITT}} Treat_d \times After_t + \theta_d + \beta_t + X'_{it}\zeta + \varepsilon_{idt} \tag{9}$$

where Y_{idt} is a binary variable equal to 1 if the child suffers from any kind of undernutrition (acute, chronic or both) and 0 otherwise. $Treat_d$ is a dummy variable equal to 1 if the child lives in any of the two treated departments – equivalent to γ_d in equation 8 – and equal to 0 if the child lives in any of the departments of the control sample. This variable measures the average permanent differences between treated and control samples. $After_t$ is a dummy variable equal to 1 if the child is observed and measured in the post-treatment period and equal to 0 if the child is observed and measured in the pre-treatment period – equivalent to λ_t in equation 8. This variable measures the common temporal trend of both the control and treated groups. The coefficient δ is the parameter of interest measuring the average effect of the rapid african palm expansion, and how it has been carried out, on all children living in Quetzaltenango and San Marcos. Because this study is not able to identify the specific population that is mainly affected by the treatment and, instead, considers as treated all children living in the departments where african palm has recently expanded rapidly, the coefficient δ corresponds to the *intention-to-treat* (ITT) effect.[13] Dummy variables at the department

[12] It is relevant to note that random assignment of the treatment ensures that the characteristics X_{it} are balanced across the treated and the control group. In this case, the simple comparison of potential nutritional status of children between groups would provide the average causal effect of the treatment. This usually happens with experimental data, and not with observational data, as the one that is used in this analysis.

[13] Ideally, the analysis should consider as treated the specific communities affected by the rapid expansion of african palm in south-west Guatemala. Since this information is not available, an alternative is to identify

level, measured by the coefficient θ_d, account for the specific time-invariant characteristics of each department. β_t are dummy variables accounting for time trends common to all the departments. X'_{it} is the vector of covariates at the child, mother and household level. And ε_{idt} is the error term assumed of mean 0 and clustered at the household level.

A second solution that is also motivated by the CIA is the *propensity score matching* strategy (non-parametric estimation method), which mainly consists on matching children from the control group to children on the treated group that have similar conditional probability of assignment to the treatment, based on the distribution of the observable characteristics (Rosenbaum and Rubin, 1983). Both matching and regression are control strategies and differences between the estimates obtained are unlikely to be of empirical relevance (Angrist and Pischke, 2008). Due to this similarity, propensity score matching with difference-in-difference is performed in this study as a robustness strategy in order to verify the stability of the results obtained from regression analysis.

To explain this more precisely, lets come back to the previous notation but this time, for simplicity, the t subscript that relates to the pre and post treatment period are obviated. So, let Y_{1id} be the potential nutritional outcome of child i living in department d if the department is affected by the recently rapid expansion of african palm cultivation, and let Y_{0id} be the nutritional outcome of the child i living in department d if the department is not affected by the recently rapid expansion of african palm cultivation. Additionally, lets denote the treatment variable D_d as a dummy variable equal to 1 if the child lives in a department d that is affected by the treatment – Quetzaltenango and San Marcos – and equal to 0 in she/he lives in a department d that is not affected by the treatment - the rest of Guatemala not concerned by the african palm cultivation. The variables X_i that might help explain the selection of a child to receive the treatment are assumed to be known and observed.

Formally, the propensity score theorem states that, if the CIA holds so that potentional nutritional outcomes of the treated and non-treated children – Y_{1id} and Y_{0id}, respectively – are independent of treatment assignment conditional on the observable characteristics X'_i:

$$\{Y_{0id}, Y_{1id}\} \perp D_d | X_i \tag{10}$$

those municipalities in San Marcos and Quetzaltenango where african palm is currently cultivated. `http://www.globalforestwatch.org` enables to identify and map hectares with african palm trees, but only for seven countries: Brazil, Cambodia, Colombia, Indonesia, Liberia, Malaysia, and Peru. The National Agricultural Survey 2015 provides information at the municipality level of the number of hectares cultivated with african palm. However, the municipalities are only coded with a number and no additional information is provided, which does not enable to properly identify those with african palm crop. Alonso-Fradejas et al. (2011) provide detailed tables on the municipalities that are suitable for african palm cultivation as well as on the municipalities that were already cultivating the crop by 2010. This valuable information would enable to provide an analysis at the municipality level. Nontheless, the National Maternal and Children's Health Survey (ENSMI) for 1998/1999, 2002 and 2008/2009, do not have GPS data available that could help to properly identify the municipalities by department. Indeed, it seems that these three waves are representative at the municipality level but the specific variable only contains numbers by department which are not only different from the ones available in the GPS data of the ENSMI 2014/2015 but also do not have a label assigned to them. This difficults the estimation of the average treatment effect on the treated children (ATT) that an analysis at the municipality level might be able to provide. Further research should focus on using the available geographic information of the ENSMI 2014/2015 to provide a closer analysis.

then, the potential nutritional outcomes are independent of treatment assignment conditional on a scalar function of these observable characteristics:

$$\{Y_{0id}, Y_{1id}\} \perp D_d | p(X_i) \tag{11}$$

where $p(X_i)$ is the propensity score defined as follows:

$$p(X_i) = E[D_d|X_i] = P[D_d = 1|X_i] \tag{12}$$

In this sense, the propensity score corresponds then to the probability that a child lives in a department where african palm has recently expanded rapidly and thus received the treatment, conditional on the observable characteristics (Angrist and Pischke, 2008).

In practice, the estimation works in two steps. First, the propensity score $p(X_i)$ is estimated by regressing the dummy variable $Treat_d$ – equivalent to D_d – on the the vector of covariates X'_{it} using a probit model. Second, each child in the treated sample is matched with a child from the control sample with the closest value of the propensity score.[14] In the current analysis, propensity score matching is combined with difference-in-difference. That is, the matching is performed in both the pre-treatment and the post-treatment period. Once the treated and the non-treated children are matched, comparing their average nutritional outcomes in the post and pre-treatment period gives the first and the second difference, respectively, so that computing the difference-in-difference gives the intention-to-treat average effect of the treatment on children living in the treated departments.

One essential issue to consider when estimating the conditional probability of the treatment is that some children in the control sample could have observable characteristics that make the assignment of the treatment very unlikely, so that they would get a lower propensity score than any of the children in the treated sample, or even get a propensity score equal to zero – which is called *lack of common support* – (Ravallion, 2001). In order to assure that the comparison between potential nutritional outcomes is done over a common range of propensity scores – which is also called *common support* –, these observations need to be excluded from the group of control.[15]

In practice, the matching can be performed using different algorithms. In this analysis three types of matching are performed in order to improve the quality and test for further robustness. First, by imposing the common support restriction and matching each treated child with at least twenty of her/his *closest neighbours*, that is, twenty children belonging to the control group whose observable characteristics are similarly distributed to those of the treated child.[16] In this case, the matching is performed with replacement, that is, each child in the control sample may be matched with more than one treated child. The second one imposes common support, twenty closest neighbours and a maximum tolerated propensity

[14] In stata this is performed using the command *psmatch2*.

[15] This can easily be done in stata by adding the option *common* available in the psmatch2 code.

