Cultivation and competition in Colombia: disentangling the effects of coca price changes on violence

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Abstract

Though evidence indicates the presence of coca increases violence, changes to the price of coca products can have both negative and positive effects on conflict. This study addresses this matter. Using novel data on local prices of coca products, production and supply chains, this study disentangles the returns to employment in the agricultural sector (cultivators) and employment in the criminal sector (militias and armed groups). This paper thereby identifies each agents' respective exposure to price changes, and estimates the effect of such changes on violence. The results show the presence of the opportunity cost effect: an increase in income from coca results in a reduction in violence. This reduction comes with an increase in school attendance for rural households. An increase in the objective prize leads to more violence. Moreover, armed groups flock to the area that witnesses an such an increase, resulting in higher levels of competition which coincides with the timing of the increase in violence. Additionally, increases in expected returns to joining a militia can potentially lead to a higher school dropout rate among children.

Keywords: conflict, income, objective prize, coca, competition

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1 Introduction

As coca cultivation in Colombia tripled between 2013 and 2017, there are signs of escalating violence (International Crisis Group, 2021). Though there is evidence indicating that the presence of coca increases violence (Angrist & Kugler, 2008), changes to the value – the price – of coca products can have both negative and positive effects on conflict: increasing wages for farmers draw labor out of the criminal sector into the agricultural sector, thus reducing violence. However, violence can also increase as higher prices make coca a more valuable good, increasing competition. This paper disentangles these contradicting forces. It develops separate measures for the returns to being active in the agricultural sector and criminal sector, and estimates the effect of changes to these returns on violence.

This is done by focusing on the 2007 – 2018 time period, which witnessed fundamental changes in the Colombian coca sector. The changes were brought on by the demobilization of the United Self-Defence forces of Colombia (AUC) as well as the peace negotiations and eventual disbandment of FARC (UNODC & Europol, 2021). Along with the breakdown of larger cartels, these changes created power vacuums that were filled by smaller groups. The criminal landscape changed radically: the presence of fewer oligopolies in the market caused the bargaining power of international wholesale sellers to increase, and the remaining armed groups saw their position weaken (UNODC & Europol, 2021). These changes affect the ability of armed groups to finance themselves through coca and drive them to compete for control over the market. Moreover, the effects of these shifts trickle down, affecting the livelihood, safety and security of those cultivating coca. These new dynamics call for re-examining the relationship between the value of coca, violence, and the roles played by various actors.

This study relies on a conceptual frameworks of Becker (1968), Grossman (1999), and Hirshleifer (1989) to adequately address the intrinsicalities of the conflict. Agents are considered to choose between employment in the agricultural and criminal sector. For those employed in the agricultural sector (farmers, cultivators and agricultural households) coca presents an important source of income. A relative increase in income from coca would draw labor out from the criminal sector, reducing violence: the opportunity cost effect (Angrist & Kugler, 2008; Collier & Hoeffler, 2005; Dube & Vargas, 2013). Agents active in the criminal sector (militias and armed groups) finance themselves through coca (O'Connor, 2009). The larger the share of the coca market that is under control of an armed group, the larger their source of income. For these agents coca forms an objective prize. A positive shock to the expected returns to the criminal sector entices those active in the agricultural sector to join militias or armed groups, leading to an increase in violence: the rapacity effect (Collier & Hoeffler, 2005; Dal Bó & Dal Bó, 2011; Hirshleifer, 1989). Within this framework, this study considers the effect of an increase in, first, the income from coca (for farmers)

and, second, of the objective prize (for armed groups) on the intensity of violence in Colombian municipalities.

The econometric analysis relies on rich and detailed data on the local prices of specific coca products (coca base, paste, leaf and hydrochloride (HCI)), coca production and supply chain differences, agricultural wages, coca cultivation, eradication, as well as data on various measures of violence. The first step of the analysis consists of creating proxies for returns from the agricultural sector (income from coca) and returns from the criminal sector (objective prize). The income proxy is constructed using data on production processes and local prices of coca products that cultivators are confronted with. To support the assumption that the proxy captures income from coca on municipal level, it is shown that there is a significant positive relationship between the income proxy and wages for rural agricultural labor in coca-cultivating areas. The price of coca HCI is used as a proxy for the armed groups' objective prize.

Second, the effect of a one percent increase in farmers' income from coca and in the objective prize of armed groups on local violent intensity is estimated. Violent intensity is measured as the total number of violent events, fatalities, guerilla attacks and bombings per 100,000 inhabitants. The results are explained through two channels: the opportunity cost and rapacity effect.

The presence of these two effects is examined further. A potential relationship between increasing income from coca and heightened labor market participation is examined. Additionally, as coca is frequently cited as the reason that parents can afford to send their children to school or university (International Crisis Group, 2021; Sanín, 2019), the impact of an increase in income on educational outcomes is considered. Evidence of increasing labor market and/or educational outcomes would support the assumption that the opportunity cost effect drives the decrease in violence. Moreover, the data used in this study allows to examine the impact of changes to the objective prize on local competition amongst armed groups. This provides further insight into the role competition plays as a determinant of violence.

Concerns with respect to endogeneity are mitigated in various ways. First, the coca prices (originally observed on municipality-month level) used to construct the proxies are averaged to region-year level. As regions contain between twenty and a couple of hundred municipalities, local dynamics affecting these average prices is unlikely. Second, only lagged values of the proxies are used in the analysis. Additional measures are taken. For example, the proxies are constructed in a similar fashion to a Bartik instrument, fixed effects are included, and the control variables are carefully selected to capture other determinants of violence, prices, supply and demand.

The results show a clear presence of the opportunity cost effect: an increase in income of coca products for farmers (an increase in the returns to employment in the agricultural sector relative to the returns from employment in the criminal sector) is associated with a reduction in the intensity of violence on municipality level. For example, the results indicate that the annual increase in income

from coca of 1.52% witnessed between 2007 and 2018 leads to 4.8% less violent events, 6.6% less bombings and 4.7% less guerilla attacks per 100,000 inhabitants in the average coca producing municipality. Moreover, increasing income from coca is associated with higher school attendance rates and less competition among armed groups.

The highest annual increase in the objective prize for armed groups was 1.82% in the time period considered. Results show that such an increase, indicating higher relative returns to employment in the criminal sector, is related to an intensification of violence: the number of violent events and guerilla attacks go up with 5.6% and 5.5%, respectively, and there are 7.9% more fatalities and 7.5% more bombings in coca-producing municipalities. Moreover, the results indicate that armed groups flock to the area that witnesses an increase in the value the objective prize. The aforementioned increase in the objective prize is linked to an increase in local competition among armed groups of about 7%. The timing of this increase in competition coincides with the increase in intensity of violence in the municipality. Additionally, there is evidence that suggests that increasing relative returns to joining a militia might lead to lower levels of school attendance.

This paper contributes to the extensive literature on the coca sector in Colombia. However, whereas most research on this topic studies the link between the presence of coca and conflict, the focus of this paper is on the economic incentives for agents involved in the coca sector and on how these affect local intensity of violence. It disentangles the effects and channels linking coca prices to violence while focusing on a time period marked by significant changes with respect to agents' bargaining power, the level of competition, and control agents have over the supply chain. This time period has – to my knowledge – not been examined. By identifying the economic incentives and disentangling the separate effects, the results of this study present a more detailed and nuanced picture than is common in the literature, which frequently does not take regional differences in coca production technologies and prices into account or (solely) relies on the presence or size of coca cultivation.[1]

In doing so, this study specifically extends the work of Angrist and Kugler (2008) who exploit an upsurge in coca cultivation and prices and show this led to small but positive economic gains for self-employed people living in rural areas as well as to higher levels of violence. Other work examining the coca-fueled conflict in Colombia focuses on violence and the armed groups involved in coca trafficking, such as on coca eradication efforts (Fisher & Meitus, 2017; Moreno-Sanchez et al., 2003), modelling the war on drugs as a resource problem (Grossman & Mejía, 2008; Mejía

[1]Though the latter has been shown to have an effect on violence by Angrist and Kugler (2008) the presence of coca is not necessarily a good indication of the local value of coca. As noted by the UNODC (2010), coca prices do not follow the 'regular' rules of supply and demand as they are affected by many other factors. Moreover, there is a considerable amount of variety in the extent to which farmers process the coca leaves they harvest, and thereby the value of the product and their income. Finally, it is common that farmers suffer a drop in income due to government interference (Thoumi, 2002), or are pressured by local militias to sell their products for a lower value (UNODC, 2018) while the price of coca chlorhydate (HCI) - militias' objective prize - remains constant.

& Restrepo, 2016), explaining different levels and types of violence (Holmes et al., 2006), armed groups involved in the coca sector (Bottía Noguera et al., 2003; O'Connor, 2009; Suárez, 2000; Thoumi, 2002) and expansion of coca cultivation (Mejia & Restrepo, 2013).
Additionally, by using data on the number of armed groups active in a certain area, this study provides evidence that competition increases in response to an increase in the objective prize. This is a novel way to show the working of the rapacity channel and the extent to which competition contributes to violence. By estimating such effects, this paper is related to the crime-rebellion nexus narrative (Cornell, 2007) as well as the work of Anderson and Worsnop (2019) who showed that the potential financial reward of engaging in drug production and trafficking can form an incentive to use violence to maintain control over cultivation and (production) processes.
Moreover, disentangling the effects of a change in income and the objective prize allows to study the potentially contradicting effects of these changes on additional outcomes. For example, the results indicate that an increase in coca income is linked to higher school attendance rates, while an increase in the objective prize might lead to lower school attendance rates. These findings contribute to the literature that shows the positive effects of coca on educational outcomes (Sanín, 2019) as well as the negative impact it can have (Bjørkhaug, 2010; Sviatschi, 2018).
Finally, this study builds on work that focuses natural resources and conflict (Collier & Hoeffler, 2005; Ross, 2003), drug-fueled conflict (Cornell, 2005, 2007) and on the effects of changes in the prices of agricultural goods on violence. The relationship between changes in the prices of agricultural goods and violence in Colombia has been documented by Dube and Vargas (2013) who consider the effects of changes in the coffee and oil price, and Rettberg (2010) who studied the breakdown of the International Coffee Agreement and the violence in Colombian coffee regions that followed.

