From Maize to Haze: Agricultural Shocks and the Growth of the Mexican Drug Sector*

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Abstract

We examine how income shocks experienced by rural producers affect the drug trade in Mexico. Our analysis exploits exogenous movements in the Mexican maize price stemming from weather conditions in U.S. maize-growing regions, as well as export flows from other major maize producers. We document that these price fluctuations have substantial effects on the income of agricultural workers. Using data on over 2200 municipios spanning 1990-2010, we find that lower prices differentially increased the cultivation of both marijuana and opium poppies among municipios more climatically suited to growing maize. We also find impacts on drug seizures, along with killings perpetrated by drug cartels. Our findings demonstrate that maize price changes contributed to the burgeoning drug trade in Mexico, and point to the violent consequences of an expanding drug sector.

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1 Introduction

The international drug trade has been a major issue concerning policymakers around the world. Although most drug consumption takes place in developed countries, most drug production takes place in the developing world. Despite this asymmetry, there has been very little work that seeks to understand how poverty and income opportunities affect incentives for drug production. It is especially important to understand these relationships given the large social costs associated with the drug trade, including violence and crime.

Our paper addresses this gap in the literature. We examine how income shocks induced by maize price fluctuations in Mexico affect the production of illicit drug crops and the growth of the drug trade. Mexico offers an ideal setting for the study of this question. In the past two decades, the country has been subject to major swings in the maize price with large consequences for its agricultural sector. In addition, the country has experienced a concomitant increase in drug-war related violence. To the best of our knowledge, this is the first paper that examines how economic shocks to rural producers affect drug production.

We focus on a set of drug-related outcomes spanning the narco-trafficking chain, from cultivation (proxied by eradication) to drug cartel violence. Our empirical strategy exploits exogenous variation in Mexican maize prices stemming from the production behavior of major exporters. Specifically, we use weather shocks in the maize-producing areas of the United States and the export volume of other major maize producers to instrument for the Mexican maize price. First, we document that the sharp fall in maize prices over the 1990s led to differential decreases in the income of agricultural workers in areas more climatically suited to growing maize. Mirroring these income results, we show that the price fall led to differential increases in both marijuana and opium poppy cultivation in the more maize suitable areas.We also find differential impacts on seizures of raw marijuana and opium gum (the paste used to manufacture heroin). Finally, we estimate larger effects on drug-related killings, including executions carried out by drug cartels over the 2007-2010 period. The results are robust to a number of economic and enforcement controls, including trends based on police presence, distance to the border, and land quality.

Our paper is related to a number of different literatures. First, an existing set of studies documents various factors contributing to the drug war in Mexico. Some papers have examined the role of domestic political factors such as rising electoral competition (Osorio 2012) and the political affiliation of local political authorities (Dell 2011). Dube et al (forthcoming) provide evidence that the availability of high-powered weapons from the United States also contributes to border violence. However, we are unaware of previous work that has examined the role of income shocks.

Our paper also speaks to the literature which examines the inter-relationship between violence and drug crop production. Lind et al (2013) posit that conflict in Afghanistan leads to increases in the cultivation of opium poppies. Conversely, Angrist and Kugler (2008) find that exogenous increases in Colombian coca cultivation led to substantial increases in violent killings, while generating only moderate increases in rural earnings. Castillo et al (2013) examine how changes in Colombian cocaine seizures impact drug war violence in Mexico.

Our paper also fits into a growing literature that examines the relationship between commodity prices and conflict, including Besley and Persson (2009), Brückner and Ciccone (2011), Bazzi and Blattman (2012) De Luca et al. (2012), Maystadt et al. (2013), Berman and Couttenier (2013) and Dube and Vargas (forthcoming). The effects we uncover are consistent with the idea that a fall in maize prices lowers the opportunity cost of participating in illicit activity, which accords with the negative relationship between income and civil conflict documented in a number of cross-country analyses (Collier and Hoeffler 1998, Fearon and Laitin 2003, Miguel et al 2004, Besley and Persson forthcoming). Several within-country studies also find negative relationships between income and conflict (Do and Iyer 2010, Hidalgo et al. 2010, Gwande et al 2012), which are consistent with opportunity cost accounts. Others find that the opposite relationship can arise owing to predation incentives, depending on which group experiences income increases (Mitra and Ray 2012).

The remainder of the paper is organized as follows: section 2 provides background on the institutional context; section 3 provides an overview of the data used in the analysis; section 4 lays out our empirical strategy; section 5 presents the results; and section 6 concludes.

2 Background

This section provides background on three relevant aspects of the institutional context. First, we document the evolution of Mexico's drug trade and drug war. Next, we provide an overview of agricultural workers in Mexico to understand incentives behind drug production. Third, we examine dynamics of the maize price over the course of our sample period.

2.1 The Mexican Drug War

The Mexican drug trade stretches as far back as the turn of the twentieth century. It burgeoned in the 1960s with rising demand in the U.S. for marijuana, and grew further during the 1980s when Mexican and Colombian traffickers began operating together to meet growing demand for cocaine north of the border (Astorga 2005, Toro 1995). Though initially sub-contractors for their Colombian counterparts, the Mexican cartels grew in power and by the 2000s dominated the drug distribution network. Simultaneously, the share of cocaine arriving to the U.S. via Mexico rose dramatically, from about 50 percent in the early 1990s to over 90 percent in the 2000s (O'Neil 2009). The growth of the Mexican drug trade has been characterized by both the increased trafficking of cocaine (produced in South America) and the production and distribution of home-grown drugs including marijuana, heroin, and methamphetamines.

Mexican cultivators grow marijuana and opium poppies, which are used to manufacture heroin. In fact, Mexico is currently the leading producer of marijuana globally (USDS 2011). During the 1990s it also became an important supplier of heroin. Between 1993 and 2008, opium production increased more than six-fold, growing from a low base of 49 to 325 metric tons (USDS 2011). As of 2009, Mexico ranked as the world's third largest opium poppy supplier after Afghanistan and Burma.

While there are no official statistics tracking illicit crop production across regions of Mexico, we are able to use drug crop eradication as a proxy for cultivation. Eradication activities undertaken by the Mexican military unfold in two stages. First, military surveillance identifies individual fields in each municipio that are planted with marijuana and opium poppy. Next, on the basis of that surveillance, the military engages in eradication efforts to destroy the illicit crops grown on those fields. Data from the Mexican military — the Secretariat of National Defense (SEDENA) — record the hectares of marijuana and poppy eradicated in each municipio, over 1990-2010. According to U.S. and Mexican officials, about 75 percent of drug production is eradicated each year (Humphrey 2003), which suggests that eradication is a good proxy for cultivation. As such, we assume that the total area eradicated is informative of the total amount of underlying drug cultivation in a given municipio-year. Figure 1 maps the mean marijuana and poppy eradication across Mexican municipios over our sample period. It is immediately clear that drug eradication is concentrated in the western spine of the country, along the western and southern ranges of the Sierra Madres and the adjacent coastal areas. According to the SEDENA data, marijuana eradication increased from approximately 5400 hectares in 1990 to 34,000 in 2003, and decreased to 17,900 in 2010. Poppy eradication started from 5950 hectares in 1990, peaked at 20,200 in 2005, and fell to 15,300 in 2010.