[16] The default matching method is single closest neighbour.

score *distance* (bandwidth or caliper) of 0.01.[17] Finally, the third and most improved matching, *kernel matching*, imposes common support, a maximum distance between matched children of 0.01, and gives larger weight to children in the control sample with smaller distances in terms of propensity score to the treated child they are matching with and lower weight to more distant observations (Caliendo and Kopeinig, 2008).

4 Data and Descriptive Statistics

As noted in the previous section, the goal of the current study is to analyse whether the treatment, defined as the recently rapid expansion of african palm crop (since 2010) and the means through which it has taken place – illegal dredging of rivers, the improper use of water resources and the purchase and forced dispossession of communal and family lands of the indigenous population –, has a significant impact in deteriorating nutritional outcomes of children under five in two departments of the south-west region of Guatemala.

To do this, the study uses survey data from the National Maternal and Children's Health Survey (ENSMI), which is carried out within the framework of the Demographic Health Survey (DHS) Program and the Reproductive Health Survey (RHS). The source where the data was withdrawn is the DHS Program and the International Household Survey Network. The national institutions that run the surveys are the Ministry of Public Health and Social Assistance (MSPAS) of Guatemala and the National Statistics Office (INE), with the financial and technical support from international cooperation agencies, governmental and non-governmental institutions such as UNICEF, the Institute of Nutrition of Central America and Panama (INCAP) and USAID, among others.

The purpose of the ENSMI is to collect information on the demographic situation of children's (under 5 years of age) health and the sexual and reproductive situation of women (15-64 years) and men (15-59 years) in Guatemala. The data is collected on a declarative basis and provides a large variety of information from more general topics, such as the socio-demographic characteristics of households (households composition, access to services, education, etc.), to more specific ones, such as fertility preferences, family planning, children's and women's nutrition and mortality, empowerment of women and violence against men and women. The data is a repeated cross-section with rounds between September and July. This means that the interviewed households in each wave are not the same but they are assumed to be representative of the national population via an individual weighting system, and thus comparable between waves. This study uses the waves of 1998/1999, 2002, 2008/2009 and 2014/2015, which are those that correspond to the period after the end of the civil war and the signing of peace agreements in 1996.

Since the treatment does not happen in but rather from a precise moment of time – 2010 – the pre-treatment period is defined by three time observations – 1998/1999, 2002 and 2008/2009 –, which allows to draw major trends of the potential predictors of child under-

[17] 0.06 is the default option in the stata command psmatch2.

Table 2: Summary statistics of the pre-treatment period: treated and control groups

	Unmatched Sample			Matched Sample		
Explicative variables	Treated	Control	Difference	Treated	Control	Difference
Household's characteristics						
Electricity, %	78.9	80.6	()	78.9	80.6	()
Refrigerator, %	21.3	28.7	(***)	21.3	20.6	()
Car, %	9.6	13.3	(***)	9.6	9.2	()
Telephone, %	8.3	13.6	(***)	8.3	8.6	()
Head of household: female, %	14.5	16.0	()	14.5	16.0	()
Urban, %	25.9	43.3	(***)	25.9	26.5	()
Mother's characteristics						
Age, years	25-29	25-29	()	25-29	25-29	()
Education, %						
-No education, preschool	25.2	28.6	(*)	25.2	28.1	()
-Primary	58.6	50.6	(***)	58.6	56.8	()
-Secondary	14.1	18.4	(***)	14.1	13.0	()
Marital status,%						
-Non union	7.2	2.8	(***)	7.2	3.7	()
-Married/with partner	91.2	92.3	(**)	91.2	91.9	()
-Widowed	1.1	1.0	()	1.1	1.0	()
-Divorced/separated	3.3	4.3	(*)	3.3	3.5	()
Indigenous, %	38.5	34.3	(**)	38.5	39.8	()
Wanted last child, situation	Wanted later	Wanted later	()	Wanted later	wanted later	()
Age at first birth, years	24.5	24.4	()	24.5	24.4	()
Child's characteristics						
Age, months	29.5	30.6	(**)	29.5	30.4	()
Gender: girl, %	49.6	50.0	()	49.6	50.0	()
Birth order, situation	3rd	3rd	()	3rd	3rd	()

	Pre-treatment			Post-treatment		
Dependent variables	Treated	Control	Difference	Treated	Control	Difference
Underweight, %	16.1	15.1	()	12.7	12.7	()
Stunting, %	52.4	49.1	(**)	52.8	45.6	(***)
Wasting, %	1.9	1.5	()	0.9	0.8	()
Observations Individuals	1,720	11,396	-	1,056	7,316	-
Observations Households	783	5,223	-	596	4,328	-

Notes: Matching is done using the propensity score matching with common support, kernel matching and a bandwidth of 0.01 (cf. Section 3 on empirical strategy and identification). Estimation results from this matching appear in part c) of table 6. *** p<0.01, ** p<0.05, * p<0.1.
Source: National Maternal and Children's Health Survey (ENSMI) 1998/1999, 2002, 2008/2009 and 2014/2015

nutrition between the group affected by the treatment and its comparison unit before the treatment took place. The post-treatment period is, thus, defined by one time observation – 2014/2015. The treated sample is composed of children that live in the departments of San Marcos and Quetzaltenango; hence, they are assumed to be affected by the rapid expansion of african palm and the ways in which it has been carried out. The control sample is composed of children that live in any other department of Guatemala, except for those where african palm is being grown. Furthermore, the analysis is restricted to children who are under five years of age and for which anthropometric data and information on the household and mother's aspects are available. The number of children in the treated sample is 2,776 and in the control sample is 18,712, which adds up to a total of 21,488 observations.

Table 2 summarises descriptive statistics of the main covariates included in the analysis[18], which provide information on household, mother and child's characteristics that may help explain the assignment of the treatment and are also assumed of having been fixed at the time the treatment took place. That is, they are not themselves outcome variables and, thus, they are considered to not be affected by the treatment. This is indeed a condition that Angrist and Pischke (2008) underline to be necessary for a variable to be a good control in order to increase the likelihood that regression estimates of equation 9 have a causal interpretation.

Since the analysis uses two methdologies (cf. previous section), the descriptives that are shown in table 2 characterise the samples of study for each of them. The unmatched sample concerns the one used for the difference-in-difference regression strategy – left side of table 2 – and the matched one corresponds to the sample analysed once the propensity score matching is applied – right side of table 2.[19]

The significance of the difference between group averages is provided in brackets. Table 2 shows that, on average and based on the observable characteristics, groups are significantly different in the unmatched sample, although these differences disappear when the matching is performed. The main statistically significant differences concern the level of education and the marital status of the mother, the area where the household lives, and the property of material assets that are a proxy of the income of the household. Related to household characteristics, on average, the share of children that live in households that owns a refrigerator, a car or a telephone is larger in the control group (28.7% versus 21.3%) and 43.3% of the children in the former live in urban areas, whereas it is only 25.9% in the treated sample. Despite the significant difference across groups in the levels of education of the mother and her marital status, on average, 50% and 90% of the children, respectively, have mothers with primary education and who are married or living with her partner. Moreover, the share of children whose mothers identify themselves as indigenous is around 40% and higher in the treated sample, half of the children under five years old are girls, they are ranked third in the order of births from the same mother and are, on average, almost three years old.