This paper is structured as follows. Section 2 discusses the coca sector in Colombia and recent changes that affected the market. A conceptual framework is presented in section 3, followed by a discussion of the data in section 4. The methodology and empirical strategy is laid out in section 5. Section 6 presents the results and section 7 concludes.

2 Institutional background

To understand the coca market in Colombia, it is important to understand the basic steps in the production process of cocaine.[2] The part of process that takes place in Colombia can be roughly divided into four stages (UNODC, 2010). In the initial three stages coca leaf is cultivated, processed into coca base, and eventually turned into coca paste. In the fourth stage coca paste is processed

[2]For an excellent in-depth discussion on the history, violence related to, and production of coca in Colombia, see Díaz and Sánchez (2004).

into coca HCI.

The first three stages are carried out by agricultural households, farmers or cultivators. For these agents, coca forms a reliable and highly profitable source of income. It is an easy crop to grow, often the most lucrative crop available,[3] and the market for coca products is almost guaranteed (Ibáñez, 2010; Mansfield, 1999; Thoumi, 2002). However, cultivating coca is associated with risk and uncertainty: municipalities where coca is cultivated experience significantly more violence (Angrist & Kugler, 2008), governments' eradication efforts can result in instant loss of the entire harvest,[4] and cultivating coca brings farmers in direct contact with militias and armed groups who purchase their products and produce coca HCI (UNODC, 2021).

The production of coca HCI is the fourth step of the production process and is solely carried out by militias, armed groups and criminal networks, who possess the capital to obtain the more scarce ingredients (such as acid and acetone) and have the technical expertise required for production (O'Connor, 2009; UNODC, 2018, 2021). Coca HCI is the product that is trafficked to its final destination by international wholesale buyers, where it is eventually processed into cocaine.

2.1 The changing coca market

The coca market in Colombia has changed significantly over the past years. Two main trends can be distinguished. First, the large cartels are being replaced by smaller criminal groups vying for control over the coca market (UNODC & Europol, 2021). This change was set on by the disbandment of the AUC in 2006, the peace negotiations leading up to and the eventual demobilization of FARC in 2016, and the gradual breakdown of the large cartels.[5] Along with the disappearance of the cartels and these armed groups in Colombia, the monopoly positions of large international trafficking organizations in their respective markets deteriorated.[6] This made it possible for other (new) international organizations to enter the market. Brokers in Latin America started playing an increasingly important role in supplying these organizations with bulk quantities of cocaine which they obtained from smaller Colombian groups. The second trend is that the main destination markets for Colombian cocaine - the United States and Europe - are growing, increasing the potential profits to be made from producing, trafficking and selling coca for some of the agents involved (UNODC & Europol, 2021). These two trends have significantly affected armed groups and cultivators.

[3] According to Ibáñez (2010) coca crops are three to five times more lucrative than other licit crops. Moreover, Ibáñez (2010) presents evidence that coca is often cultivated due to not being able to make a living from legal crops.

[4] The chemicals used for eradication can affect coca as well as other crops and render land unusable for years. Additionally, the chemicals used present significant health risks (Veilette & Arvelo-Velez, 2003).

[5] Such as the Medellin and Cali cartel in the '90s, and eventually the Norte del Valle cartel around 2008.

[6] Specifically the Italian *'Ndrangheta*.

The fragmented market and presence of brokers caused the bargaining power of armed groups to deteriorate (UNODC & Europol, 2021). Moreover, the price of coca HCI has been considered fixed for militias since the power shifted from groups within Colombia to international traffickers from Europe or the United States (Millán-Quijano, 2020). This loss of bargaining power and control over the market has lead to lower profits for armed groups, pushing them to compete over territory. Territorial control is of fundamental importance to these groups as it guarantees trafficking routes, a social base (in terms of a local labor force and farmers to buy products from) and income from taxation (Díaz & Sánchez, 2004). Evidence from 2019 suggests that the total revenue from taxes imposed on cultivators by armed groups was around 33 million USD (UNODC & Europol, 2021). This illustrates the importance of coca, often noted as one of the most important sources of income for militias and other armed groups (O'Connor, 2009).[7,8]

The recent changes in the coca market exacerbated the uncertainty facing those cultivating coca. One of the ways the recent trends have affected cultivators is through the prices they receive for their coca products. Prices of coca products are affected by other factors than (the usual) supply and demand dynamics (UNODC, 2017). Prices are often determined by the rules set by buyers present in an area (International Crisis Group, 2021). For example, buyers and farmers often agree who takes on labor costs for harvesting and processing coca leaf, prior to the harvest taking place. As the weaker party, cultivators have little to no bargaining power and have to accept the offer – trying to sell coca products to another group is dangerous and can lead to retribution. With armed groups finding it increasingly difficult to finance themselves through coca, they raise taxes or extract more resources from farmers and cultivators in other manners, for example by decreasing the prices paid for products. Additionally, groups might pressure farmers to increase coca production, sometimes using violent means (International Crisis Group, 2021; UNODC, 2018). Moreover, the larger number of armed groups vying for territorial control exposes cultivators to changing buyers setting different prices for coca products, as well as violence. Fluctuating prices and buyers cause heightened uncertainty with respect to the income from coca for cultivators, compared to when the larger cartels or armed groups were present.[9] The uncertainty and risk is illustrated by a situation recorded by the UNODC (2017): a drop in market activity due to a sudden absence of buyers in a local market lead to an oversupply of leaf, base and paste and a negative income shock for

[7]Coca has been an important source of funding for decades. According to Vargas (1999), almost half of the income of guerilla groups in the period 1991-1996 came from drug trafficking. About one-fourth came from extortion and robbery, and one-fifth from kidnapping, and a small fraction originated from municipal funds.

[8]However, illicit alluvial gold mining has also proved to be a source of financing for these groups since 2007 (Rettberg & Ortiz-Riomalo, 2016) and is linked to coca production (UNODC, 2013). When the international gold price collapsed in 2015, more groups were pushed into the cocaine market to make up for lost profits, exacerbating the conflict further (International Crisis Group, 2021).

[9]For example, FARC was known to set a fixed price for coca products that was guaranteed to cover the basic costs incurred for farmers (Cook, 2011).

cultivators. The markets started working again only when new types of buyers appeared.

3 Conceptual framework

This section describes a simple conceptual framework to adequately address the intrinsicalities of the coca market, economic incentives of agents, and the connection to violence. Following the framework of Becker (1968) and as described in Dube and Vargas (2013), agents are considered to choose employment in the agricultural or criminal sector, depending on where the expected returns are the highest. Employment in the agricultural sector focuses on the production of a good or resource, and the criminal sector on extracting value through (illegal) taxation, appropriation, rent-seeking and theft (Grossman, 1999). In this setting, goods and resources can lead to violence and conflict through two channels: the opportunity cost or rapacity channel.
First, a relative increase in expected payoffs from, or returns to, employment in the agricultural sector would draw labor from the criminal sector into the agricultural sector, reducing violence. This is the opportunity cost effect (Angrist & Kugler, 2008; Collier & Hoeffler, 2005; Dube & Vargas, 2013). Vice versa, a positive shock to the expected returns to the criminal sector would draw labor from the agricultural sector into the criminal sector, leading to an increase in violence. This is the rapacity effect (Collier & Hoeffler, 2005; Hirshleifer, 1989).

This framework is applied to the coca market in Colombia, as to understand the relationship between returns to cultivating coca and producing leaves, base and paste (the agricultural sector), the returns to being a member of an armed group or militia which finances itself through trafficking and producing coca HCI (the criminal sector), and violence. The expected returns to being employed in the agricultural sector are presented by the income from cultivating coca and selling coca products (leaf, base and paste). An increase in the expected returns to cultivating coca has the potential to draw labor out of the criminal sector, i.e., members of armed groups or militias might forego criminal activities to work in the agricultural sector, which in turn would reduce violence.
The presence of this opportunity cost effect will be estimated empirically by using a proxy for returns to being active in the agricultural sector. Moreover, as there is evidence that an positive income shocks can affect the number of hours worked and employment rates (Angrist & Kugler, 2008), or educational outcomes such as education level and school attendance (International Crisis Group, 2021; Sanín, 2019; Sviatschi, 2018), the relationship between shifts in coca income and these outcomes will be investigated.

The returns to employment in the criminal sector are captured by the value that can be obtained through appropriation and rent-seeking, and will be referred to as the objective prize. An increase in the relative value of the objective prize with respect to the income from coca cultivation can

cause the rapacity effect. One such way that this could happen is through a negative income shock for those employed in the agricultural sector. Facing such a shock, these agents can choose to increase coca production, cultivate other crops, or – especially day-laborers, being more flexible and not tied down by farm-ownership – are considered to have the opportunity to work in another sector,[10] or join a militia or an armed group, i.e., finding employment in the criminal sector.[11] This flow of labor from the agricultural sector into the criminal sector would lead to an increase in violence. Empirically, the rapacity effect will be examined by estimating the effect of a change in a proxy for the objective prize on violence.