The growth of the drug trade in Mexico has been closely linked to rising violence. Drug-trafficking violence was relatively restrained through the 1980s, owing in part to underlying political conditions in Mexico and the industrial organization of cartel activity during that period. The PRI political party had dominated electoral politics since the 1930s. The absence of political competition facilitated consolidated patron-client relationships between drug traffickers, the police and local elected officials (O' Neil 2009). As such, implicit agreements with officials enabled particular cartels to operate in particular locations with relative impunity. However, the entry of other political parties in local elections during the early 1990s undermined these arrangement (Barta 2012, O' Neil 2009), incentivizing territorial expansion and in-fighting among rival cartels (Osorio 2012). In essence, the resultant cartel de-stabilization led to rising drug-related violence which skyrocketed in the 2000s. Two major turning points are worth noting. First, in 2001, the leader of the Sinaloa cartel, Joaquín "El Chapo" Guzmán, escaped from prison and attempted to take over important drug routes near Texas and California. Violence subsequently increased in both the drug production areas and crossing points along the U.S.-Mexico border (Luhnow and de Cordoba 2009). Second, in December 2006, President Felipe Calderón launched an aggressive military campaign against the drug cartels. These operations were phased-in geographically, and resulted in dramatic and haphazard violence increases throughout the country.[1] Estimates suggest that up to 50,000 organized crime homicides have taken place in Mexico over 2006-2011 (Ríos and Shirk 2011).

While the drug war has been largely concentrated in urban areas, rural areas engaged in drug crop cultivation have also witnessed rising violence (Escalante 2009). This has been linked to rival cartels contesting territory in the attempt to control trafficking routes from production areas to the border (Astorga 2007, Ravelo 2008). For example, in the northern state of Sinaloa, La Linea cartel has challenged their rival, the Sinaloa cartel (STRATFOR 2013). Similarly, disputes among cartels in the southern state of Michoacan were linked to attempts to take over production areas and routes (Maldonado 2012).

2.2 A Snapshot of Maize and Agricultural Workers

To contextualize the incentives of farmers to produce illicit drug crops, it is useful to examine the characteristics of agricultural workers in Mexico at the beginning of our sample period. Using data from the 1990 Mexican Census, we construct a sample of 748,486 working men between the ages of 18 and 65 in rural municipios.[2] Table 1 presents summary statistics for some basic demographic and labor variables for three groups in these municipios: all workers, agricultural workers, and maize workers. About 48% of all workers held occupations classified as agricultural. Maize has historically dominated the Mexican agricultural sector. About 29% of agricultural workers (representing 14% of all workers) were identified as maize workers in 1990. However, this likely understates the number of individuals that depended on maize for a substantial fraction of their monetary income. Forty-one percent of all agricultural workers were not associated with any particular crop, and these unassigned individuals likely grew a variety of crops including maize. By contrast, coffee and cacao workers represent the second largest group tied to a specific crop, and account for only 4% of agricultural workers.

The agricultural sector is characterized by a mix of small-scale family farmers and individuals working for wages on larger farms. Table 1 shows that 48% of agricultural workers (62% of maize workers) are classified as "own-account," meaning that they do not have a boss or supervisor.

[1] According to data from the Instituto Nacional de Estadística y Geografía (INEGI), homicide rates increased nearly four-fold in 2008 in municipios within 100 miles of the border.

[2] Rural municipios are defined as those that do not contain any individuals who live in sub-municipio localities of population 100,000 or more in the 1990 Census.

Owners of family farms would fall into this category. A substantial number of agricultural workers thus find work as wage employees (38%), yet only about 1% of agricultural workers report directly hiring other workers.

Workers at nearly every point in the agricultural income distribution can be characterized as poor in comparison to non-agricultural workers in these rural areas. A large number of agricultural workers engage in subsistence farming which generates little or no monetary income. About 27% of the agricultural workers (37% of maize workers) report earning zero income despite currently working. By contrast, only 2% of non-agricultural workers report earning zero income. This reflects both the prevalence of subsistence agriculture and the fact that some individuals work without pay for family farms that generate monetary income. Conditional on earning positive income, the average worker in these municipios earns about $4,500$ pesos per month. This is about $450 (in 2005 dollars). The income of the average agricultural worker is substantially lower (about 3,150 pesos per month), and the average maize worker earns even less (about 2,500 pesos per month). While there is substantial variation within the set of agricultural workers, it is clear that the vast majority are poor. The 75th percentile of the positive income distribution for agricultural workers (2650.451) is below the median positive income for non-agricultural workers in these rural areas (3232.592). Very few agricultural workers, and even fewer maize workers, earn substantial monetary sums.

2.3 Evolution of the Maize Price

Over the course of the 1990s and 2000s, several major fluctuations in the maize price impacted the income opportunities of maize workers in Mexico. Figure 2 displays the evolution of the Mexican and international maize prices over 1990-2010. The implementation of the North American Free Trade Agreement (NAFTA) in 1994 initiated liberalization of the maize sector, expanding import quotas and reducing tariffs. This process culminated in 2008 with the elimination of both restrictions on trade with the U.S. and Canada. The introduction of NAFTA precipitated a large decline in the price of maize in Mexico: between 1993 and 1994, it dropped by 20%, the largest one-year decline in our sample period. With the exception of a spike in 1995-1996, prices continuously declined throughout the 1990s. The price jump in 1995-1996, which also appears in the international price, has been attributed to the restriction of Chinese exports and adverse drought conditions in the United States that impacted the maize crop (Stevens 2000). Another weather-related price jump occurred in 2002-2003 in response to another drought episode in the United States. Finally, prices increased sharply in 2005 in what has become known as the International Food Crisis. This has been attributed to a variety of causes, including rising global demand for food and biofuels, as well as weather shocks in important producing countries (Trostle 2008).

3 Data

In addition to the SEDENA data on eradication, we also obtain SEDENA data on drug seizures for the 1990-2010 period. Categories include raw and processed marijuana; opium gum and heroin; as well as cocaine and crystal meth. Data on drug-related killings come from the Mexican National Security Council, and are available for the 2007-2010 period. Executions are killings attributed to criminal organizations, which are classified as drug-related in consideration of tell-tale signs of drug cartel homicides, such as the use of beheadings and incinerations, or explicit messages left at the crime scene. Drug-related confrontations measure deaths stemming from fights among cartels, or between cartels and the army. Cartel attacks refer to deaths stemming from attacks by drug cartels on state security forces. These three variables are aggregated into total drug-related killings. Figure 3 maps this variable in per capita terms. Clearly there is a concentration of this type of violence around the border region and areas with drug crops in the northern part of the country.

To account for enforcement, we use data from the Mexican Attorney General's Office (PGR, by its Spanish acronym), to generate a measure of distance to the nearest state security station, defined as either a federal police headquarter, military garrison, or air-force base in 2000. Municipal-level electoral data from the Center of Research for Development (CIDAC) provides the political affiliation of the mayor, specifically whether he or she is from the left-leaning PRI, conservative PAN or other political party. We also control for distance to the nearest point on the U.S.-Mexico border, and whether the municipio has a major highway, both of which are likely to affect the extent of trade in the municipio. Data on rainfall and temperature at the municipio-month level originate from the University of Delaware's Center for Climatic Research. In addition, we utilize a soil quality variable from the Workability dataset of the Food and Agricultural Organization (FAO) of the United Nations. This variable measures land workability constraints that hinder agricultural cultivation. We also develop a measure of municipal ruggedness. The ruggedness in a grid point inside of a municipio is defined as the average difference in elevation between the point and its neighbors, and we take the average across all points in a municipio.

We utilize data from the 1990 Mexican Census to obtain start-of-sample characteristics for our municipios of interest. These include the fraction of males employed in agriculture as a proxy for rurality, and the average agricultural income in each municipio in 1990. To explore the relationship between the maize price and economic outcomes for rural workers, we construct a sample that pools observations from the various waves of the Encuesta Nacional de Ingresos y Gastos en los Hogares (ENIGH). The ENIGH is a nationally representative survey of Mexican households which focuses on gathering detailed information about household income and expenditures. We combine the 10 biennial waves from 1992 to 2010 with a 2005 wave.

For all outcomes, we restrict our samples to municipios that can be classified as rural. This is important for two reasons. First, we are primarily interested in the impact of maize prices on drug crop cultivation among agricultural producers. This is an inherently rural phenomenon. Furthermore, the relationship between maize prices and illicit activities may be fundamentally different in urban areas where individuals are the consumers of maize rather than producers. Second, inclusion of urban municipios may lead us to over-estimate the impact on homicides, since dense urban areas with little maize cultivation witnessed a dramatic increase in violence in the late 2000s.