The three outcomes in the table correspond to the three standard measures of undernutrition as defined by the World Health Organisation (De-Onis and Blossner, 1997): wasting (low height-for-weight), stunting (low height-for-age) and underweight (low weight-for-age).[20] Acute malnutrition and underweight have decreased over the period in both treated and control groups and respectively characterised 1% and 13% of the children in the sample. However, the percentage of stunted children in both groups is relatively high: around 50% of the children faced a situation of low height for their age during the pre-treatment period. Table 2 shows that this number has decreased in the control sample, whereas it has slightly increased in the treated one, as previously noted in table 1 from section 3. The difference in the average share of children stunted between treated and control sample seems to be significant

[18] Please, refer to Appendix A for detailed information on these variables.

[19] The matching that has been perfomed uses common support, kernel matching and a maximum tolerated propensity score distance of 0.01. Estimation results from this matching are presented in part c) of table 6. This matching corresponds to the most improved one among the three that are performed in this study.

[20] Please, refer to the Appendix A for a detailed description of how these measures are calculated.

in the pre-treatment period, justifying the empirical strategy of the analysis. The difference is, nonetheless, more significant in the post-treatment period and this analysis seeks then to understand to what extent this difference can be due to the rapidly recent expansion of african palm in the two departments of south-west Guatemala, and the means through which it has taken place.

5 Main Results and Heterogeneity Analysis

In this section, I present the main results from the estimation of equation 9 and I analyse the presence of heterogenous effects by considering differences between samples of population – rural vs. urban, indigneous mother vs. non-indigenous and whether the household head is a man or a woman.

Table 3: Main results of the diffrence-in-difference estimation - all nutritional outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Underweight	Wasting	Stunting	Underweight3	Wasting3	Stunting3
ITT	0.000	-0.003	0.061***	0.008	-0.002	0.016
	(0.016)	(0.005)	(0.022)	(0.007)	(0.002)	(0.018)
Observations	21,488	21,488	21,488	21,488	21,488	21,488
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
Department dummies	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes

Notes: robust standard errors grouped at household level in parentheses. Weighting is according to the weight of the household. Covariates include mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). Stunting, wasting and underweight make reference to low height-for-age, low height-for-weight and low weight-for-age (z-score is -2 standard deviation from the WHO median). Stunting3, wasting3 and underweight3 make reference to low height-for-age, low height-for-weight and low weight-for-age (z-score is -3 standard deviation from the WHO median). Department dummies are binary variables for each department and time dummies are binary variables for each survey year. *** p<0.01, ** p<0.05, * p<0.1

Table 3 shows main results of the average intention-to-treat (ITT) effect of the recently rapid african palm crop expansion on the nutritional health of children under five in the two department of south-west Guatemala. Each column shows estimation of equation 9 for the three types of undernutrition that a child can experience – stunting (low heigh-for age), underweight (low weight-for-age) and wasting (low height-for-weight) – on the treatment, the pre/post period and the interaction of both terms (the ITT); on dummy variables at the department level as well as for each year in the analysis; and the covariates listed in table 2. Results from the analysis suggest that children under five years of age, living in San Marcos and Quetzaltenango – the departments affected by water pollution and the forced displacement of indigenous populations – are more likely to suffer from chronic malnutrition than those living in other departments of Guatemala where african palm is not cultivated - indeed, this probability increases by 6.1 percentage points (p.p.), on average. However, it does not seem to significantly increase the probability of suffering wasting or underweight.

Table 4: Main results of the difference-in-difference estimation - heterogeneity analysis

Variables	(1) Stunting	(2) Stunting	(3) Stunting	(4) Stunting	(5) Stunting	(6) Stunting	(7) Stunting
ITT	0.061***						
	(0.022)						
ITT if urban area		0.152***					
		(0.037)					
ITT if rural area			0.013				
			(0.027)				
ITT if mother is indigenous				0.070**			
				(0.033)			
ITT if mother is not indigenous					0.062**		
					(0.030)		
ITT if household head female						-0.003	
						(0.054)	
ITT if household head male							0.076***
							(0.025)
Observations	21,488	7,690	13,798	8,180	13,308	3,739	17,749
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Department dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: robust standard errors grouped at household level in parentheses. Weighting is according to the weight of the household. Covariates include mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). Department dummies are binary variables for each department and time dummies are binary variables for each survey year. *** p<0.01, ** p<0.05, * p<0.1

Table 4 presents the average effect of the african palm crop expansion on chronic child malnutrition in south-west Guatemala and its heterogeneity by area, ethnicity and gender of the head of the household. Results in column 1 of table 4 corresponds to those in column 3 of table 3. Each of the other columns show the estimates from the same regression but for each sample according to the criteria of heterogeneity considered. Children with indigenous mohers seem to be the most negatively affected, since the probability of facing a situation of food and nutrition insecurity increases by 7.0 p.p.. Moreover, results suggest that the probability that children who live in the urban areas of San Marcos and Quetzaltenango suffer from chronic malnutrition increases by 15.2 p.p., with respect to those who live in urban areas in departments where african palm in not grown. Additionally, another result from table 4 reveals that children living in households where the head of the family is a man are those who are particularly affected, since the probability of presenting low height for their age increases by 7.6 p.p..[21]

These results provide evidence of the impact that the expansion of the african palm cultivation has on the established order within families and indigenous communities in the south-west region of Guatemala, which compromises the nutritional health of children under five years of age.

[21]Results are the same when adding an interaction term instead of splitting the sample and they can be provided upon request.

6 Robustness Checks

In this section, I check the results found in the previous section against four robustness tests in order to be able to draw conclusions from them.

Table 5: Robustness checks: control group - departments from same region and without african palm

Variables	(1) Stunting	(2) Stunting	(3) Stunting	(4) Stunting	(5) Stunting	(6) Stunting	(7) Stunting
ITT	0.067**						
	(0.027)						
ITT if urban area		0.166***					
		(0.047)					
ITT if rural area			0.019				
			(0.032)				
ITT if mother is indigenous				0.061*			
				(0.036)			
ITT if mother is not indigenous					0.068		
					(0.043)		
ITT if household head female						0.056	
						(0.063)	
ITT if household head male							0.078***
							(0.030)
Observations	6,527	1,968	4,559	3,773	2,754	1,087	5,440
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Department dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: robust standard errors grouped at household level in parentheses. Weighting is according to the weight of the household. Covariates include mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). Department dummies are binary variables for each department and time dummies are binary variables for each survey year. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

To do this, I proceed to modify the control sample by restraining it to only consider children living in the other departments from the south-west region where african palm does not grow. Table 5 presents results from regressions of stunting on the treatment variable, the pre/post period variable, the interaction of both and the same covariates and dummies considered in the previous tables. Column 1 shows that the probability of children suffering from chronic malnutrition still increases significantly, on average, when they are exposed to the treatment, compared to children who live in neighboring departments within the same region. Further, results in columns 2, 4 and 7 support that children particularly affected are those living in urban areas, with indigenous mothers and in families with a male head of the family, respectively. Moreover, coefficients remain quite stable. This suggests that the recently rapid expansion of african palm crop, that has been taking place in Quetzaltenango and San Marcos since 2010 and which has involved water pollution, forced population displacement and increased labour force within palm plantations, affects nutritional health of children under five not only when the treated group is compared to the corresponding cohort within the rest of the country but also when the comparison group is restrained to the same region where the affected children live.