Aside from an inflow of labor into the criminal sector, a relative increase in the value of the objective prize can also influence the behavior of those already active in the sector, specifically with respect to competition. As described in the previous section, the changes in the coca market in Colombia have fundamentally affected the size and number of armed groups active in the coca market, leading to increased competition and changing the behavior of such groups (UNODC & Europol, 2021). Conceptually, the behavior of armed groups can be understood within the stationary and roving bandits framework of Olson (1993). Based on this framework groups can either be stationary, where they are in control of their own territory, or roving, where they enter unclaimed or another groups' territory. As stationary bandits, armed groups are able to extract resources from the local farmers in their territory, which in the setting of this study translates to pushing down prices paid to cultivators for coca leaf, base or paste.[12] A second way armed groups can increase their income (as roving bandits) is through expanding the territory under control or attempting to gain access to another groups' territory, in order to gain access to the objective prize. A higher value of the objective prize makes this option more attractive. This might cause an increase in violence: violence is linked to instilling fear in the local population after having taken over control (Díaz & Sánchez, 2004; International Crisis Group, 2021) as well as armed groups competing for territory (UNODC & Europol, 2021). In order to assess the role of competition as a driver behind the rapacity effect, the relationship between an increase in the value of the objective prize and local competition – measured as the number of different armed groups carrying out violent attacks locally – will be examined.

Summarizing, this study conceptualizes the coca market in Colombia as consisting of an agricultural and criminal sector with agents choosing employment in either sector, depending on the

[10]The link between coca production and gold mining is discussed in Rettberg and Ortiz-Riomalo (2016) As it is a feasible option in regions where gold is present, the empirical analysis will account for this: see section 5.

[11]Militias are known to pay wages to their members (Angrist & Kugler, 2008). This has also recently been reported by the International Crisis Group (2021).

[12]This is supported by evidence of the UNODC (2013), who state that prices for farmers' products are often set by armed groups in control of those areas.

expected relative returns. The impact of this choice on violence is explained through the rapacity and opportunity cost effect. Specifically, the framework predicts that an positive income shock in the agricultural sector leads to a reduction in violence through the opportunity cost effect. With respect to armed groups and militias, active in the criminal sector, an increase in the value of the objective prize will lead to an increase in violence through the rapacity channel. This increase in violence might be caused by higher levels of local competition. Empirically, proxies for the expected returns from coca in the agricultural sector and for the expected returns from being active in the criminal sector are developed. By using two proxies capturing expected payoffs of employment in each sector, it is possible to estimate the effect of a relative change to the returns in one sector while keeping the returns from the other sector constant, disentangling the two effects.[13]

4 Data and sample

Data on coca cultivation and eradication is obtained from the United Nations Office on Drugs and Crime (UNODC). Data on coca derivative prices and production processes comes from the productivity studies from the UNODC. These productivity studies focus on three general areas: coca cultivation and general productivity trends, socio-economic characteristics of agents active in coca cultivation, and the persistence of coca cultivation. The data is collected through interviews conducted with cultivators, and harvest trials are carried out to estimate the potential coca yield. The studies provide the UNODC with insight into local price fluctuations, long-term trends of production processes, and technological developments in the coca sector.

There are a few important things to note with respect to the prices of coca products. First, production studies and reports that focus on the prices of coca products in Colombia, such as the UNODC (2013), mention that these prices "retain no logical relation to variations in supply and demand" and that "buyers can pressure the production exchange, presenting a controlled price scenario [...]. This situation forces producers to adopt the enforced condition" (p.56). These observations support the fact, discussed in section 2, that cultivators are price takers with limited to no bargaining power, and that the price is set by the respective buyers of their product.

Second, prices of the coca products considered in this study vary across municipalities. They depend on ease of reaching markets, the presence of buyers and the rules set by them, the quality of the product, and the municipal or village-level supply and demand for coca products (UNODC, 2013). The UNODC collects municipality-month level price data, and reports the average monthly prices for each region. Every region contains a varying number of municipalities. In the final sample, the smallest region contains 23 and the largest region a few hundred municipalities (the average number of municipalities per region is 159). This study uses annual averages of the regional prices.

[13] Discussed in-depth in section 5.2.

The risk of prices being endogenous to municipality-level dynamics is thereby mitigated (this is discussed further in section 5.2). All prices are adjusted for inflation. Figure 1 shows the annual changes in the prices for the four different coca products considered in this study for the various Colombian regions.

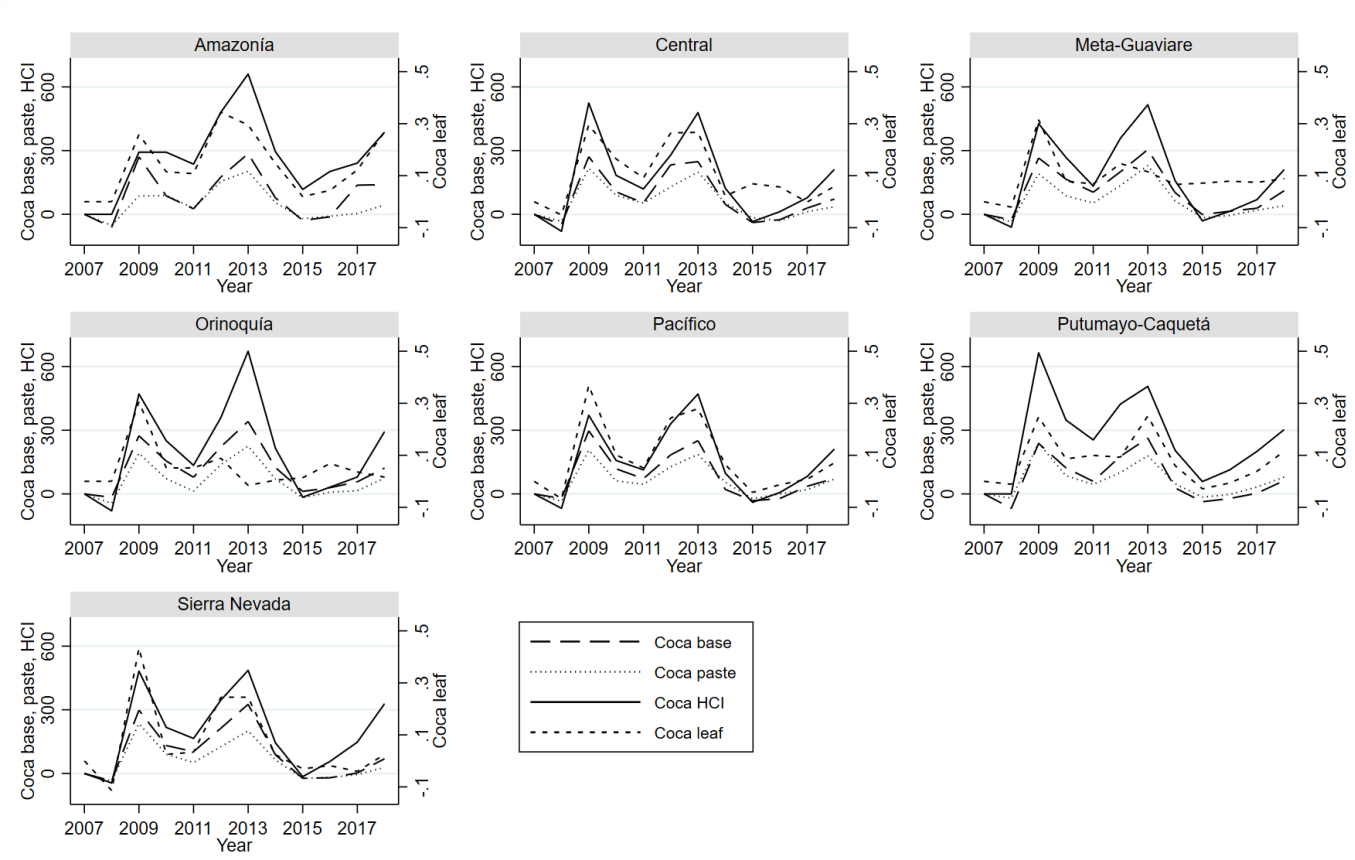

Figure 1: Prices of coca products by region and year. *Note:* Annual levels of the inflation-corrected prices of coca base, paste and HCl (left y-axis) and leaf (right y-axis) in thousands of Colombian pesos by region (as defined by the UNODC) and year. To illustrate fluctuations in the prices over time and ensure comparability across products, 2007 is taken as the base year for the price of each product.

Data on violence comes from the Global Terrorism Database (GTD). The GTD (LaFree & Dugan, 2007) is an event-based data set. It includes the exact location, perpetrator(s), target, number of fatalities, and the type of attack. As the database only contains acts of terrorism, any "regular" crime or homicide is excluded. The measures of violence used in this study are the number of violent events, fatalities, guerilla attacks and bombings.[14] These variables are measured as the number of occurrences per 100,000 inhabitants of the municipality. This is done to account

[14]In the time period considered there was a low frequency of paramilitary attacks, hence these are not considered. Moreover, bombings are a type of attack frequently used by groups such as the National Liberation Army (ELN, a guerilla group) and former FARC factions who are known to compete for control over territory.

for more attacks taking place in more densely populated municipalities.[15]
Cross-sectional data on monthly income for agricultural labor comes from the rural component of the Great Integrated Household Survey (GEIH) (DANE, 2011). The sample is restricted to include respondents that indicate that they are self-employed or work in agriculture, and averaged to municipality-year level. As not every municipality is sampled monthly, some observations are missing and the sample and does not include all Colombian municipalities. These restrictions affect the external validity of the results, and this sub-sample is not nationally representative. However, the data is solely used to examine a potential relationship between coca production, income and education in coca-producing municipalities.
Additional data on international crop prices comes from the Federal Reserve Economic Database (FRED). This data is adjusted for inflation and converted from US dollars to Colombian pesos using the annual exchange rates, in order to ensure comparability to the prices of coca products. Rainfall and temperature data is from Murray et al. (2020).