To exclude largely urban municipios, we use data from the 1990 Census to calculate the fraction of individuals in each municipio who live in very large urban localities with populations of 100,000 or more. We include in our sample those municipios where no individuals in the 1990 Census lived in such large urban areas. Applying this criterion eliminates 104 municipios, leaving us with a final sample of 2,299 municipios.[3]

4 Empirical Strategy

Although one could simply regress a drug outcome in a particular municipio-year against the national price of maize, such an empirical strategy is problematic for three reasons. First, this would estimate the impact of price using only national-level time-series variation, making it difficult to separately identify the effect of price from an ongoing trend. Second, this would ignore an important source of variation in the sensitivity of drug trade activity to the price of maize. The impact of price fluctuations on total drug crop cultivation in a particular municipio should depend on the extent to which individuals there depend on maize cultivation. Our empirical strategy therefore employs a difference-in-differences approach: we examine whether changes in the maize price lead to differential effects on illicit activity in the municipios more suited to cultivating maize.

The FAO provides municipio-level measures of agro-climatically attainable yields for maize under different assumptions about available inputs. These indices are based on exogenous factors such as location-specific geography, rainfall, and temperature over the period 1961-1990. Our measure of maize suitability is the average of these FAO indices across different input levels. This FAO suitability measure is preferable to direct measures of maize production or cultivation, which may endogenously respond to both eradication and contemporaneous maize prices. This concern is exacerbated in the Mexican context since complete municipio-level data on land devoted to maize cultivation and production are only available after 2003. As Figure 4 demonstrates, all states and regions in Mexico contain substantial variation in

[3] Our panel also does not include 51 municipios that were newly created over the sample period.

maize suitability, ensuring that the effects of maize price fluctuations are not driven by any one particular geographic area.

A third problem with directly examining the impact of the Mexican maize price is that the domestic price may be endogenous to the outcomes of interest. For instance, greater drug crop cultivation may reduce maize cultivation and boost the maize price via a supply effect. This form of reverse causality would generate an upward bias (toward zero) on the estimated relationship between maize prices and drug eradication. To circumvent endogeneity concerns, we use an instrumental variables strategy that exploits changes in the maize price induced by the production behavior of major global maize players — the U.S., Argentina, France and China, which are the four largest maize exporters over this period.

We directly utilize the export volume of the three non-U.S. producers as instruments for the national maize price in Mexico. Mexico does not import any maize from these nations, and their exports are unlikely to respond to economic production fundamentals in Mexico given this market segmentation. Figure 5 shows the international maize price, Mexican maize price, and the export volumes of the three countries. All three export series are negatively correlated with the price series, and as suggested by the figure, the negative correlation coefficient is largest for China. Chinese export policy, in particular, appears to be heavily influenced by idiosyncratic political factors. The U.S. Department of Agriculture claims that Chinese policy is a substantial driver of the international market, noting that "China has been a significant source of uncertainty in world corn trade." Moreover, Chinese policy seems to be driven by political considerations that are exogenous with respect to production fundamentals and any economic development in Mexico:

> China's corn exports are largely a function of government export subsidies and tax rebates, because corn prices in China are mostly higher than those in the world market. Large corn stocks are expensive for the government to maintain, and Chinese corn export policy has fluctuated with little relationship to the country's production, making China's corn trade difficult to predict. (USDA 2013b)

This further underscores the idea that Chinese export behavior is unlikely to respond to Mexican agricultural production, bolstering the validity of these instruments.

In contrast to the other major exporters, 99.5 percent of Mexican maize imports come from the United States.[4] This partly reflects the reduction of import tariffs and expansion of import quotas for maize under the NAFTA trade agreement. The extent of maize trade between the two countries, as well as their geographic proximity and political ties creates stronger concerns that U.S. exports could reflect crop production patterns in Mexico. For example, greater drug

[4] This calculation is based on data from the United Nations COMTRADE database, covering the 1990-2010 period.

crop production in maize areas could affect maize production in Mexico, which in turn could influence U.S. production decisions.

Therefore, we exploit weather conditions in the major maize producing states in the U.S., which serve as an exogenous factor in U.S. crop production. We focus on the five largest U.S. maize producing states (Iowa, Illinois, Nebraska, Minnesota, Indiana). We use global gridded data from University of Delaware's Center for Climatic Research to create a state-level measure of average rainfall (millimeters) and temperature (C) for each month in our sample period. For each year, we track average rainfall in these states over June and July, since these are critical months of the maize planting season, when drought can severely damage the crops (Tannura et al 2008). In addition, we also track temperature during April and May, since frosts early in the planting season prove particularly harmful . We generate deviations of both weather variables relative to the mean over our sample period, and utilize their lag, as harvests take place at the end of the calendar year, over October and November. Figure 5 also shows the negative relationship between lagged U.S. weather conditions and the international and Mexican maize price.

We utilize these weather conditions and the export levels of the other major producers as instruments for the Mexican maize price. Let Y_{it} refer to the value of dependent variable Y in municipio i during year t. Our basic second-stage specification is given by:

$$Y_{it} = \alpha_{2i} + \tau_{2t} + (\widehat{MAIZE_i \times PRICE_t})\delta + \mathbf{X}'_{it}\phi + \varepsilon_{it} \tag{1}$$

Here the α_{2i} are second-stage municipio fixed effects that control for time-invariant characteristics of Mexican municipios; τ_{2t} are second-stage year fixed effects that account for common shocks in a given year; $MAIZE_i$ is the average agro-climatically attainable yield for maize per hectare in municipio i; $PRICE_t$ is the natural log of the national maize price in year t; and the coefficient δ is our main parameter of interest measuring the differential effect of maize prices on the outcome in municipios with higher maize suitability.[5] $\mathbf{X}_{it}$ is a vector of additional controls which varies across specifications, and we detail our full control set below.

The first stage equation explaining $MAIZE_i \times PRICE_t$ is given by:

$$\begin{aligned} MAIZE_i \times PRICE_t \;=\; & \alpha_{1i} + \tau_{1t} + (MAIZE_i \times US\_TEMP_t)\beta + (MAIZE_i \times US\_RAIN_t)\gamma \\ & +(MAIZE_i \times CHN_t)\psi + (MAIZE_t \times ARG_t)\sigma + (MAIZE_i \times FRA_t)\,\theta \\ & +\mathbf{X}'_{it}\rho + \omega_{it} \end{aligned} \tag{2}$$

Here α_{1i} and τ_{1t} represent first-stage municipio and year fixed effects, respectively. US_TEMP_t

[5]Note that the base terms of the interaction do not appear separately in equation (1) since $PRICE_t$ is absorbed by year fixed effects while $MAIZE_i$ is absorbed by municipio fixed effects.

denotes the temperature deviation in April and May in major U.S. maize states in year t. US_RAIN_t denotes the annual rainfall deviation in these states over June and July. CHN_t, ARG_t and FRA_t represent the log of Chinese, Argentine and French maize exports in year t. Certain dependent variables are scaled by either the area or population of each municipio. Since $MAIZE_i$ is the attainable yield per hectare, we also scale the marijuana and poppy eradication outcomes by total municipal area, measuring these outcomes per 10,000 hectares. Killings are measured as a rate per 10,000 population. We take the log of all dependent variables after adding a one. This ensures that municipio-year observations with zero eradication or homicide levels are included in our specifications. Unless otherwise noted, all parameters are estimated via 2SLS, and our standard errors are clustered at the municipio level.