The second robustness test consists on replicating estimations from table 4 using the *propensity score mathing*, detailed in section 3, as an alternative method to control for the potential differences among treated and control samples of children that may help explain the assignment of the treatment.

As explained in detail in section 3, this alternative estimation method identifies treated and non-treated children with similar propensity score, based on the distribution of the observed characteristics – household's, mother's and individual's – and, by doing so, enables to remove remaining confounding factors that might interfere in the estimation of the treatment effect. Results from the three types of matching algorithms used are presented in part a), b) and c) of table 6. The three types of matching are performed for the stunting outcome in the pre-treatment period (1998/1999, 2002 and 2008/2009) and the post-treatment period 2014/2015. Standard errors are obtained using bootstrapping methods and a number of tests have been carried out in order to assess the quality of the matching (Caliendo and Kopeinig, 2008). In particular, the tests that have been performed are: the percentage bias among covariates in the treated and control group, considering that matching should remove a large part of it – Rosenbaum and Rubin (1983) suggests that a standardized difference higher than 20 should be considered as large –; and the pseudo-R^2, which measures the extent to which the covariates explain the probability of receiving the treatment (Caliendo and Kopeinig, 2008) – if the propensity score balances covariates well, the covariates should be similarly distributed so they would not explain any more the probability to receive the treatment, and hence the pseudo-R^2 should be fairly low in the matched sample.

Results of these tests for the pre-treatment period are provided in the last rows of each part of table 6[22], from which it is possible to observe that the matching was very successful in reducing the percentage bias in the covariates. Indeed, the percentage bias before the matching was significantly high, whereas once each matching is performed, it reduces to not exceed the value of 12.9, suggesting that the technique seems to have produced a good balancing of the covariates in the sample. Additionally, the pseudo-R^2 test reveals that, after computing the matching, covariates explain a very low part of the likelihood of belonging to either group.

The drawback of this estimation method is that it does not enable to include dummies at the departments and at the year level, so results do not account for either the specific characteristics of each department or each year. Nontheless, coefficients from baseline results are still highly significant and stable when the matching is performed using any of the three algorithms. The substantial negative impact of the rapid expansion of african palm crop in the two departments of the south-west region of Guatemala seems robust in increasing the probability of urban children, with indigenous mothers, living in households with a male family head, to suffer from chronic malnutrition.

[22]Balance tests for the post-treatment period provide similar results from the matching. They are not shown in this table but they can be provided upon request.

Table 6: Robustness checks: propensity score matching

(a) PSM with at least 20 matches (closest neighbors)

Sample	**All**	**Urban**	**Rural**	**Indigenous**	**Non indigenous**	**Female head**	**Male head**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	Stunting	Stunting	Stunting	Stunting	Stunting	Stunting	Stunting
ITT	0.068***	0.150***	0.027	0.060*	0.042	-0.013	0.081***
	[0.002]	[0.000]	[0.300]	[0.062]	[0.133]	[0.802]	[0.001]
Observations	21,475	7,675	13,774	8,170	13,270	3,701	17,730
Bias before matching "Pre-treatment"	38.6	53.5	36.4	43.9	55.1	59.1	40.2
Bias after matching "Pre-treatment"	3.3	8.8	5.1	10.6	6.7	14.4	4.2
Pseudo R^2 before matching "Pre-treatment"	0.022	0.040	0.20	0.028	0.043	0.048	0.024
Pseudo R^2 after matching "Pre-treatment"	0.000	0.001	0.000	0.002	0.001	0.004	0.000

(b) PSM with at least 20 matches and smaller bandwidth (0.01)

Sample	**All**	**Urban**	**Rural**	**Indigenous**	**Non indigenous**	**Female head**	**Male head**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	Stunting	Stunting	Stunting	Stunting	Stunting	Stunting	Stunting
ITT	0.068***	0.153***	0.028	0.058*	0.039	-0.010	0.081***
	[0.002]	[0.000]	[0.292]	[0.074]	[0.165]	[0.848]	[0.001]
Observations	21,475	7,674	13,774	8,169	13,268	3,701	17,730
Bias before matching "Pre-treatment"	38.6	53.5	36.4	43.9	55.1	59.1	40.2
Bias after matching "Post-treatment"	3.3	8.9	5.0	10.9	6.5	15.4	4.3
Pseudo R^2 before matching "Pre-treatment"	0.022	0.040	0.020	0.028	0.043	0.048	0.024
Pseudo R^2 after matching "Pre-treatment"	0.000	0.001	0.000	0.002	0.001	0.004	0.000

(c) PSM with kernel matching and smaller bandwidth (0.01)

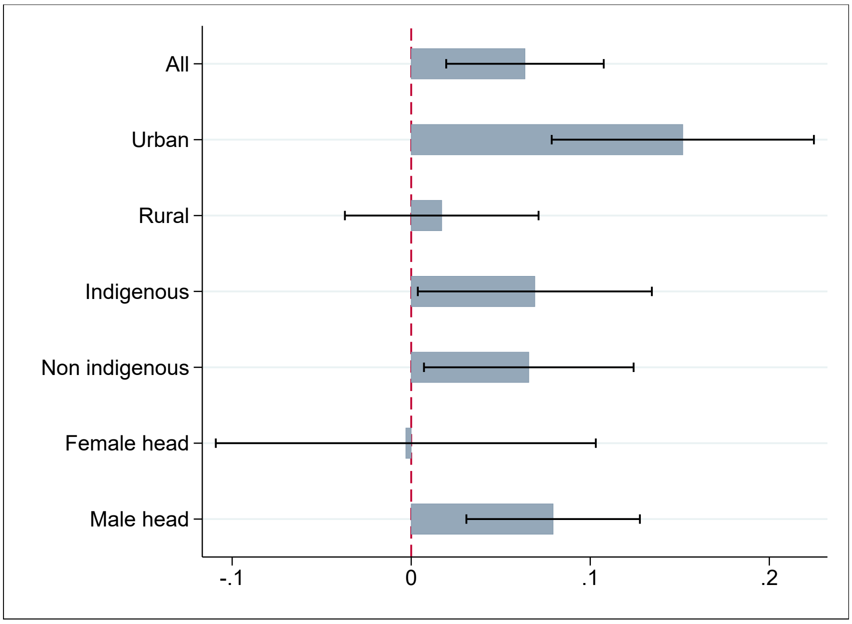
Sample	**All**	**Urban**	**Rural**	**Indigenous**	**Non indigenous**	**Female head**	**Male head**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	Stunting	Stunting	Stunting	Stunting	Stunting	Stunting	Stunting
ITT	0.064***	0.153***	0.030	0.069**	0.041	-0.005	0.078***
	[0.003]	[0.000]	[0.245]	[0.027]	[0.136]	[0.922]	[0.001]
Observations	21,475	7,675	13,774	8,170	13,270	3,701	17,730
Bias before matching "Pre-treatment"	38.6	53.5	36.4	43.9	55.1	59.1	40.2
Bias after matching "Pre-treatment"	10.6	12.9	10.0	12.6	8.8	12.5	10.6
Pseudo R^2 before matching "Pre-treatment"	0.022	0.040	0.020	0.028	0.043	0.048	0.024
Pseudo R^2 after matching "Pre-treatment"	0.002	0.003	0.002	0.003	0.001	0.003	0.002

Notes: p-value in brackets. Matching covariates are mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). *** p<0.01, ** p<0.05, * p<0.1.