All data is combined to create a panel data set on municipality-year level spanning 2007-2018. The data set has 13,435 observations across 1119 municipalities, in 32 departments within seven regions.[16] Of these municipalities, 195 were coca-producers in 2007. These municipalities were spread across 23 departments within all regions included in the sample. An overview of the variables and their descriptive statistics can be found in table A.4.

4.1 Relationship between coca (prices) and violence

The conceptual framework suggest that a relative increase (decrease) in the returns to employment in the criminal sector can lead to an in (out) flow of labor into the criminal sector. An inflow of labor would increase competition, rent-seeking and appropriation, causing violence to rise. Figure 2 presents a simple, straightforward visualization to examine the potential relationship between the objective prize and violence using the data described above. The figure shows the average value of coca HCI, an indicator of the objective prize value, and average number of violent events, guerilla attacks, bombings and fatalities per 100,000 inhabitants for coca and non-coca producing municipalities for the 2007 – 2018 time period. It is clear that those that produce coca have considerably higher levels of violent intensity than non-producers. Moreover, the spike in violent intensity for coca-producing municipalities around 2014 seems to be preceded by an increase in coca HCI. At least when considering the second part of the time period (as we do not see such effects for the increase in HCI around 2009), it appears that the relationship between the value of

[15] All results are robust to specifying violence in levels: see the appendix.

[16] The UNODC distinguishes seven regions: Amazonia, Central-Sur de Bolivar-Catatumb, Meta-Guaviare, Orinoquia, Pacifico, Putumayo-Caqueta and Sierra Nevada.

the objective prize and violence might be present.[17] Moreover, the decrease of the value of coca HCI – which could cause an outflow of labor from the criminal sector into the agricultural sector – seems to lead to a decrease in violence between 2014 – 2016.

This study emphasizes the importance of distinguishing the economic incentives that coca forms for different agents, and examines how these incentives affect violence in the light of the changing dynamics in the coca market. An underlying assumption of this research is that shifts in the value of coca precede changes in violence. The trends shown in figure 2 address any concerns regarding potential reverse causality, i.e., shifts in violence leading to changes in prices instead of the other way around.

For completion, figure 3 visually depicts the often discussed link between coca production and violence. It seems that the increase in violence (especially the large spike that started around 2011 and ended in 2014) precedes the increase in coca production rather than follows it. This is contrary to previous findings of for example Angrist and Kugler (2008), who, studying the upsurge in coca production in 90s', found that "areas that saw accelerated coca production subsequently became considerably more violent" (p. 191). The fact that this relationship might not be present in the period considered in this study emphasizes the need to re-examine the link between coca and violence in Colombia.

5 Empirical approach

One of the contributions of this paper is the disentanglement of the effects of a change to the returns to the agricultural and criminal sector in the coca market in Colombia, i.e., the income generated from coca for farmers and the objective prize for armed groups, on violence. Rich data on local prices of coca products and production processes is used to, first, create proxies for farmers' income from coca and armed groups' objective prize. Second, the effect of a one percent increase of farmers' income from coca and the objective prize of armed groups on local violent intensity is estimated. Finally, the effects are investigated further, considering the relationship between income and labor market and educational outcomes, as well as the link between the objective prize and local competition.

[17] There is evidence that the decreasing gold prices around 2015 pushed armed groups into the coca market (International Crisis Group, 2021). First, this does not seem to drive the levels of violence presented in the graph as these levels, across the board, are decreasing around 2015. However, to allow for the possibility that some violence is explained by this, the presence of gold in the municipality will be accounted for in the analysis.

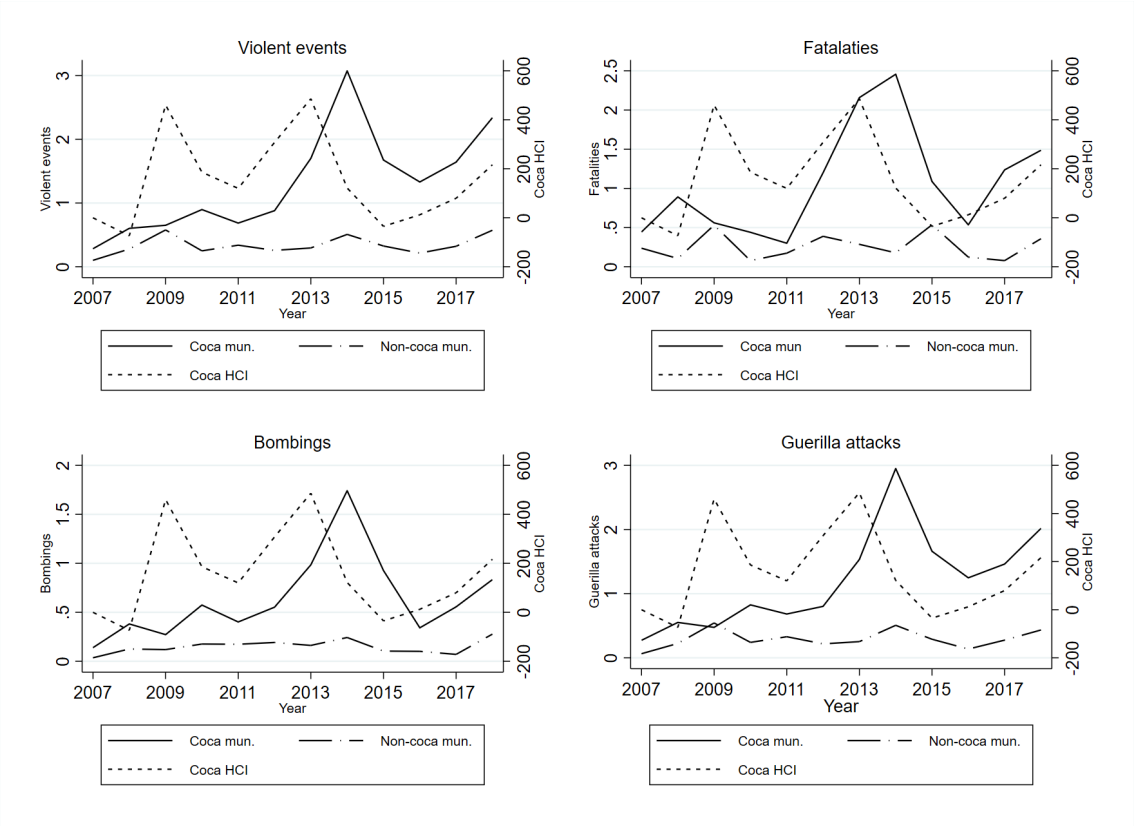

Figure 2: Violence and the price of coca HCI. *Note:* The panels show the average annual levels of violent intensity in terms of number of events, fatalities, bombings and guerilla attacks per 100,000 persons (left y-axis) for both coca and non-coca producing municipalities. The inflation-corrected prices of coca HCI (right y-axis) in thousands of Colombian pesos with 2007 as base year as before.

5.1 Income and objective prize

For those who cultivate coca, the price of their final product (leaves, base or paste) largely determine their income. A proxy for the income from coca is created using data on the prices of coca leaf, base and paste, and weighting this by the fraction of farmers that indicate that they produce each of these products.[18] Similar to Dube and Vargas (2013), this price is weighted by the relative coca production in the municipality at $t = 1$ (similar to a Bartik instrument). Doing so prevents potential adjustments of the production level in response to external factors from biasing the results. For example, there is evidence that coca production can be scaled up or down based on the needs of armed groups (Díaz & Sánchez, 2004), as well as that cultivators adjust production to coca prices – though it is noted that the price elasticity of coca cultivation is relatively small (Moreno-Sanchez

[18]In UNODC production surveys farmers are asked whether they only produce and sell leaf, or process leaf to base or paste. The extent to which farmers process leaf varies greatly within regions. For this reason the prices are weighted by this 'prevalence of production' rate, to create a proxy for the average price that farmers receive for their products.

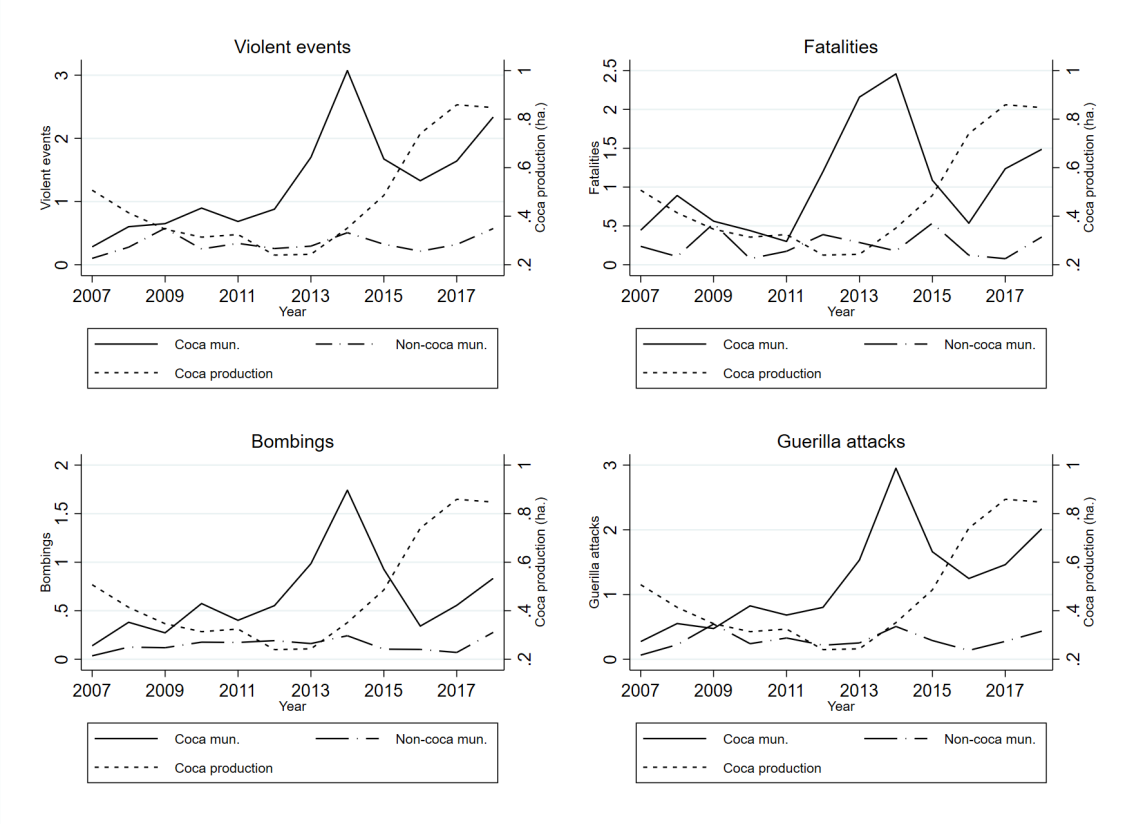

Figure 3: Violence and coca production. *Note:* The panels show the average annual levels of violent intensity in terms of number of events, fatalities, bombings and guerilla attacks per 100,000 persons (left y-axis) for both coca and non-coca producing municipalities and the average coca production (measured in hundreds of hectares dedicated to coca cultivation) in coca producing municipalities (right y-axis).