Since our empirical strategy utilizes the interaction of municipal maize suitability with annual prices and the time-varying instruments, this raises the concern that the first stage will appear to display a strong relationship owing solely to the inclusion of the suitability variable on both sides of Equation (2). However, Table 2 presents simple time series regressions which show that the lagged U.S. weather variables, alongside the export volumes of China, France and Argentina are important determinants of the Mexican maize price. Column 1 includes no controls and the R-sqr indicates that these variables alone explain up to 75 percent of the variation in the price series. Columns (2) and (3) introduce controls for the U.S-Mexico real exchange rate and a linear time trend. The instruments are jointly significant at the 1 percent level (with a F test-statistic of 14.90). This underscores the strength of the time series relationships underlying our empirical strategy.

Our preferred specifications include a gamut of weather, enforcement and economic controls to address potential confounds. If places suited to growing maize generally have higher land quality, this raises the possibility that increases in drug production estimated with our empirical strategy may reflect trends based on land quality differences, rather than the effect of maize *per se*. We therefore control flexibly for the effect of soil quality by introducing interactions of year effects with our land workability measure. We also control for time-varying rainfall and temperature conditions in Mexican municipios over June and July, as well as temperature conditions during the early maize planting period in April and May.

Another concern is that measured eradication efforts reflect both drug crop cultivation and policy decisions around state enforcement. Since the degree of enforcement within a municipio will vary based on proximity to police stations and other state security facilities, we include controls for linear time trends interacted with (log) distance to the nearest security station. We also control for trends by distance to the U.S. border. This helps account for confounds related to the fact that the drug trade burgeoned in the less maize suitable maize areas along the border in the post-2005 period (see Figure 4), precisely when maize prices started rising. This border variable, along with trends based on the presence of a major highway also account for potential differences in the evolution of our outcomes based on the degree of market integration. This is important since NAFTA's implementation in 1994 may have facilitated trade in illegal as well as legal goods (Andreas 1996).

In addition, drug-related violence has increased disproportionately in urban areas over this period, where little maize is cultivated. Although our core sample already eliminates 104 large urban areas, we further account for this effect with trends interacted with our rurality measure. Analogously, since agricultural workers residing in maize areas are relatively poor, we control for trends based on average agricultural income in the beginning of our sample period. We refer to this collection of controls as our full control set in the remainder of the paper. Tables 3A and 3B present the descriptive statistics of the key variables in our analysis.

5 Results

5.1 Effects on Income

Our first set of results investigates the impact of maize price fluctuations on the incomes and occupations of workers in rural areas. For this analysis, we use a sample of rural workers from several waves of the ENIGH spanning 1992-2010. We estimate the individual-level equivalent of Equation (1) with the log of total income (sum of labor income and business income) as our dependent variable. In addition to the full municipal-level control set, we also include several individual-specific controls. These include controls for age, education, survey month, an indicator for those identified as maize or bean workers, and indicators for the class of worker (wage worker, self-employed, etc.).

Our main income sample consists of men between the ages of 18 and 65 who reported working in agriculture full-time (20 or more hours per week) and earned positive income during the previous month. We examine impacts on all agricultural workers, not only those identified as maize workers in the ENIGH. We do this for at least two reasons. First, many households grow a variety of crops, making it difficult to identify them with any one particular output. Indeed, in the 1990 Census, over 40 percent of agricultural workers were not classified as cultivating any one particular crop. Ethnographic studies suggest that even those farmers associated with non-maize crops devote a non-trivial fraction of their land to maize cultivation (Eakin 2006, pp. 54-82). As such, only considering individuals identified as maize workers will understate the fraction of farmers whose income stream is sensitive to changes in maize prices. Second, households may endogenously change the mix of crops they plant (and thus their occupational designation) in response to changing crop prices. To avoid bias stemming from compositional changes, the effect of the maize price should be estimated with data for all agricultural households.

Columns (1)-(2) of Table 4 indicate that the elasticity of income with respect to the maize price is significantly higher in those municipios that are more suited to growing maize. The OLS and the IV estimates are quite consistent (0.105 and 0.108, respectively). To interpret the magnitude of these coefficients, consider two workers: one from a municipio at the 10th percentile of the maize suitability distribution ($MAIZE$=4.48) and one from a municipio at the 90th percentile ($MAIZE$=8.63). The estimated coefficient of 0.108 from the IV specification suggests the income elasticity with respect to the maize price is higher by 0.45 in the more maize suitable municipio. These estimates suggest that as the maize price declined by 59 percent between 1990 and 2005, average incomes of agricultural workers in the more maize suitable municipio fell by an additional 26 percentage points.

Columns (3)-(4) of Table 4 present results on occupational change. Specifically, we examine whether a fall in maize prices causes workers to shift into non-agricultural employment. Our dependent variable is now an indicator for non-agricultural employment, and our sample now includes workers of all occupations. The regression specification is identical to that used in Columns (1)-(2), except we exclude the dummies for maize and bean worker and the class of worker. Although the coefficient is imprecisely estimated in the OLS specification, the point estimate of 0.038 in the IV specification is significant at the 10 percent level. Again consider workers from communities at the 10th and 90th percentiles of maize suitability. The estimated coefficient of 0.038 suggests that in response to a 59 percent decline in the maize price, the share of non-agricultural workers would rise by 9 more percentage points in the highly suitable municipio. To put this in perspective, about 33% of workers were involved in non-agricultural occupations in our sample in 1992. Both the income and occupation effects demonstrate that workers in more maize suitable areas were differentially impacted by changes in maize prices.

5.2 Effects on Drug Trade Outcomes

In this section, we examine the relationship between eradication and exposure to maize price changes. The first four columns in Table 5 present a motivational specification that examines the impact of the annual maize price, without exploiting the cross-sectional variation in maize suitability. Since the national price varies annually, we are not able to include year fixed effects but instead, control for a year trend, along with the real exchange rate. In columns (3)-(4) we instrument the national price with the export volume of China, France and Argentina along with planting season temperature and rainfall deviations in the United States. All four columns indicate a negative relationship between the maize price and both drug crop outcomes: when the prize falls, there is greater eradication of marijuana and heroin poppies.

Our main estimation strategy moves beyond these suggestive time-series relationships and tests for differential impacts of the price change across municipios of varying maize suitability.

We begin by presenting visual evidence. Figure 6 graphs the national maize price alongside the difference in log eradication and seizure outcomes between municipios with above and below mean maize suitability. For all four outcomes, the difference increased as the maize fell sharply over 1990-2005. Moreover, it fell after 2005 when the maize price started rising, and generally remained low as price continued increasing. The exception to this pattern can be seen for opium seizures in 2009-2010, owing to increased seizures of this drug in border areas, which have low maize suitability. This figure is merely suggestive as it is devoid of any controls, and divides the suitability measure discretely around the mean cutoff. Nonetheless, the patterns strongly suggest that increases (decreases) in the maize price correspond to differential decreases (increases) in drug-related outcomes among more maize dependent municipios.[6]

The second half of Table 5 builds on this visual evidence, by examining the interactive effect of the maize price and the continuous index of municipal maize suitability. Columns (5)-(6) present the OLS estimates while (7)-(8) present the IV estimates, corresponding to equation (1). The significant, negative coefficients across all eight specifications indicate that a rise in the maize price leads to a differential fall in drug crop cultivation among municipios with higher maize suitability. The IV coefficients are somewhat larger in magnitude, which is consistent with reverse causality stemming from supply effects biasing the least squares estimates toward zero.

The first stage is strong, as indicated by a large rk Wald F statistic ($2.2x10^9$), which exceeds the relevant Stock Yogo critical value. Since both sides of the first-stage equation are products of time-invariant maize suitability and the time-series variables (maize price, U.S. weather conditions, and exports of other major maize producers), this raises the possibility that the strength of the first stage is driven solely by the cross-sectional suitability. However, as discussed above in the Empirical strategy section, the time-series instruments stand on their own as strong predictors of the Mexican maize price (see Table 2).