The third robustness check included in this analysis aims at testing whether the Storm Agatha, that took place in 2010 (at the same time as the rapid expansion of african palm in the south-west region) and that had a significant and sizable negative impact on household welfare (Baez et al., 2017), could represent a confunding factor on the main results obtained in the previous section.

In May 2010, Guatemala was strongly hit by the tropical storm Agatha, which was considered as the 'strongest tropical storm ever to strike Guatemala since rainfall records have been kept' (Baez et al., 2017). The effects on household welfare were devastating: per capita consumption fell by 12.6% and poverty increased by 18%; food consumption was severely cut and expenditures on basic durables were reduced. The storm touched twenty out of twenty two departments, including the treated departments. Because the recent expansion of african palm crop in the south-west region of Guatemala started by the time this natural hazard took place, it is likely that the storm might have intensified the negative effect on child's nutritional outcomes, in which case baseline results would be overestimated.

Figure 6: Robustness checks: storm agatha



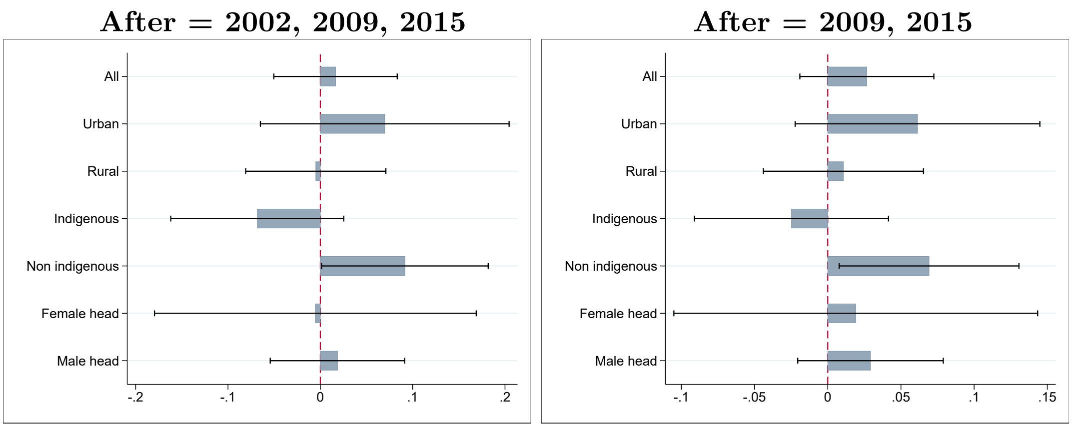
Notes: bars are 95% confidence intervals from robust standard errors clustered at household level. Weighting is according to the weight of the household. Covariates include mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). Department dummies are binary variables for each department and time dummies are binary variables for each survey year.

In order to dissipate these doubts, I introduce two additional covariates in the estimated equation: a dummy variable called $agatha_{id}$ equal to 1 if the child lives in the department hit by the storm (and 0 otherwise) and the interaction term between $agatha_{id}$ and $After_{it}$. This way, estimations control for the average effect of the storm Agatha on children living in the departments hit by the storm, compared to those that were not affected. Figure 6 shows that previous findings are robust and coefficients are stable when controlling for the tropical storm.

In the fourth exercise, I try a falsification test where I modify the pre/post period assuming that the expansion of african palm in the south-west region took place a) after 1998 and b) after 2002. In a) the $After_{it}$ is a dummy variable equal to 1 if the child is observed and measured in 2002, 2008/2009 and 2014/2015 and equal to 0 if the child is observed and measured in 1998/1999. In b) the $After_{it}$ is a dummy variable equal to 1 if the child is observed and measured in 2008/2009 and 2014/2015 and equal to 0 if the child is observed and measured in 2002 and 1998/1999.

The main purpose of this robustness check is to assess whether, before the recent increase in the cultivated hectares with african palm and conditional on observable characteristics, there were significant differences in stunting outcomes between children living in the departments that will become affected by it – Quetzaltenango and San Marcos – and those that will not – the rest of the departments except from those where african palm is grown. Finding positive statistically significant coefficients would mean that the increase in the probability of children suffering from stunting in the treated departments is not due to the rapid expansion of the crop and the conditions through which it has taken place, but rather to something else. Results are presented in Figure 7.

Figure 7: Robustness checks: time falsification tests



Notes: bars are 95% confidence intervals from robust standard errors clustered at household level. Weighting is according to the weight of the household. Covariates include mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). Department dummies are binary variables for each department and time dummies are binary variables for each survey year.

Both falsification tests show that coefficients are not statistically significant in any of the samples analysed except for those children with non-indigenous mothers, which shows that results shown in column 5 of table 4 are not robust, reinforcing results concerning children with indigenous mothers. Therefore, it is possible to assert that the baseline results presented in column 3 of table 3 (and in column 1 of table 4) are specific to the rapid expansion of the african palm crop and how it has been carried out.

The last robustness check that I perform is the modification of the control group to only consider children living in departments that are suitable for african palm cultivation but where the crop has not yet expanded. Alonso-Fradejas et al. (2011) identifies four departments: Huehuetenango in the north-west, Zacapa in the north-east, Santa Rosa in the south-east and Retalhuleu in the south-west. The data portal Global Agro-Ecological Zones (GAEZ) from the Food and Agriculture Organization of the United Nations (FAO)[23], maps the suitable hectares for high, intermediate and low input level rain-fed oil palm. The departments that are identified are those from Alonso-Fradejas et al. (2011) and two additional: Chiquimula in the north-east and Jutiapa in the south-east. I use these six departments to build a control sample and I proceed to estimate previous regressions. Table 7 presents the results.

Table 7: Robustness checks: control group - suitable departments for african palm cultivation

Variables	(1) Stunting	(2) Stunting	(3) Stunting	(4) Stunting	(5) Stunting	(6) Stunting	(7) Stunting
ITT	0.041*						
	(0.024)						
ITT if urban area		0.144***					
		(0.044)					
ITT if rural area			-0.010				
			(0.029)				
ITT if mother is indigenous				0.032			
				(0.039)			
ITT if mother is not indigenous					0.049		
					(0.031)		
ITT if household head female						0.007	
						(0.059)	
ITT if household head male							0.051*
							(0.027)
Observations	10,244	2,504	7,740	2,899	7,345	1,721	8,523
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Department dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: robust standard errors grouped at household level in parentheses. Weighting is according to the weight of the household. Covariates include mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). Department dummies are binary variables for each department and time dummies are binary variables for each survey year. *** p<0.01, ** p<0.05, * p<0.1

Column 1 shows that, although the coefficient and its significance are lower, the overall result is robust when comparing the average nutritional health of children living in San Marcos and Quetzaltenango with those living in departments that are suitable (but yet not used) for the cropping of african palm, before and after the treatment took place. Indeed, the probability of these children under five years of age of facing chronic malnutrition increases significantly by 4.1 p.p., on average. Column 2 shows that urban children are still those particularly affected, and the coefficient remains highly significant and quite close to the one found in table 4. Concerning the sex of the head of the household, results obtained in columns 6 and 7 show that children from families with a man at the head are still those with higher

[23]http://www.gaez.fao.org/ calculates de Crop Suitability Index (SI) based on the average climate of a baseline period (1961-1990) and reflects the suitability levels and distributions within grid cells by classes based on SI values between 0 and 100.

vulnerability of facing a situation of undernutrition than those living in a household led by a woman, although the coefficient and its significance are lower. Nonetheless, results concerning the ethnicity of the mother do not seem to be robust to this alternative specification of the control group.