et al., 2003). These possible adjustments of coca production are controlled for by using the level of coca production in 2007, the first time period observed, in the construction of the proxy. Moreover, by weighting the prices by the prevalence of coca production the relative exposure to coca, or coca intensity, on municipal level taken into account. The proxy is constructed as follows:

$$Income_{i,d,t} = coca_{i,d,t=2007} * ln(\sum_{x=i,b,p} (F_{x,r,t} * P_{x,r,t})) \tag{1}$$

Where *coca* is the number of hectares, in thousands, dedicated to coca cultivation in municipality i in department d and year t. $F_{x,r,t}$ is the fraction of farmers dedicated to cultivating and producing x in region r, and $P_{x,r,t}$ is the price of x per kilo in ten thousands of COP, where x is either leaf (l), paste (p) or base (b). In order to verify whether the proxy is significantly correlated to agricultural wages, the following equation is estimated:

$$wage_{i,d,t} = \lambda_t + \phi_i + \beta Income_{i,d,t} + \theta X_{i,d,t} + \epsilon_{i,d,t} \tag{2}$$

Where $wage_{i,d,t}$ are average monthly wages, averaged to municipal-year level (as described in section 4) for those living in rural areas and who indicate that they, or their household, work(s) in agriculture as a day laborer or is/are self-employed. The proxy for farmers' income from coca is captured by $Income_{i,d,t}$. $X_{i,d,t}$ includes control variables on municipal and departmental level, among which the logs of international prices of common other (agricultural) goods such as bananas, cocoa, coffee, sugar, palm kernel and gold.[19] These prices are interacted with the relative intensity of production of these crops on municipal level (measured in thousands of hectares dedicated to the cultivation of the good). This is done to control for shifts in prices potential other goods aside from coca, as coca is often grown by households who also cultivate other crops (Mansfield, 1999). Additional controls included are rain, temperature, and the average age, highest education completed, and the fraction of people that are employed per municipality. λ_t and ϕ_i capture time and municipality fixed effects, respectively. Finally, it is likely that there are spatial spill-overs, as well as serial-correlation over time and across municipalities within a department. In order to address this all standard errors are clustered on departmental level in every analysis moving forward.
The results for the estimation of equation 2 are shown in table 1 for a sub-sample of coca-producing municipalities for which the GEIH data was available. There is a significant, positive effect of a one percent increase of the proxy for income on average monthly wages. This supports the assumption that the proxy captures farmers' income from coca.[20]

Militias and armed groups produce coca HCI and sell this to international traffickers and resellers. For these groups, the value of coca HCI forms an objective prize.[21] Similar to the proxy for income from coca, the objective prize is measured as:

$$OP_{i,d,t} = coca_{i,d,t=2007} * ln(P_{HCI,r,t}) \tag{3}$$

Where $OP_{i,d,t}$ captures the objective prize in municipality i, in department d, in year t. $P_{HCI,r,t}$ is the value of coca HCI in region r in year t. *coca* is, as before, the production of coca in municipality i at $t = 1$ to account for the local presence and size of the coca sector.

The average fluctuations of the income from coca and the objective prize for coca producing municipalities, together with the four types of violence for the average coca and non-coca producing municipalities, are illustrated in figure 4. Though the figure shows relatively similar trends for the income and objective prize proxy (due to averaging them across all municipalities), the average

[19] Illicit alluvial gold mining (Rettberg & Ortiz-Riomalo, 2016) is linked to coca production (UNODC, 2013) and can be a feasible alternative source of income for cultivators in certain areas.

[20] As there are only 16 clusters in the sub-sample, the robustness of the results is tested by using the wild bootstrap method proposed by Cameron et al. (2008). The results presented are robust to this specification.

[21] The value of HCI is also used by the UNODC (2018) as a variable that captures the value of coca for producers.

Table 1: Proxy for income

	Monthly agricultural income
Coca	3.44795**
	(1.35300)
Banana	-16.47309
	(12.74617)
Tobacco	-1228.34844*
	(598.64076)
Palm kernel	0.59619*
	(0.28407)
Coffee	0.52496
	(0.75346)
Sugar	-6.73467
	(6.75701)
Cacao	-0.16901
	(0.48277)
Gold	0.01073**
	(0.00463)
Controls	Yes
Year FE	Yes
Municipality FE	Yes
N	616
Clusters	16

Note: The table shows the results of the estimation of equation 1, and indicates whether average monthly income, in thousands of COP, of agricultural workers is significantly correlated to the proxy of farmers' income from coca in coca-producing municipalities. Other variables are the production size (in thousands of hectares) in 2007 multiplied by the international price (expressed in thousands of COP, inflation-adjusted) for coffee, bananas, tobacco, palm kernel, sugar cane, cacao and gold to capture other sources of income. Additional controls, not shown, are average age, education level, and gender of the respondents on municipal level, as well as whether they were employed, and rain and temperature. These are included in table A.5. Standard errors, clustered by department, in parentheses. *p<0.1; **p<0.05; ***p<0.01.

annual changes and the largest in- and decreases in both proxies differ. For the average coca producing municipality, with 396 hectares dedicated to coca cultivation, the income from coca that cultivators received increased with 0.04% per year on average. The largest decrease in income recorded in the time period considered is 0.67%, and the largest increase 1.52%. The objective prize increased more strongly, with an average annual growth of 0.07%. The sharpest decrease of the value is 0.73%, and strongest increase 1.82%. We will return to this in order to interpret the results.

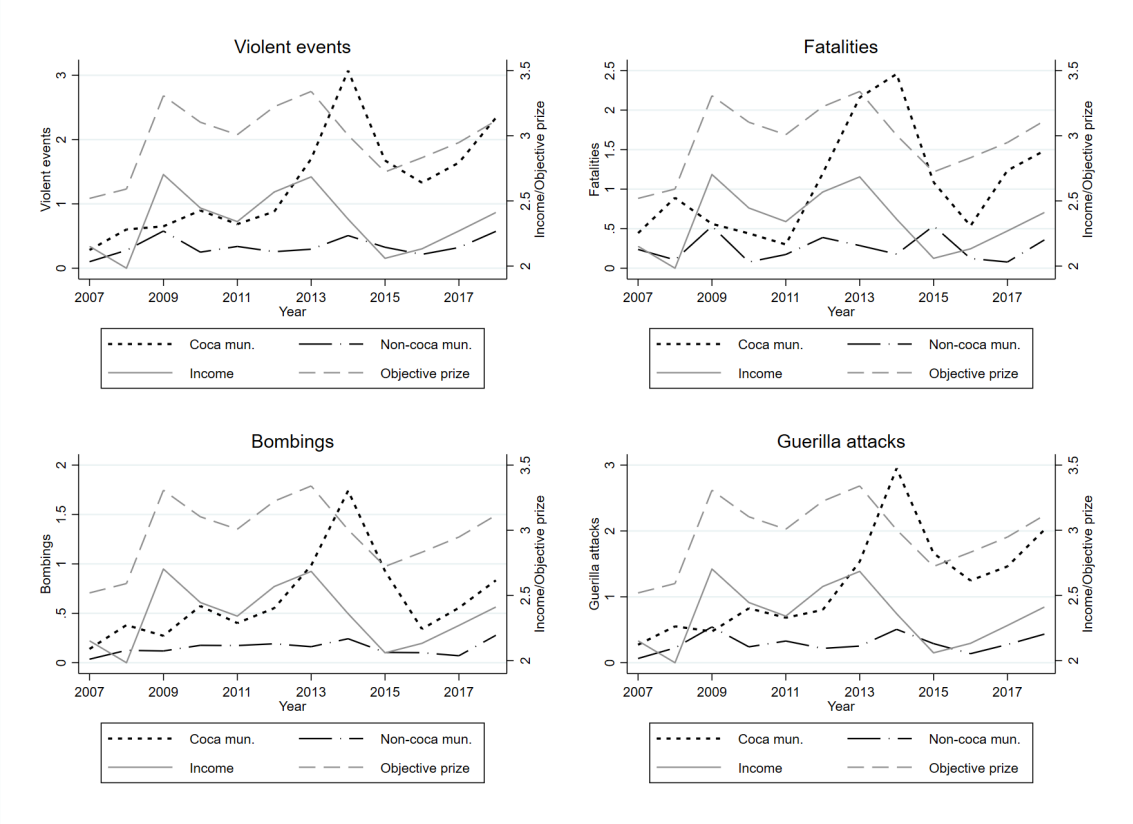

Figure 4: Income, objective prize and violence. *Note:* The panels show the average annual levels of violent intensity in terms of number of events, fatalities, bombings and guerilla attacks per 100,000 persons (left y-axis) for both coca and non-coca producing municipalities, as well as the average annual income and objective prize proxies (right y-axis).