In Table 6, we consider a number of alternative specifications to rule out potential confounds that may bias these estimated effects. Columns (1)-(2) include the full control set of weather, economic, and enforcement controls enumerated in the Empirical Strategy section, including those related to land quality, border proximity and distance to the nearest police station. Columns (3)-(4) also control for the political party of the mayor holding office in each municipio.[7] This provides an additional accounting of enforcement policy effects, which are likely to be shaped by the political leanings of the local authorities. For example, mayors from the conservative PAN party increased enforcement against drug cartels in the post-2000 period, and these changes have influenced drug trafficking patterns and associated violence

[6]The difference in opium seizures is relatively low over this period since the level of opium seizures was low nation-wide at this time.

[7]Note that since party of the president varies only at the annual level, the impact of particular presidential administrations is captured by the year effects.

(Dell, 2011). The inclusion of this control reduces the sample size substantially in light of missingness in the electoral data, but does not affect the magnitude or significance of our estimates. Finally, columns (5)-(6) drop the 31 sample municipios that lie along the U.S.-Mexico border. Our results are also robust to this restriction, to further ensure that border effects do not drive the estimated effects. Reassuringly, the coefficients display marked stability across various specifications.

We consider the baseline in columns (1)-(2), which includes the full control set in the complete sample, to be our primary specification. The coefficients of -.03 and -.02 for marijuana and poppy eradication imply economically meaningful effects. For marijuana, moving from the 10th to the 90th percentile of the maize suitability distribution implies that a 59 percent price fall would induce 8 percent more eradication. The equivalent calculation for poppy implies 6 percent more eradication.

If maize price changes induce greater drug crop cultivation in maize suitable municipios, to what extent does this cultivation also stimulate additional illicit activities along the narco-trafficking chain? To examine this question, we utilize data on drug seizures, which separately measure seizures of manufactured and raw drug products. In particular, the data distinguish between heroin and opium gum, a primary product used to manufacture heroin. Analogously, processed marijuana seizures are distinguished from raw marijuana seizures.

Table 7 presents the impact on drug seizures. Panel A is the baseline specification with our full control set, Panel B tests robustness to the political affiliation of the mayor, while Panel C excludes the border municipios. The latter restriction is particularly important given the rise of drug seizures along the U.S.-Mexico border during the 2000s. Across all three panels, we find significant negative impacts on seizures of raw marijuana, but no equivalent impacts on processed marijuana. The effect on raw marijuana seizures given by the coefficient in Panel A-Column (1) is substantial: a 59 percent maize price fall implies 16.4 percent more seizures in municipios at the 90th versus 10th percentile of maize suitability.

We also observe significant negative effects on opium gum seizures, without corresponding impacts on processed heroin seizures. Since Figure 6 reveals a large spike in differential opium gum seizures in 2009 and 2010, we verify that the results continue to hold when we exclude these two years, without a meaningful change in estimated effects.[8] However, these effects are relatively small. The coefficient in Panel A-column (3) implies that a 59 percent maize price fall would result in 1.2 percent more opium seizures in municipios at the 90th versus those at the10th percentile of maize suitability.

The larger estimates for raw versus processed components are consistent with our expectation that the maize price affects the output decisions of farmers, but does not necessarily affect cartel incentives to process drugs in particular areas. These results are consistent with home-

[8] These estimates are available upon request.

grown drug crops being produced in rural locations, even if processing takes place elsewhere. We also observe small, but significant impacts on the seizure of cocaine (largely imported from Colombia), suggesting spillovers into other types of drug trafficking. The coefficient in Panel A-column (5) implies that there are 2.7 percent more cocaine seizures in municipios at the 90th vs. 10th percentile owing to the 59 percent price fall.

Given the documented rise in drug production, we next gauge impacts on drug-war related violence. Specifically, our dependent variables are deaths arising from different types of cartel violence. Total drug-related killings are composed of executions (85%), deaths from cartel confrontations with each other and the army (13%), as well as deaths related to cartel attacks on state security forces (2%). Since these data are only available for 2007-2010, we are not able to utilize all of our time-varying instruments in the short time series. We instead pare down our instrument set to the U.S. rainfall deviations interacted with maize suitability. [9] Table 8 presents these results. We find significant increases in total killings, with the largest effects on executions. Notably, these estimates remain significant after border municipios are eliminated from the sample, which is an important check, given large spikes in homicides in border cities during the post-2005 period.

Columns (1) and (2) imply substantial effects, even by the most conservative estimates in Panel C. The coefficients suggest that the 8 percent increase in the maize price over 2007-2008 led to 11.4 percent fewer total drug war killings and 10.1 percent fewer executions, among municipios at the 90th versus 10th percentile of the maize suitability distribution. The coefficients in columns (3)-(4) imply equivalent effects of 2.9 and 1.4 percent fewer deaths from confrontations and cartel attacks, respectively.

Across specifications for various drug outcomes, we have interpreted the estimated coefficient on $MAIZE_i \times PRICE_t$ as stemming from greater income changes experience by farmers in more maize suitable areas. This is consistent with the income effects found in Table 4. However, if maize suitability is highly correlated with marijuana and opium poppy suitability, then these differential effects could instead reflect the ease with which drug crops are grown in maize suitable areas. This suggests the import of controlling for drug crop suitability to bolster the income-based interpretation of the differential effects.[10] Additionally, estimated effects may be larger in areas that are suited to cultivating these drug crops. There are no pre-existing measures of either marijuana or opium poppy suitability analogous to the FAO maize measure. However, we initially proxy for drug crop suitability by simply taking the average marijuana and poppy eradication in each municipio over the first three years of our sample period (1990-1993) which precede the sharp fall in the maize price in 1994. The first two columns

[9] Using the alternate IV strategy of summing the export volumes of China, France and Argentina also gives us similar results.

[10] Note that our basic control set already includes land workability effects, accounting for the potential correlation of maize suitability to general land quality.

of Table 9 present the results that include interactions of the suitability measures with year effects. These variables control not only for potential differences in drug suitability but also other potential characteristics of drug producing municipios that are correlated with the extent of eradication in these areas. The results presented in columns (1)-(2) are very similar to those in columns (1)-(2) of Table 6. Columns (3)-(8) examine the drug seizures outcomes taking the equivalent approach of controlling for drug suitability by including the dependent variable of the relevant drug seizure over 1990-1993 and interacting it with year effects. These results also remain similar to those presented in Table 6. Panel B of Table 9 repeats the same exercise for the drug war outcomes. Here we control for both the marijuana and poppy eradication over 1990-1993 interacted with year effects, since the suitability of both crops may be relevant for these outcomes.

5.3 Heterogeneous Effects

The relationship between the maize price and drug cultivation in a municipio should depend on the ease with which farmers can respond to an income shock by growing illicit drugs. We expect the effect of price change on marijuana or opium poppy cultivation to be larger in those areas that are better suited to growing these crops. To test this hypothesis, we build on the simple measure used in the previous section: we construct municipio-level measures of marijuana and poppy suitability and estimate our main specifications separately for municipios above and below the median suitability for these crops. Different factors are important in determining these suitabilities. To generate a crop-specific measure, we run cross-sectional regressions explaining the average 1990-1993 cultivation as a function of plausibly exogenous agro-climatic factors. For marijuana, we regress average cultivation on a second-order polynomial in the average annual rainfall and average annual temperature of a municipio over our sample period.[11] For poppy, which grows best at higher elevations — especially 1000 meters above sea level (Humphrey 2003) — we regress average cultivation on a second-order polynomial in the median slope and median elevation of the municipio. We use the parameter estimates from these cross-sectional regressions to predict 1990-1993 eradication for each crop, and we take these predicted values as our measures of marijuana and poppy suitability.