All in all, the analysis of the present study is able to show that the increase in the cultivated hectares with african palm that is taking place since 2010 and has involved the destructuration of the established order within indigenous communities and has compromised the nutritional health of the most vulnerable members, has had a signifcant impact on deteriorating children's nutritional health in south-west Guatemala.

7 Additional Analysis

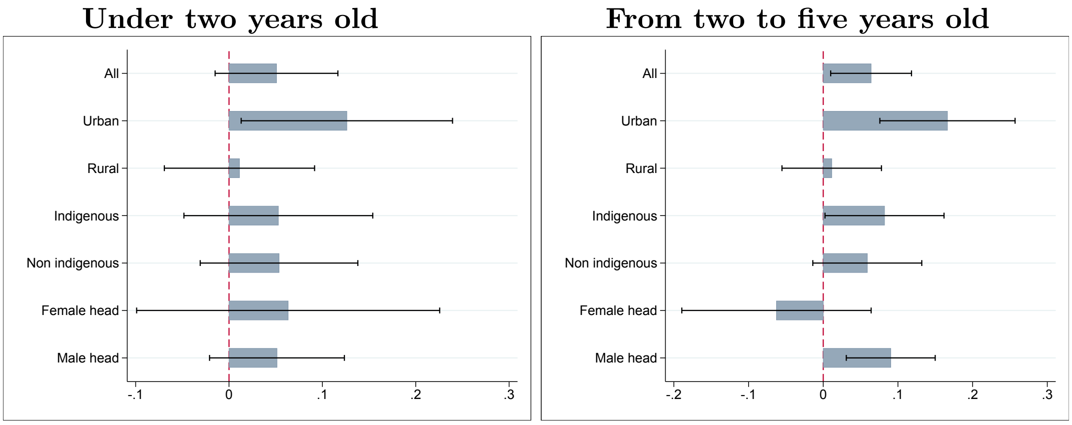
In this section, I present some additional analysis and statistics that might contribute to the understanding of the results found in this article.

For instance, it is noteworthy to understand why in this analysis, the impact of the recently rapid expansion of african palm in the south-west region of Guatemala on children's nutritional health, is manifested only in the anthropometric indicator of low height-for-age. Indeed, the first 1,000 days from the beggining of the pregnancy of the mother to the second birthday of the child are those when the child is growing more rapidly and requires higher nutritional intake, adequate health care, and a good environment to reach her/his full growth and development potential (Cashin and Oot, 2018). During this period, if their nutritional intake is deficient, children are most vulnerable to be stunted and face irreversible consequences such as increased risk of illness and death, delayed mental development, poor school perfomance and reduced intellectual capacity (WHO, 2010). In other words, the loss of growth and development of a child during these first 1,000 days are difficult to recover after the age of two (Cashin and Oot, 2018).

Since the treatment took place in 2010 and the survey that followed was in 2014/2015, children affected by the expansion of african palm in Quetzaltenango and San Marcos, might have faced deficient nutritional intake even before they were born, due to maternal undernutrition. If this is the case, and this situation was not reversed through improvement in their diet, these same children would most likely present an irreversible low height for their age when the survey took place in 2014/2015. Because anthropometric information is only available for children under five years of age, children surveyed in 2014/2015 had to be born, at least, around 2010 and, at last, around 2013. Consequently, the impact of the treatment would be most likely to be observed through an increase in the average of stunted children rather than in other growth indicator.

In order to check this, I proceed to estimate regressions from table 4 by age group, splitting the sample between under two year old children and children between two and five years old.

Figure 8: Additional analysis: splitting the sample - children under two & from two to five



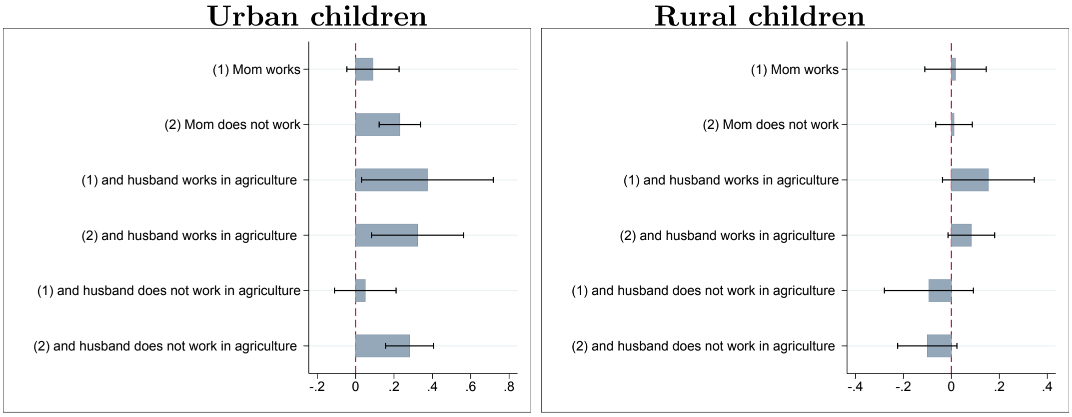
Notes: bars are 95% confidence intervals from robust standard errors clustered at household level. Weighting is according to the weight of the household. Covariates include mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). Department dummies are binary variables for each department and time dummies are binary variables for each survey year.

From figure 8, I observe that the results found throughout the paper mainly concern children between two and five years of age, which supports the explanation here above. Children living in urban areas seem to be affected indistinctively of their age, although the coefficient for children under two year old is only significant at the 5% confidence level. Therefore, it seems fair to consider, that the rapid expansion of african palm in that is taking place in Quetzaltenango and San Marcos since 2010, particularly contributed to a deficient nutritional intake of children that were born between 2010 and 2013, increasing their probability of being irreversibly stunted after the age of two.