5.2 Baseline model

Having established proxies for the income from coca and the objective prize, we can estimate the effect of both measures on the intensity of violence in a municipality.

$$violence_{i,d,t} = \lambda_t + \phi_i + \delta Income_{i,d,t-1} + \psi OP_{i,d,t-1} + \theta Z_{i,d,t} + \epsilon_{i,d,t} \tag{4}$$

Where $violence_{i,d,t}$ captures the number of fatalities, violent events, guerilla attacks or bombings per 100,000 inhabitants of municipality i in department d and year t.[22] The potential presence of endogeneity in this model is addressed in various ways. First, lagged values of both proxies are used as instruments: $Income_{i,d,t-1}$ is the lagged value of the proxy for income from coca for cultivators, and $OP_{i,d,t-1}$ the lagged value of the objective prize for armed groups. Second, the original municipality-month level data on coca product prices and production technology underlying the proxies has been averaged to region-year level as discussed in section 4. By using these averaged

[22]The results are robust for specification of violence in levels: see table A.7.

prices, it is unlikely that the local municipal circumstances affect prices or technology the data on the level used in this study.[23] Combined, these measures – as well as additional measures discussed below – ensure that endogeneity concerns are mitigated.

Many drivers of coca-related violence are also determinants of prices of coca products. $Z_{i,d,t}$ captures control variables on municipal and departmental level that are measures of these drivers. First, local government intervention in the coca sector, affecting both prices and violence, is addressed by including municipal-level controls for the number of hectares (in thousands) of coca fields that are eradicated, as well as growth rates capturing changes in the levels of the kilos (in thousands) of coca leaf, base, paste and HCI that have been confiscated. Controlling for such types of government interference in the coca sector also captures whether government forces are active in a municipality, and potential violence or conflict stemming from this presence. Moreover, though the analysis will focus on the first lag of each proxy, additional lags of the proxies are included as controls. The final number of lags (four in total) included in the model is chosen based on the Bayesian Information Criterion (BIC), in order to select the model that presented the best fit. The leading principle was to include sufficient lags to address endogeneity and autocorrelation concerns while ensuring to not over-fit the model. In addition, changes to the presence of armed groups can lead to heightened levels of violence, lower prices for farmers' products, or an increase in coca production through competition. The entry or exit of an armed group from an area, by itself, can also be a source of violence. This is controlled for by including a variable that captures changes in, and the presence of, the number of armed groups in the municipality. Furthermore, $Z_{i,d,t}$ includes linear time trends for municipalities that produce coca, gold and coffee. The latter two are included to account for outside options of coca cultivators to change to another sector, as well as potential alternative sources of financing for armed groups. Additionally, both coffee production and (illicit alluvial) gold mining are associated with conflict (Dube & Vargas, 2013; International Crisis Group, 2021). Finally, rain and temperature are included as important measures of potential production levels as well as determinants of conflict. Year (λ_t) and municipality (ϕ_i) fixed effects are included to capture any additional (un)-observed time-invariant variables.

The coefficients of interest are δ and ψ. δ captures the differential effect of the income from coca for farmers, cultivators and agricultural households on violence in municipalities that cultivate relatively more coca. Similarly, ψ captures the differential effect of the objective prize for militias and armed groups on violence in municipalities that cultivate relatively more coca.

[23] In a way this is similar to Dube and Vargas (2013), who use international prices for coffee and oil while ensuring that Colombia's internal price does not affect these international prices.

5.3 Opportunity cost and rapacity channel

If the results show that an increase in income from coca leads to lower levels of violence, the conceptual framework posits that this might be due to the opportunity cost effect. The opportunity cost effect suggest that an increase in potential returns to cultivating coca leads to an increase in employment in the agricultural sector. This can imply, first, an increase in the number of hours worked by those active in the sector in order to reap the higher returns (Angrist & Kugler, 2008). This is examined by regressing the income proxy on the number of hours worked per week.
Second, the income from coca cultivation is frequently cited as the reason that parents can afford to send their children to school (International Crisis Group, 2021), with one national survey finding that more than half of the families involved in coca cultivation invested their profits mainly in education (Sanín, 2019). However, Sviatschi (2018) shows that an increase in coca prices leads to higher levels of child labor in areas suitable for coca cultivation, as well as children (especially of secondary school age) dropping out of school to help their family. This implies that the effect of increased income from coca cultivation on education can go both ways. Moreover, it is worth noting that there is anecdotal evidence that an increase in the potential returns to joining a militia have been associated with children dropping out of school (Bjørkhaug, 2010).[24] This suggests that the rapacity effect, caused by an increase in the objective prize, does not solely draw labor out of the agricultural sector, but that the increase also has the potential to entice children to drop out of school. These potential effects are examined by regressing the income and objective prize proxies on school attendance rates and average educational attainment.
Finally, one of the main predictions of the conceptual framework is that an increase in the objective prize causes an increase in violence through higher levels of competition among armed groups. Measuring competition as the number of different perpetrators responsible for at least one violent event per year in a municipality, the extent to which competition drives violence is investigated.
These various outcomes are considered in order to present a more detailed picture of the effects that changes in income and the objective prize have, and through what channels the opportunity cost and rapacity effect work:

$$Y_{i,d,t} = \lambda_t + \phi_i + \beta Income_{i,d,t-1} + \psi OP_{i,d,t-1} + \theta Z_{i,d,t} + \epsilon_{i,d,t} \tag{5}$$

Where $Y_{i,d,t}$ is either the municipal average of the number of hours worked per week, school attendance rates, or the highest education achieved for those living in rural areas and that indicate that they, or their household, work(s) in agriculture as a day laborer or is/are self-employed. When considering the rapacity channel, $Y_{i,d,t}$ captures the level of competition in the municipality. All

[24] In the same vein, Vargas and Restrepo-Jaramillo (2016) show that lack of access to education contributes to child recruitment.

other variables are as before. However, in the case that labor market or educational outcomes are considered, the control variables additionally include gender and age.

6 Results

6.1 Baseline model

Table 2 shows the results of the baseline model 4. The coefficients capture the effect on violence in response to a one percentage point increase in income and objective prize for the average coca producing municipality. The results show a negative, significant differential effect from a one percent increase in the coca income for cultivators on violent intensity. This suggests the presence of the opportunity cost effect. Additionally, there is a positive, significant differential effect from a one percent increase in the objective prize on violent intensity, which suggests that the rapacity effect is present.

According to the data, the income from coca for cultivators, representing the returns to employment in the agricultural sector, increased with at most 1.52% in the average coca producing municipality during the time period considered. Interpreting the coefficients as deviations from the mean, the results imply that such an increase in the income from coca is associated with a decrease of 4.8%, 6.6% and 4.7%, in violent events, bombings and guerilla attacks per 100,000 inhabitants, respectively. Similarly, the largest increase of the objective prize – which captures the returns to being active in the criminal sector – was 1.82%. The results imply that in response to such an increase in the value of the objective prize there were 5.6% more violent events, 5.5% more guerilla attacks, 7.9% more fatalities and 7.5% more bombings. Vice versa, the largest decrease in the income from coca recorded is 0.67%. Such a decrease, based on these estimates, would result in a 2.1–3% increase in the intensity of total events, guerilla attacks and bombings. Moreover, the decrease in the value of the objective prize of 0.73% is linked to a 2.3–3.2% decrease in the intensity of violence, given each measure.

6.2 Opportunity cost and rapacity channel

Having found evidence that supports the presence of the opportunity cost and rapacity effect, the effects of changes in income and the objective prize on additional outcomes are considered. Labor market and educational outcomes, as well as competition among armed groups on a local level are examined following equation 5. The results are presented in table 3.

Column one, two and three show the results for labor market and educational outcomes. Though there are no effects on the number of hours worked nor the level of education, there are significant

Table 2: Income, objective prize and violence

	Total events	**Fatalities**	**Guerilla attacks**	**Bombings**
Income_{t-1}	-1.61222**	-1.54788	-1.38809**	-1.01226**
	(0.62966)	(0.96925)	(0.56443)	(0.45932)
OP_{t-1}	1.57989**	1.74646*	1.38038**	0.96952**
	(0.66819)	(0.93024)	(0.59862)	(0.36770)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
N	8857	8857	8857	8857
Cluster	32	32	32	32

Note: The table shows the results for the baseline estimation 4. Dependent variables capture violent intensity on municipal level, measured as number of events, fatalities, guerilla attacks or bombings per 100,000 inhabitants. The full results, including controls, are shown in table A.6. The results for the dependent variables measured in levels are presented in table A.7. Standard errors, clustered by department, in parentheses. *p<0.1; **p<0.05; ***p<0.01.

effects on school attendance. First, there is a positive effect on school attendance in response to an increase in income. This is in line with the literature, as well as with anecdotal evidence referred to before, that income from coca in rural areas is frequently invested in education of children. However, at the same time, there is a negative effect of an increase in the objective prize on school attendance. This supports the other side of the story as reported by Bjørkhaug (2010): when the potential returns to joining a militia are relatively high, it can be attractive - especially for young males - to drop out of school and join an armed group.