Panel A of Table 10 presents estimation results for our eradication and seizure outcomes when we split the sample into groups with above and below median poppy suitability. In line with expectations, we consistently estimate larger effects across all of our outcomes in those municipios with above median poppy suitability. For poppy eradication, we estimate a differential maize price effect of -0.038 in the municipios with above median poppy suitability, compared

[11] That is, if RN_{it} represents mean rainfall and TMP_{it} represents mean temperature, we regress cultivation on : RN_{it}, TMP_{it}, $RN_{it} \times TMP_{it}$, RN_{it}^2, TMP_{it}^2, $RN_{it}^2 \times TMP_{it}$, $RN_{it} \times TMP_{it}^2$, and $RN_{it}^2 \times TMP_{it}^2$.

to an estimated differential effect of -0.009 in the below median group. Similarly, we estimate a differential effect of -0.010 on opium gum seizures in the poppy-suitable municipios, while we find essentially no effect in the less suitable sub-sample. The magnitude of the estimated effect on poppy eradication in the poppy-suitable municipios is substantial. The estimates in column (4) suggests that a 59% decline in the maize price would result in a 9 percentage point larger increase in poppy eradication and a 2 percentage point larger increase in opium gum seizures in a municipio at the 90th percentile of maize suitability versus one at the 10th percentile.

Panel A of Table 10 presents estimation results when the sample is split on the basis of the marijuana suitability index. Across outcomes, we again consistently find differential price effects in those municipios with above median marijuana suitability. Indeed, we do not find any statistically significant effects in municipios below the median. The estimated differential effects for marijuana eradication (-0.061) and raw marijuana seizures (-0.098) are particularly large. The coefficients in columns (2) and (6) suggest that a 59% decline in the maize price would yield a 15 percentage point larger increase in marijuana eradication and a 24 percentage point larger increase in raw marijuana seizures in the 90th percentile municipio versus the 10th percentile municipio.

Table 10 also reveals that there are important cross-crop suitability effects. There are larger differential price effects on both marijuana and poppy outcomes in municipios with above median poppy suitability, and above median marijuana suitability. These cross-crop effects are consistent with the important role that mountainous areas play in drug crop production (Humphrey 2003). High elevation is required for poppy cultivation. In turn, mountainous areas may be well suited to the production of marijuana both because of the existing drug-trade infrastructure and because the rugged terrain helps farmers conceal illegal activity. Indeed, Panel C of Table 10 indicates that when we split the sample based on our ruggedness measure, we find substantially higher differential price effects in the more rugged areas.[12]

6 Conclusion

We examine how maize price dynamics have affected the drug trade in Mexico, over 1990 to 2010. Using municipal-level data, we demonstrate that maize price changes induce differential drug market outcomes for municipios with varying levels of maize suitability. We instrument the Mexican maize price with maize exports of China, France and Argentina, and weather conditions in maize producing regions of the United States. Our results are robust to a number of controls and restrictions that address concerns regarding targeting of enforcement and differential trends

[12] Ruggedness in a particular geographic point inside of a municipio is defined as the average difference in elevation between a grid point and its neighbors. The ruggedness measure is the average ruggedness for all points in a municipio.

in drug-trafficking along the border or in rural areas.

Our estimated effects span the entire narco-trafficking chain, starting with increases in illicit drug crops and ending with cartel violence. The sizable effects on drug-related killings underscore the potential for large social costs stemming from these price changes. Does the rise of the drug sector represent a temporary adjustment to price fluctuations or a permanent change in economic structure? Future work should explore these questions.

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Table 1: Characteristics of Rural Workers (1990 Census)

	All Workers		*Agricultural Workers*		*Maize Workers*	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age	35.22	12.56	36.93	13.44	37.15	13.4
Educ	5.13	4.16	3.41	3.12	2.94	2.85
Full Time	0.91	0.29	0.91	0.29	0.93	0.26
Agr. Worker	0.48	0.5	-	-	-	-
Maize Worker	0.14	0.35	0.29	0.45	-	-
Class of Worker:						
Own Account	0.35	0.48	0.48	0.5	0.62	0.49
Unpaid	0.04	0.2	0.07	0.26	0.1	0.29
Employer	0.02	0.13	0.01	0.1	<0.01	0.06
Paid Employee	0.56	0.5	0.38	0.49	0.23	0.42
Zero Income	0.14	0.35	0.27	0.44	0.37	0.48
Monthly Inc. (if >0)	4,517.66	21,115.26	3,153.839	19,855.35	2,519.218	20,230.78
Total Observations	748,486		361,511		105,643	

Notes. Full Time indicates an individual working at least 20 hours per week. For each subsample, we list total observations, which is the largest number of observations in the subsample used to calculate a particular sample mean. However, for some variables, we use fewer observations because of missing data. For All Workers, we have 748,486 total observations, but fewer for education (735,441) and monthly income conditional on positive income (716,819). Similarly, for Agricultural Workers, we have 361,511 total workers but fewer for education (357,371) and monthly income (343,317). For Maize Workers, we have 105,643 total observations, but fewer for education (104,812) and monthly income (100,890).

Table 2: Maize Price, U.S. Weather, and Exports

VARIABLES	(1) Log national maize price	(2) Log national maize price	(3) Log national maize price
CHN	-0.028	-0.046	-0.108***
	(0.019)	(0.027)	(0.028)
FRA	-0.352**	-0.340*	-0.494***
	(0.163)	(0.186)	(0.163)
ARG	-0.495***	-0.542***	-0.193
	(0.078)	(0.092)	(0.126)
US_RAIN	-0.073**	-0.089**	-0.068**
	(0.033)	(0.037)	(0.029)
US_TEMP	-0.033	-0.051	-0.049*
	(0.036)	(0.035)	(0.026)
Year trend?		Y	Y
Real exchange rate?			Y
F-statistic for instruments	21.3	16.1	14.9
Observations	21	21	21
R-squared	0.753	0.766	0.870

Notes. CHN, ARG, and FRA represent the log of Chinese, Argentine and French maize exports. US_TEMP denotes the temperature deviation in April and May in major U.S. maize states, and US_RAIN denotes the rainfall deviation in these states over June and July. The real exchange rate refers to the U.S.-Mexico exchange rate. *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

Table 3A: Descriptive Statistics of Municipal and Annual Variables

	Observations	Mean	Standard Deviation
Panel-level municipal variables			
Log marijuana eradication	46,872	0.132	0.470
Log poppy eradication	46,872	0.070	0.392
Log raw marijuana seizures	46,872	0.175	0.919
Log processed marijuana seizures	46,872	0.258	1.231
Log opium gum seizures	46,872	0.007	0.129
Log heroin seizures	46,872	0.002	0.067
Log cocaine seizures	46,872	0.025	0.328
Log meth seizures	46,872	0.006	0.157
Log total drug-related killings	8,928	0.225	0.551
Log drug-related executions	8,928	0.200	0.505
Log killings from confrontations	8,928	0.038	0.244
Log killings from cartel attacks	8,928	0.007	0.089
Log population	46,872	9.266	1.279
Temperature April-May	46,872	22.436	4.148
Temperature June-July	46,872	22.652	4.542
Rainfall June-July	46,872	175.267	111.946
PAN mayor	40,731	0.133	0.339
PRD mayor	40,731	0.118	0.323
Other mayor	40,731	0.035	0.184
Cross-sectional municipal variables			
Maize suitability (Kg DW/ha)	2,232	6.632	1.601
Log distance to security station	2,232	3.082	0.798
Log distance to U.S. border	2,232	6.024	0.644
Highway indicator	2,232	0.559	0.497
Border indicator	2,232	0.014	0.117
Ruggedness	2,232	173.971	136.436
Predicted poppy suitability	2,232	0.068	0.043
Predicted marijuana suitability	2,232	0.160	0.069
Soil workability	2,232	2.254	1.003
Average agricultural income (1990)	2,232	12.058	0.721
Fraction of agricultural workers	2,232	0.670	0.335
Annual-level variables			
Log national maize price (2010 pesos)	21	1.077	0.277
Log Chinese maize exports (tons)	21	14.800	1.726
Log French maize exports (tons)	21	15.742	0.158
Log Argentine maize exports (tons)	21	15.972	0.494
Lag. U.S. rainfall	21	-0.049	0.998
Lag. U.S. temperature	21	-0.064	0.978
Log exchange rate	21	2.437	0.106