Other results that are worth to discuss are whether other variables related to children's growth could be affected by the rapid expansion of african palm crop in Quetzaltenango and San Marcos; why urban children are the ones most negatively affected, rather than rural children; and why children living in households with a male at the head are also those whose probability of suffering low height for their age increase significantly. The challenge with this additional analysis is that some useful information such as child's birth weight, the body mass index of the mother, the access to vitamin A intake by the child, the access to land used for agriculture or whether the household has ran out of food in the last 30 days preceeding the survey, are either not available for at least one of the two main years (2008/2009 for the pre-treatment period and 2014/2015 for the post-treatment period), or some information is available but the questions asked in the survey and the coding do not enable to build a homogenous variable for at least these two main years.[24]

[24]For instance, birth weight and mother's body mass index are available for the wave of 2014/2015 and 1998/1999 but not for 2008/2009 and 2002; the intake of vitamin A and the lack of food during the 30 days preceeding the survey (this last variable has also a very small recall time) are only available for the wave of 2014/2015 and the access to arable land is asked as 'household owns land usable for agriculture' in 2014/2015 but in 2008/2009 the question that is first asked is 'does your partner works mainly in agriculture?' and if the answer is yes, then the question is 'in which type of land does he work?'. When using this information to create a unique variable for both main years, numbers resulted in a surprisingly high increase in the access to land in the treated and the control groups, which does not correspond to what is found in the context of

Figure 9: Additional descriptive results: splitting the sample - urban and rural children



Notes: bars are 95% confidence intervals from robust standard errors clustered at household level. Weighting is according to the weight of the household. Covariates include mother's education, mother's age, the order of the child within the total number of children the mother has, whether the mother wanted the child (then, after or wanted no more), the age of the mother at her first pregnancy, the marital status of the mother, the sex of the head of the family, access to electricity, ownership of refrigerator, car and telephone, mother is indigenous (or not), area (rural / urban), child's gender and child age (with a quadratic specification). Department dummies are binary variables for each department and time dummies are binary variables for each survey year.

Two dummy variables that I am able to build from the available information are whether the mother of the child works – equal to 1 and 0 otherwise – and whether her partner works in agriculture (self-employed) – equal to 1 and 0 otherwise. Because these variables are only available for the year 2008/2009 in the pre-treatment period and the year 2014/2015 in the post-treatment period, I use them to provide additional results from a descriptive point of view, in relation to the difference in the impact of the expansion of african palm crop among children living in urban and rural areas. It is noteworthy to highlight from section 2, that a plausible explanation to this result is the migration of the affected families from rural to urban areas, which implies their relocation in a more precarious way (Hurtado, 2008); or the migration of women, in search for a complementary job that allows them to complete family income (Castro et al., 2015). A very useful online data portal with available information from census microdata on the migration status of the individual is IPUMS International.[25] However, the last available data for Guatemala is for the year 2002, which does not enable to draw current statistics on the subject. Consequently, I proceed to use the two variables that I describe above and estimate equation 9 for stunting among urban and rural children.

Figure 9 presents descriptive results for children living in urban areas and in rural areas, conditional on the mother working at the time of the interview and her partner being self-employed in agriculture. The first observation is that children living in urban, and not rural, areas present a significant increase in the probability of being stunted when they live in the departments affected by the rapid expansion of african palm crop, as noted throughout the last two sections. The first two bars ((1) and (2)) suggest that, among urban children, those whose mother does not work are the ones that seem to be particularly affected. In the third and the fourth bars, it is noted that when the mother's partner works in agriculture, children

Guatemala and seems to indicate that this information can't be used to build a homogenous variable.

[25] https://international.ipums.org/international/

are more likely to suffer chronic malnutrition, and the significance is higher when the mother of the child does not work either. These results might correspond to subsistance families, cultivating their own crops. However, the highest statistically significance of an increase in the probability of children being stunted when they live in the two affected departments, is shown in the last bar, which concerns urban children whose mother does not work and her partner is not self-employed in agriculture.

To better understand these last descriptive results, the survey of 2014/2015 provides additional information of the husband/partner's occupation. Almost 40% of children live in households where the partner of the mother is self-employed in agriculture and the occupations that follow are skilled manual (27.4%) and sales (9%). One could think that cultivating their own crops, provides the family with a source of food which might be more difficult to access through the market, even when other jobs might report some income to the household. Cultural practices and power relationships within the family could also play a role. Indeed, during times of food scarcity, women and children are sometimes forced to reduce their nutritional intake in favour of other members of the households (SIDA, 2015). Taking into consideration the context of Guatemala, one could think that when the only source of income in the household comes from work done by the male household head, he could be considered a priority in the access to available food, making children whose mother does not work and with no access to staple food through their own family production, more vulnerable to have a deficient nutritional intake. Furthermore, in line with evidence from previous studies analysing the relationship between mother's work and child care in Guatemala[26], migration from rural to urban areas tends to push women away from family protection and access to informal child care givers, which could increase their vulnerability within this context.

Finally, the national living standards survey (ENCOVI) of 2014, provides information on which municipality the respondent lived in 2009. The drawback is that there is no available information on the municipality where the respondent currently lives, but the information is available at the department level. Checking this data, I observe that the highest percentage of the population currently living in the neighbour department to Quetzaltenango and San Marcos where african palm is not cultivated by 2015, Retalhuleu, used to live in 2009 in the municipalities of Ayutla (San Marcos) – 21.03% –, Coatepeque (Quetzaltenango) – 19.82% and Ocós (San Marcos) – 8.43%. These municipalities are identified by Alonso-Fradejas et al. (2011) as those where african palm was being cultivated in 2010. The population who used to live in Ocós claim to have emigrated for marriage reasons, those who used to live in Coatepeque justify their migration with housing and services reasons and those who used to live in Ayutla – the municipality with the highest number of hectares cultivated with african palm (Alonso-Fradejas et al., 2011) – state that the main reason they emigrated for was violence. Although individuals interviewed in this survey might not be those from the DHS used in this article, this descriptive information might just provide some useful statistical evidence about the difficulties encountered by the population living in the municipalities of Quetzaltenango and

[26] See Hallman et al. (2005) for a review.

San Marcos where african palm crop has rapidly expanded since 2010.

8 Conclusions

This study analyses the impact of african palm crop expansion on child undernutrition in Guatemala. Results have shown that the bad practices of this expansion in two departments of the south-west region have had a significant and negative impact on the nutritional health of children under five years of age during the last decade. Using a difference-in-differences identification strategy to assess the average intetion-to-treat effect, results show that children under five years of age, living in San Marcos and Quetzaltenango - the departments affected by water pollution and the forced displacement of indigenous populations - are more likely to suffer from chronic malnutrition than those living in other departments of Guatemala where african palm is not cultivated - indeed, this probability increases by 6.1 percentage points, on average. However, it does not seem to significantly increase the probability of suffering wasting or underweight. This might be due to the lag of time between the treatment took place and the implementation of the survey. Indeed, additional analysis suggest that children between two and five years of age are those particularly affected, since a deficient nutritional intake during the first two years of life increases the vulnerability of children of facing irreversible low height for thir age.

The heterogeneity analysis shows that the effect particularly concerns children from indigenous mothers (7.0 p.p.), living in urban areas (15.2 p.p.) and in households where the head of the family is a man (7.6 p.p.). These results are robust when the control sample only considers children living in the other departments from the south-west region where african palm does not grow; when applying matching techniques to reduce heterogeneity among samples; when controlling for the tropical storm Agatha that frapped Guatemala by 2010; when doing falsication tests by modifying the pre/post period; and when modifying the control group to just consider departments that are suitable for african palm cultivation but where the crop was not yet expanded by 2010.