A significant part of the conceptual model was dedicated to explaining the role of competition with respect to violence and the behavior of armed groups. It was noted that aside from drawing labor from the agricultural sector into the criminal sector, an increase in the objective prize can affect the behavior of agents already active in the criminal sector. For example, a relative increase in the value of the objective prize can lead to an increase in violence when militias and armed groups compete for control over the market, spurred on by rent-seeking behavior. The role of competition with respect to a changing objective prize value is examined by estimating equation 5, and the result is presented in column four of table 3. Local competition increases in response to an increase in the objective prize. For the average coca-producing municipality, an increase of 1.82% in the objective prize would result in a 2.3% increase in the level of local competition (7% in municipalities that do not produce coca, where the average number of armed groups is lower). However, an increase in income of 1.52% from cultivating coca relative to the returns to being part of a militia or armed group seems to decrease local competition by about 1.7% in the average coca producing municipality. This finding further supports the opportunity cost channel, as it indicates that when income increases and employment in the agricultural sector becomes more attractive, members of armed groups and militias might (temporarily) seek employment in this sector.

Table 3: Opportunity cost and rapacity effect

	Hours worked (1)	**Highest level of education** (2)	**Attending school** (3)	**Local Competition** (4)
Income_{t-1}	-2.27501	-0.14190	0.01376**	-0.24597***
	(2.95637)	(0.18493)	(0.00597)	(0.08318)
OP_{t-1}	0.56277	0.12303	-0.01494**	0.28471***
	(2.84959)	(0.19547)	(0.00664)	(0.08419)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
N	3437	3437	3437	8857
Clusters	24	24	24	32

Note: The table contains the results for estimation of equation 5. Controls include the lagged values of the income and objective prize proxy, age, gender and the measure for competition (for column (1)-(3)), whether time trends for gold and coffee producing municipalities, rain, temperature, and measures for government interference in the coca sector (confiscation of leaf, base, paste, HCI, and eradication of coca fields). The full results, including controls, are shown in table A.8. Standard errors, clustered by department, in parentheses. *p<0.1; **p<0.05; ***p<0.01.

7 Concluding remarks

This paper focuses on 2007 – 2018, a time period during which the Colombian coca sector changed fundamentally. First, the large cartels were replaced by an increasing number of smaller criminal groups vying for control over the coca market. The second trend is that the main destination markets for Colombian cocaine - the United States and Europe - are growing, increasing the potential profits to be made from producing, trafficking and selling coca for some of the agents involved (UNODC & Europol, 2021). These two trends have significantly affected armed groups and cultivators. The first are confronted with less bargaining power and higher levels of competition; the latter have seen these changes impact their livelihood, safety and security. The changing market structure and shifting roles of agents in the Colombian coca market emphasize the need for understanding agents' behavior and how they respond to (economic) incentives.

This study aims to shed light on how these recent changes have impacted the link between coca and violence. It examines the effect of changes in the returns to being active in the agricultural sector and in the criminal sector on violent intensity in Colombian municipalities. This is done by developing a proxy for the income from coca for those employed in the agricultural sector and a proxy for the objective prize, presenting the returns to being employed in the criminal sector. By constructing separate measures, the paper identifies and disentangles the (contradicting) effects of changes to the value of coca on violent intensity.

The results indicate that, with respect to cultivators and farmers active in the agricultural sector, increases in the income from coca result in lower levels of intensity of violence (the opportunity cost effect). Moreover, there is evidence that increasing income can lead to higher school attendance rates, supporting previous findings that a share of the proceeds of coca is invested in education.

There is suggestive evidence that a relatively higher – compared to the objective prize – income from cultivation might entice members of militias and armed groups to seek employment in the agricultural sector, as well as reduce the pressure on groups to compete for territory and financial gain. Furthermore, the results suggest the presence of the rapacity effect: an increase in the objective prize is associated with an increase in the intensity of violence. This increase in the potential return from joining a militia or armed group might entice children or young adults to drop out of school, lowering school attendance rates. Finally, armed groups tend to gravitate towards areas where the expected returns are higher: the increasing value of the objective prize leads to higher levels of local competition.

Coca cultivation in Colombia tripled between 2013 and 2017, reaching an all-time high, and violence escalates (International Crisis Group, 2021). It is a difficult matter: on the one hand, coca is a very lucrative crop and stable source of income in a country with a large rural agricultural sector, where approximately 36% of people live in poverty (Worldbank, 2018). Simultaneously, coca is an important source of financing and thereby a good worth competing for among armed groups, who are involved in a conflict considered responsible for at least 260,000 deaths (Reuters, 2020). The complexity emphasizes the need for a deep understanding of the incentives for agents involved in the sector and how these affect their choices and behavior, especially given the new and rapidly changing dynamics in the Colombian coca market. This is further illustrated by realizing the extent to which many policies aimed at decreasing cultivators' reliance on coca are based on economic incentives, such as subsidy or crop substitution programs. This study contributes to this goal by identifying incentives, disentangling the separate effects, examining the impact on labor market and educational outcomes, and considering (violent) competition among armed groups.

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A Appendix

Table A.4: Descriptive statistics

Variable	Level	Mean	SD	Min.	Max.	Source
Total events	Municipality	0.505	2.633	0	53.949	GTD
Fatalities	Municipality	0.303	3.203	0	135.213	GTD
Guerilla attacks	Municipality	0.441	2.443	0	53.949	GTD
Bombings	Municipality	0.064	0.447	0	20	GTD
Competition	Municipality	0.074	0.298	0	3	GTD
Eradication coca fields	Municipality	0.122	1.085	0	31.357	UNODC
Manual eradication coca fields	Municipality	0.038	0.385	0	15.678	UNODC
Confiscation coca HCI	Municipality	0.038	0.346	0	10.347	UNODC
Confiscation coca base & paste	Municipality	0.008	0.039	0	0.818	UNODC
Confiscation coca leaf	Municipality	0.078	0.535	0	13.086	UNODC
Banana prod.	Municipality	0.081	0.322	0	3.04	Agronet
Cacao prod.	Municipality	0.339	1.633	0	19.986	Agronet
Coca prod.	Municipality	0.083	0.412	0	5.642	Agronet
Coffee prod.	Municipality	1.931	5.949	0	63.56	Agronet
Palm prod.	Municipality	0.738	3.907	0	37.632	Agronet
Sugar prod.	Municipality	0.489	2.680	0	33.9	Agronet
Tabacco prod.	Municipality	0.021	0.164	0	2.14	Agronet
Gold prod.	Municipality	14.022	146.58	0	3361.54	Agronet
Hourly wage, x1000 COP	Municipality	2.299	1.023	0	21.429	DANE
Monthly income, x1000 COP	Municipality	413.660	190.246	0	4800	DANE
Age	Municipality	42.890	4.687	24	74	DANE
Highest education	Municipality	3.182	0.410	1	6	DANE
Population (in 100,000)	Municipality	0.783	1.824	0.022	25.334	DANE
Rainfall, mm.	Department	124.928	64.251	1.926	424.884	Murray et al. (2020)
Temperature, Celsius	Department	21.914	3.403	16.181	28.953	Murray et al. (2020)
Coca leaf price	Region	0.248	0.0714	0.075	0.415	UNODC
Coca base price	Region	254.174	20.688	196.41	307.07	UNODC
Coca paste price	Region	188.679	20.859	145.63	222.55	UNODC
Coca HCI price	Region	457.775	34.315	310	583.54	UNODC
Farmers growing leaf (%)	Region	57.973	25.224	14	92	UNODC
Farmers growing leaf, producing paste (%)	Region	31.748	29.926	1	87	UNODC
Farmers growing leaf, producing base (%)	Region	10.246	14.702	0	66	UNODC
Banana price	International	192.34	81.67	68.55	338.31	FRED
Cacao price	International	0.510	0.192	0.179	0.899	FRED
Coca price	International	0.083	0.412	0	5.642	FRED
Coffee price	International	0.333	0.127	0.112	0.484	FRED
Palm price	International	148.394	55.185	70.136	233.465	FRED
Sugar price	International	0.035	0.016	0.010	0.062	FRED
Tabacco price	International	22.267	8.760	8.616	37.293	FRED
Gold price	International	252.088	111.725	70.834	431.208	FRED
N	13,428					

Note: Descriptive statistics of all variables used in the analysis. Violent incidents are per 100,000 inhabitants of the municipality; prices of coca products are in thousands of COP; growing variables indicate the percentage of farmers that grow leaf (only), and/or process it into paste/base; eradication is total number of hectares (in thousands) eradicated; confiscation variables are expressed in thousands of kilos; municipal production is measured in thousands of hectares in 2007; hourly and monthly wage/income is in thousands of COP; population is in 100,000; competition is measured as the number of active (carrying out violent attacks) armed groups in a municipality; rainfall in millimeters, temperature in degrees Celsius, both annual averages.