Notes. Log marijuana and poppy eradication are measured as log of area eradicated per 10,000 hectares plus 1. Log raw marijuana, processed marijuana, opium gum, heroin, cocaine, and meth seizures are measured as log of kilograms seized. Log total drug-related killings, drug-related executions, killings from confrontations, and killings from cartel attacks, are measured as log of killings (or executions) per 10,000 people. PAN mayor, PRD mayor, and Other mayor, are indicators for PAN, PRD, and mayors from other political parties in office. Maize suitability measures the average attainable yield for maize (in Kg DW/ha). Log distance to security station is measured as the log of distance (in miles) to the nearest federal police headquarters, military garrison or air-force base. The log distance to the U.S. is measured as the log distance (in miles) to the nearest point on the U.S.-Mexico border. Highway is an indicator equal to one if a municipio has a major road. Border is an indicator for the municipios located along the U.S-Mexico border. Ruggedness is a municipal measure of rough terrain. The log of national maize price is measured as the log of the real price in 2010 Mexican pesos. Log Chinese, French, and Argentine maize exports are measured as the log of tons exported. Lag U.S. temperature denotes the lagged annual temperature deviation in April and May in major U.S. maize states, and Lag U.S. rainfall denotes the lagged rainfall deviation in these states over June and July. Log exchange rate refers to the U.S. Mexico real exchange rate.

Table 3B: Descriptive Statistics of Individual-level Variables

	Observations	Mean	Standard Deviation
Sample: Agricultural workers			
Age	24,529,284	40.293	13.259
Education	24,529,103	3.948	3.196
Agr. Worker	24,529,284	1.000	0.000
Maize Worker	24,529,284	0.395	0.489
Total Income (2005 Pesos)	24,529,284	1886.324	3797.046
Sample: All workers			
Age	50,876,264	37.410	13.201
Education	50,861,624	5.257	3.788
Agr. Worker	50,876,264	0.580	0.494
Maize Worker	50,876,264	0.246	0.431

Notes. Data come from the ENIGH.

Table 4: Maize Price, Maize Suitability and Income

VARIABLES	(1) Log Income	(2) Log Income	(3) Ag. Worker	(4) Ag. Worker
MAIZE x PRICE	0.105**	0.108**	0.019	0.038*
	-0.042	-0.049	-0.017	-0.022
Observations	21,270	21,247	45,103	45,102

Notes. Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown included in all columns are: municipio fixed effects, year effects, temperature and rainfall conditions in Mexican municipios, land quality interacted with year effects, trends by several variables (average agricultural income in 1990, the fraction of agricultural workers, major highway presence, distance to the U.S. border, distance to the nearest security station), survey month, age, and education. In addition, columns (1)-(2) include controls for whether or not the individual is a maize or bean worker, and indicators for the class of worker. *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

Table 5: Maize Price, Maize Suitability, and Illicit Crops

VARIABLES	(1) Log marijuana eradication	(2) Log poppy eradication	(3) Log marijuana eradication	(4) Log poppy eradication	(5) Log marijuana eradication	(6) Log poppy eradication	(7) Log marijuana eradication	(8) Log poppy eradication
PRICE	-0.135***	-0.052***	-0.170***	-0.070***				
	(0.012)	(0.008)	(0.013)	(0.009)				
MAIZE x PRICE					-0.017***	-0.012***	-0.028***	-0.022***
					(0.005)	(0.004)	(0.005)	(0.004)
Observations	48,279	48,279	48,279	48,279	48,279	48,279	48,279	48,279
Municipios	2,299	2,299	2,299	2,299	2,299	2,299	2,299	2,299
Estimation method	OLS	OLS	IV-2SLS	IV-2SLS	OLS	OLS	IV-2SLS	IV-2SLS

Notes. Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown include municipio fixed effects and log population in all columns. Log marijuana and poppy eradication are measured as log of area eradicated per 10,000 hectares plus 1. Columns (1)-(4) control for a linear time trend and the log U.S. Mexico real exchange rate. In columns (3)-(4) the log national maize price is instrumented with lagged rainfall and temperature deviations in the major maize producing U.S. states and the log export volume of China, France and Argentina. Columns (5)-(8) control for year fixed effects and the interaction of maize suitability with the (log) U.S. Mexico real exchange rate. In columns (7) and (8), the interaction of maize suitability and the log national maize price is instrumented with the interaction of maize suitability and the lagged rainfall and temperature deviations in the major maize producing U.S. states and the log export volume of China, France and Argentina. *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

Table 6: Additional Controls and Sample Restrictions

VARIABLES	(1) Log marijuana eradication	(2) Log poppy eradication	(3) Log marijuana eradication	(4) Log poppy eradication	(5) Log marijuana eradication	(6) Log poppy eradication
	Baseline sample		*Controlling for mayor's party*		*Eliminating border municipios*	
MAIZE x PRICE	-0.033***	-0.023***	-0.038***	-0.024***	-0.033***	-0.022***
	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)
Weather, economic and enforcement controls?	Y	Y	Y	Y	Y	Y
Observations	46,872	46,872	40,731	40,731	46,221	46,221
Municipios	2,232	2,232	2,228	2,228	2,201	2,201

Notes. Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown include municipio fixed effects, log population, and the interaction of maize suitability with the (log) U.S. Mexico real exchange rate in all columns. Log marijuana and poppy eradication are measured as log of area eradicated per 10,000 hectares plus 1.Tthe interaction of maize suitability and the log national maize price is instrumented with the interaction of maize suitability and the lagged rainfall and temperature deviations in the major maize producing U.S. states and the log export volume of China, France and Argentina. Weather, economic and enforcement controls include temperature and rainfall conditions in Mexican municipios, land quality interacted with year effects, as well as trends by average agricultural income in 1990, the fraction of agricultural workers, major highway presence, distance to the U.S. border, and distance to the nearest security station. *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

Table 7: Maize Price, Maize Suitability, and Drug Seizures

VARIABLES	(1) Log raw marijuana seizures	(2) Log processed marijuana seizures	(3) Log opium gum seizures	(4) Log heroin seizures	(5) Log cocaine seizures	(6) Log meth seizures
	Panel A: Baseline sample					
MAIZE x PRICE	-0.067***	-0.012	-0.005***	-0.001	-0.011**	-0.001
	(0.014)	(0.024)	(0.002)	(0.001)	(0.005)	(0.003)
Observations	46,872	46,872	46,872	46,872	46,872	46,872
Municipios	2,232	2,232	2,232	2,232	2,232	2,232
	Panel B: Sample controlling for mayor's political party					
MAIZE x PRICE	-0.069***	-0.012	-0.006***	-0.001	-0.011*	-0.001
	(0.015)	(0.026)	(0.002)	(0.002)	(0.006)	(0.003)
Observations	40,731	40,731	40,731	40,731	40,731	40,731
Municipios	2,228	2,228	2,228	2,228	2,228	2,228
	Panel C: Sample eliminating border municipios					
MAIZE x PRICE	-0.071***	-0.033	-0.005***	0.000	-0.008*	0.001
	(0.013)	(0.022)	(0.002)	(0.001)	(0.005)	(0.002)
Observations	46,221	46,221	46,221	46,221	46,221	46,221
Municipios	2,201	2,201	2,201	2,201	2,201	2,201