Despite this study is focused on the social impact, it is noteworthy to underline that the negative impact has also been environmental and, thus, economic. Since other parts of Guatemala are currently being damaged by the aggressive expansion of african palm crop – such as those in the northen region of Petén and the lowlands of northern Guatemala – , it is difficult to quantify the potential long-term impact that these practices will have on the economic and sustainable development of the country. Nonetheless, public policies which operate at the local level and involve the protection of the most vulnerable population can be particularly effective in preventing child malnutrition from increasing.

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A Description of Variables

A.1 Variables on Undernutrition

Malnutrition may appear in the form of undernutrition or overweight (De-Onis and Blossner, 1997). This study focuses on undernutrition and its major types that are:

- Acute malnutrition (wasting/low weight-for-height): wasting indicates, in most cases, a recent and serious risk of weight loss, that is most frequently associated with acute hunger and/or serious disease. Nonetheless, wasting can also be the result of chronic unfavorable conditions.

- Chronic malnutrition (stunting/low height-for-age): low height-for-age reflects a process of inability to reach a linear growth potential as a result of suboptimal health and/or nutritional conditions. At the population base, high levels of stunting are associated with bad socioeconomic conditions and a higher risk of frequent and sooner exposure to adverse conditions, like diseases and/or inadequate feed practices.

- Underweight (combine stunting and wasting/ low weight-for-age): low weight-for-age reflects low body mass in relation to the chronologic age of the child, and it is influenced by both the height of the child (height-for-age) and his/her weight (weight-for-height). This indicator fails to distinguish between short children of adequate body weight and tall, thin children. Nonetheless, in the absence of significant wasting within a community, similar information is provided by weight-for-age and height-for-age, in that both reflect the long-term health and nutritional experience of the individual or population.

The way to identify whether a child from birth to five years of age faces any of the three types of malnutrition is through her/his anthropometric measurement (weight-for-age, height-for-age and weight-for-height). According to these measures, a z-score is calculated, which is used to compare the results from the child to those from the accepted international reference population's median value calculated by the World Health Organisation (WHO) and which is sex-specific. If the z-score is below minus two standard deviations from the median of the reference population, the child can be either classified with low weight-for-height (wasted), low height-for-age (stunted) and low weight-for-age (underweight). If the z-score is below minus three standard deviations from the median of the reference population, the child is classified as severely wasted, stunted or underweight.

A.2 Variables on the Child, Mother and Household's Characteristics

Child's characteristics

- Birth order: binary variable for the order of the child within the total number of children the mother has.

- Age: age of child in months.

- Girl: binary variable equal to 1 if the child is a girl, and 0 if the child is a boy.

Monther's characteristics

- Education: binary variables for no education/preschool, primary, secondary and higher education
- Age: age of the mother in years.
- Wanted the child: binary variables for whether the mother wanted the child then, wanted later or did not want the child.
- Age at her first pregnancy: age of the mother when she got first pregnant in years.
- Marital status: binary variable for the marital status of the mother, which can be without union, with partner/married, widowed and divorced/separated.
- Ethnicity: binary variable equal to 1 if the mother is indigenous, and 0 otherwise.

Household's characteristics

- Female household head: binary variable equal to 1 if the head of the household is female, and 0 if the head of the household is male.
- Access to electricity: binary variable equal to 1 if the household has access to electricity, and 0 otherwise.
- Ownership of refrigerator: binary variable equal to 1 if the household owns a refrigerator, and 0 otherwise.
- Ownership of car: binary variable equal to 1 if the household owns a car, and 0 otherwise.
- Ownership of telephone: binary variable equal to 1 if the household owns a telephone, and 0 otherwise.
- Urban: binary variable equal to 1 if the household lives in urban area, and 0 if the household lives in rural are.

B Trade Balance of Palm Oil

Figure B.1: Trade Balance of palm oil

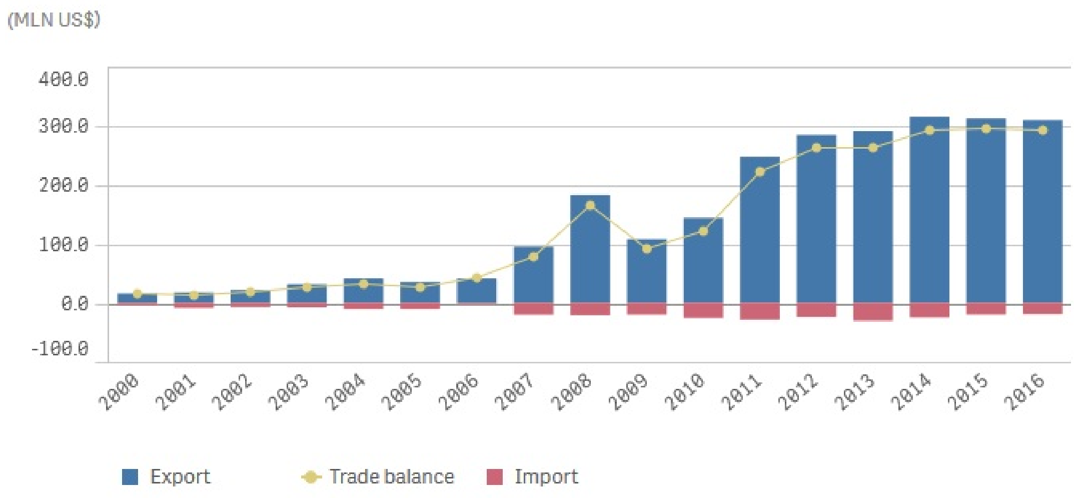
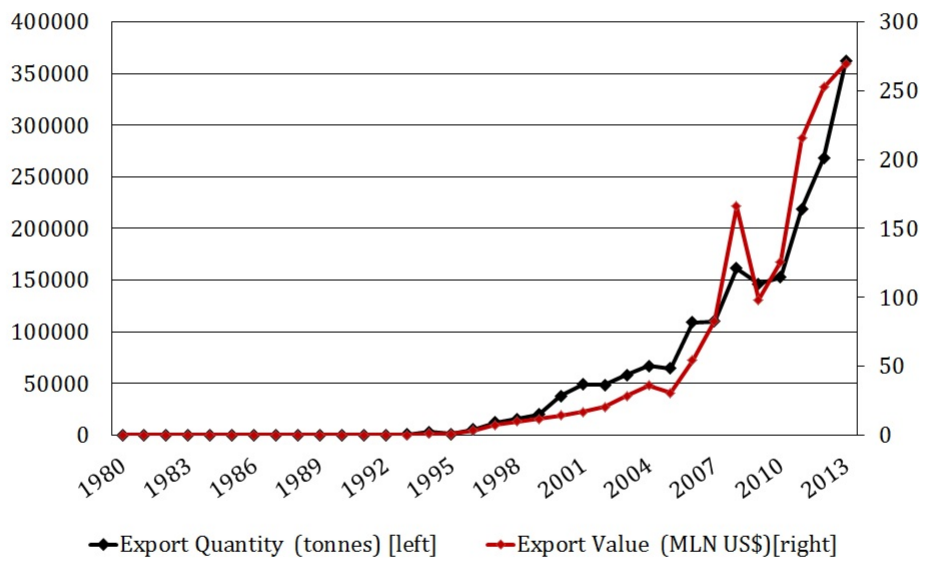


Figure B.2: Palm Oil Exports. Quantities and value



Source: UN Comtrade and FAO