Table A.5: Proxy for income

	Monthly agricultural income
Coca	3.44795**
	(1.35300)
Banana	-16.47309
	(12.74617)
Tobacco	-1228.34844*
	(598.64076)
Palm kernel	0.59619*
	(0.28407)
Coffee	0.52496
	(0.75346)
Sugar	-6.73467
	(6.75701)
Cacao	-0.16901
	(0.48277)
Gold	0.01073**
	(0.00463)
Gender	-13.21408
	(7.84497)
Age	0.03943
	(0.31105)
Highest education	2.29771
	(4.24373)
Employment	-0.32644
	(1.35022)
Rain	0.03015
	(0.02474)
Temperature	9.82399
	(6.63355)
Controls	Yes
Year FE	Yes
Municipality FE	Yes
N	616
Clusters	16

Note: The table shows the results of the estimation of equation 1, and indicates whether average monthly income, in thousands of COP, of agricultural workers is significantly correlated to the proxy of farmers' income from coca in coca-producing municipalities. Other variables are the production size (in thousands of hectares) in 2007 multiplied by the international price (expressed in thousands of COP, inflation-adjusted) for coffee, bananas, tobacco, palm kernel, sugar cane, cacao and gold to capture other sources of income. Standard errors, clustered by department, in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table A.6: Income, objective prize and violence

	Total events	**Fatalities**	**Guerilla attacks**	**Bombings**
Income_{t-1}	-1.61222**	-1.54788	-1.38809**	-1.01226**
	(0.62966)	(0.96925)	(0.56443)	(0.45932)
OP_{t-1}	1.57989**	1.74646*	1.38038**	0.96952**
	(0.66819)	(0.93024)	(0.59862)	(0.36770)
Competition	0.00065***	0.00063***	0.00055***	0.00027***
	(0.00006)	(0.00010)	(0.00006)	(0.00004)
Gold producer	0.00009	-0.00004	0.00009	0.00009*
	(0.00007)	(0.00016)	(0.00007)	(0.00005)
Coffee producer	-0.00959	0.04121	-0.01376	-0.02169
	(0.03114)	(0.03583)	(0.03069)	(0.02061)
Coca producer	-0.00008	-0.00004	-0.00014	-0.00013**
	(0.00013)	(0.00019)	(0.00014)	(0.00005)
Man. eradication	-0.27098	-0.32308	-0.23986	-0.21859***
	(0.17311)	(0.24397)	(0.17308)	(0.06988)
Eradication	0.01433	-0.03127	0.01484	0.04319
	(0.14579)	(0.41715)	(0.14407)	(0.07823)
Rain	-0.00079	0.00150	-0.00136	-0.00011
	(0.00126)	(0.00218)	(0.00112)	(0.00154)
Temperature	0.19089	0.26951	0.10042	-0.02696
	(0.28480)	(0.40792)	(0.28208)	(0.10716)
Confisc. leaf	-0.00003***	-0.00013***	-0.00002*	-0.00000
	(0.00001)	(0.00003)	(0.00001)	(0.00001)
Confisc. base/paste	-0.00003	-0.00003	-0.00003	-0.00003
	(0.00005)	(0.00003)	(0.00005)	(0.00003)
Confisc. HCI	0.00002***	-0.00001***	-0.00000	0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00001)
Income_{t-2}	-2.45441*	-1.93251	-2.39274*	-1.60875**
	(1.28153)	(1.51492)	(1.32007)	(0.66010)
Income_{t-3}	-0.55274	-0.85334	-0.31449	-0.17724
	(1.31282)	(0.85978)	(1.24407)	(0.66655)
Income_{t-4}	-0.13751	-0.76121	-0.12606	-0.04146
	(0.50059)	(0.65051)	(0.50735)	(0.26583)
OP_{t-2}	2.47673	0.78353	2.51057	1.72568**
	(1.59891)	(1.66194)	(1.68035)	(0.72647)
OP_{t-3}	0.38736	0.93967	0.20194	-0.03258
	(1.29584)	(1.00765)	(1.23187)	(0.68759)
OP_{t-4}	0.26456	0.19860	0.33365	0.10556
	(0.62958)	(0.60812)	(0.63818)	(0.30864)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
N	8857	8857	8857	8857
Cluster	32	32	32	32

Note: The table shows the results for the baseline estimation 4. Dependent variables capture violent intensity on municipal level, measured as number of events, fatalities, guerilla attacks or bombings per 100,000 inhabitants. Standard errors, clustered by department, in parentheses. *p<0.1; **p<0.05; ***p<0.01.

Table A.7: Income, objective prize and violence

	Total events	**Fatalities**	**Guerilla attacks**	**Paramilitary attacks**
Income_{t-1}	-0.73463***	-0.63477**	-0.69148***	-0.52206**
	(0.23402)	(0.29865)	(0.17941)	(0.23708)
Income_{t-2}	-1.45091***	-1.22611**	-1.47125***	-0.91570***
	(0.31079)	(0.46203)	(0.24983)	(0.22118)
Income_{t-3}	-0.09914	-0.12408	0.00389	-0.14743
	(0.37346)	(0.47485)	(0.31407)	(0.26469)
Income_{t-4}	-0.05636	-0.82431	-0.07842	0.00980
	(0.21693)	(0.54076)	(0.20009)	(0.20235)
OP_{t-1}	0.97361***	0.98529***	0.93653***	0.73485**
	(0.26177)	(0.29705)	(0.20831)	(0.30915)
OP_{t-2}	1.39644***	0.54435	1.46639***	0.81987***
	(0.30464)	(0.37325)	(0.27818)	(0.21544)
OP_{t-3}	0.09003	0.41818	0.00827	0.12670
	(0.36426)	(0.51922)	(0.30857)	(0.25898)
OP_{t-4}	0.10109	0.32284	0.14176	-0.05000
	(0.24188)	(0.39049)	(0.21923)	(0.22819)
Competition	0.00010***	0.00010***	0.00007***	0.00004***
	(0.00000)	(0.00001)	(0.00000)	(0.00000)
Gold producer	0.00001	0.00001	0.00002	0.00001
	(0.00002)	(0.00001)	(0.00002)	(0.00002)
Coffee producer	-0.00768	0.00409	-0.00812	-0.00528
	(0.00541)	(0.00424)	(0.00624)	(0.00343)
Coca producer	-0.00002	0.00003	-0.00003	-0.00002
	(0.00002)	(0.00005)	(0.00003)	(0.00001)
Man. eradication	-0.13883***	-0.18893***	-0.21538***	-0.16272***
	(0.02981)	(0.06255)	(0.05273)	(0.03804)
Eradication	0.08876**	0.06633	0.06488*	0.03895
	(0.03635)	(0.10444)	(0.03579)	(0.02490)
Rain	0.00009	-0.00013	0.00000	-0.00002
	(0.00020)	(0.00028)	(0.00020)	(0.00020)
Temperature	0.04272	0.08715	0.01883	-0.00325
	(0.05214)	(0.06644)	(0.04727)	(0.02294)
Confisc. leaf	0.00000**	-0.00003***	0.00000***	0.00000***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Confisc. base/paste	-0.00001	-0.00001	-0.00001	-0.00001
	(0.00001)	(0.00001)	(0.00001)	(0.00001)
Confisc. HCI	0.00000	-0.00000***	-0.00000	0.00000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
N	8857	8857	8857	8857
Cluster	32	32	32	32

Note: The table shows the results for the baseline estimation 4. Dependent variables capture the level of violence on municipal level, measured as number of events, fatalities, guerilla attacks or bombings. Standard errors, clustered by department, in parentheses. *p<0.1; **p<0.05; ***p<0.01. ***p<0.01.

Table A.8: Opportunity cost and rapacity effect

	Hours worked	**Highest level of education**	**Attending school**	**Local Competition**
Income_{t-1}	-2.28197	-0.15449	0.01371**	-0.14860
	(2.95024)	(0.18499)	(0.00598)	(0.09575)
Income_{t-2}	-3.25386	0.08199	-0.01219	-0.18312
	(2.10241)	(0.11660)	(0.01679)	(0.13821)
Income_{t-3}	-3.52506	0.05866	-0.00548	-0.02956
	(3.35845)	(0.18673)	(0.02170)	(0.11235)
Income_{t-4}	3.11047	0.13243**	0.00699	-0.02345
	(3.01430)	(0.05532)	(0.01158)	(0.07035)
OP_{t-1}	0.57595	0.13412	-0.01481**	0.24710***
	(2.84606)	(0.19574)	(0.00666)	(0.08842)
OP_{t-2}	4.27761*	-0.05325	0.01181	0.13203
	(2.29091)	(0.13269)	(0.01748)	(0.16299)
OP_{t-3}	2.86812	-0.07920	0.00644	0.06175
	(3.52015)	(0.22714)	(0.02199)	(0.12060)
OP_{t-4}	-3.23043	-0.11992*	-0.00759	0.06032
	(2.78623)	(0.06201)	(0.01131)	(0.05421)
Age	-0.11311***	-0.02540***	0.00189***	
	(0.02820)	(0.00301)	(0.00022)	
Gender	-14.12262***	0.51393***	-0.02503***	
	(2.84288)	(0.07080)	(0.00756)	
Competition	0.00003	0.00000	-0.00000	
	(0.00003)	(0.00000)	(0.00000)	
Gold producer	-0.00000	-0.00001	-0.00000	-0.00000
	(0.00048)	(0.00001)	(0.00000)	(0.00001)
Coffee producer	0.13322	0.00303	-0.00097	-0.00021
	(0.12032)	(0.00635)	(0.00057)	(0.00353)
Coca producer	0.00025	0.00001	-0.00000	0.00000
	(0.00025)	(0.00001)	(0.00000)	(0.00001)
Man. eradication	-0.94226**	-0.04314*	0.00251*	0.05202
	(0.34131)	(0.02145)	(0.00137)	(0.03109)
Eradication	0.78925**	0.02590*	-0.00085	0.02363
	(0.29533)	(0.01409)	(0.00107)	(0.01665)
Rain	-0.01202*	-0.00001	0.00001	0.00015
	(0.00641)	(0.00028)	(0.00002)	(0.00018)
Temperature	-0.43119	0.01367	-0.00103	0.02329
	(0.88310)	(0.03137)	(0.00328)	(0.03875)
Confisc. leaf	-0.00036	-0.00001	0.00001*	0.00000***
	(0.00034)	(0.00001)	(0.00000)	(0.00000)
Confisc. base/paste	-0.00001	-0.00000	-0.00000	0.00000
	(0.00002)	(0.00000)	(0.00000)	(0.00000)
Confisc. HCI	-0.00000	0.00000	0.00000	0.00000***
	(0.00001)	(0.00000)	(0.00000)	(0.00000)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
N	3437	3437	3437	8857
Clusters	24	24	24	32

Note: results for estimation of equation 5. Standard errors, clustered by department, in parentheses. *p<0.1; **p<0.05; ***p<0.01.