Notes. Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown include municipio fixed effects, log population, and the interaction of maize suitability with the (log) U.S. Mexico real exchange rate in all columns. In addition, all regressions control for temperature and rainfall conditions in Mexican municipios, land quality interacted with year effects, trends by average agricultural income in 1990, the fraction of agricultural workers, major highway presence, distance to the U.S. border, and distance to the nearest security station. Log raw marijuana, processed marijuana, opium gum, heroin, cocaine, and meth seizures are measured as log of kilograms seized. The interaction of maize suitability and the log national maize price is instrumented with the interaction of maize suitability and the lagged rainfall and temperature deviations in the major maize producing U.S. states and the log export volume of China, France and Argentina. Estimates reported in Panel A are based on the baseline sample. In Panel B, the sample is restricted to those observations for which the mayor's political party is available. In Panel C, the set of municipios along the U.S.-Mexico border is excluded from the sample. *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

Table 8: Maize Price, Maize Suitability, and Drug War Violence

VARIABLES	(1) Log total drug-related killings	(2) Log drug-related executions	(3) Log killings from confrontations	(4) Log killings from cartel attacks
	Panel A: Baseline sample			
MAIZE x PRICE	-0.389***	-0.353***	-0.112**	-0.036*
	(0.089)	(0.082)	(0.052)	(0.019)
Observations	8,928	8,928	8,928	8,928
Municipios	2,232	2,232	2,232	2,232
	Panel B: Sample controlling for mayor's political party			
MAIZE x PRICE	-0.450***	-0.407***	-0.138**	-0.039*
	(0.095)	(0.087)	(0.057)	(0.021)
Observations	7,474	7,474	7,474	7,474
Municipios	1,869	1,869	1,869	1,869
	Panel C: Sample eliminating border municipios			
MAIZE x PRICE	-0.343***	-0.304***	-0.087*	-0.042**
	(0.089)	(0.081)	(0.051)	(0.017)
Observations	8,804	8,804	8,804	8,804
Municipios	2,201	2,201	2,201	2,201

Notes. Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown include municipio fixed effects and log population in all columns. In addition, all regressions control for temperature and rainfall conditions in Mexican municipios, land quality interacted with year effects, trends by average agricultural income in 1990, the fraction of agricultural workers, major highway presence, distance to the U.S. border, and distance to the nearest security station. Log total drug-related killings, drug-related executions, killings from confrontations, and killings from cartel attacks are measured as log of killings (or executions) per 10,000 people. The interaction of maize suitability and the log national maize price is instrumented with the interaction of maize suitability and the lagged rainfall deviation in the major maize producing U.S. states. *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

Table 9: Accounting for Drug Crop Suitability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A: Drug Eradication and Drug Seizures Outcomes							
	Log marijuana eradication	Log poppy eradication	Log raw marijuana seizures	Log processed marijuana seizures	Log opium gum seizures	Log heroin seizures	Log cocaine seizures	Log meth seizures
MAIZE x PRICE	-0.028***	-0.020***	-0.062***	-0.007	-0.005***	-0.002	-0.009*	-0.001
	(0.006)	(0.005)	(0.014)	(0.024)	(0.002)	(0.001)	(0.005)	(0.003)
Observations	46,872	46,872	46,872	46,872	46,872	46,872	46,872	46,872
Municipios	2,232	2,232	2,232	2,232	2,232	2,232	2,232	2,232
	Panel B: Drug-War Violence Outcomes							
					Log total drug-related killings	Log drug-related executions	Log killings from confrontations	Log killings from cartel attacks
MAIZE x PRICE					-0.382***	-0.345***	-0.117**	-0.035*
					(0.090)	(0.083)	(0.052)	(0.018)
Observations					8,928	8,928	8,928	8,928
Municipios					2,232	2,232	2,232	2,232

Notes. Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown include municipio fixed effects, log population, temperature and rainfall conditions in Mexican municipios, land quality interacted with year effects, trends by average agricultural income in 1990, the fraction of agricultural workers, major highway presence, distance to the U.S. border, and distance to the nearest security station. Additional controls in Panel A include the mean of the dependent variable over 1990-1993 interacted with year effects. Additional controls in Panel B include log marijuana and poppy eradication over 1990-1993 interacted with year effects.
In Panel A, the interaction of maize suitability and the log national maize price is instrumented with the interaction of maize suitability and the lagged rainfall and temperature deviations in the major maize producing U.S. states and the log export volume of China, France and Argentina. In Panel B, the interaction of maize suitability and the log national maize price is instrumented with the interaction of maize suitability and the lagged rainfall deviation in the major maize producing U.S. states. *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

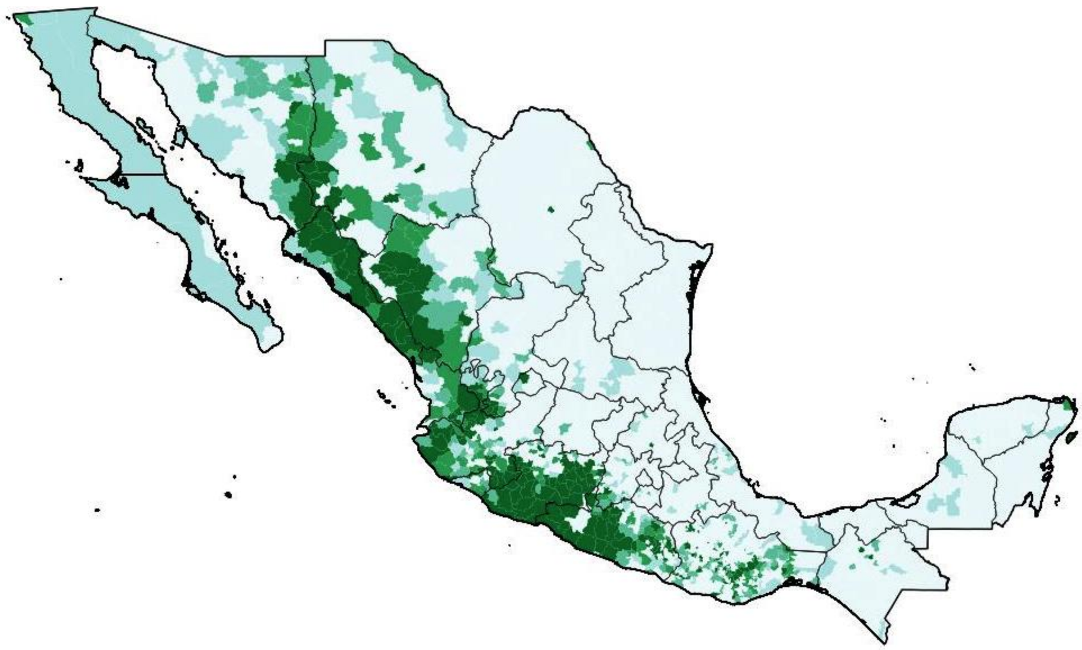
Table 10: Heterogeneous Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log marijuana eradication		Log poppy eradication		Log raw marijuana seizures		Log opium gum seizures	
	Panel A: Results by Poppy Suitability							
Suitability	*Below Median*	*Above Median*	*Below Median*	*Above Median*	*Below Median*	*Above Median*	*Below Median*	*Above Median*
MAIZE x PRICE	-0.013**	-0.058***	-0.009**	-0.038***	-0.045***	-0.071***	-0.001	-0.010***
	(0.006)	(0.011)	(0.005)	(0.009)	(0.018)	(0.024)	(0.002)	(0.003)
Observations	23,436	23,436	23,436	23,436	23,436	23,436	23,436	23,436
Municipios	1,116	1,116	1,116	1,116	1,116	1,116	1,116	1,116
	Panel B: Results by Marijuana Suitability							
Suitability	*Below Median*	*Above Median*	*Below Median*	*Above Median*	*Below Median*	*Above Median*	*Below Median*	*Above Median*
MAIZE x PRICE	-0.002	-0.061***	-0.006	-0.035***	-0.023	-0.098***	0.000	-0.010***
	(0.007)	(0.010)	(0.005)	(0.008)	(0.018)	(0.021)	(0.001)	(0.003)
Observations	23,436	23,436	23,436	23,436	23,436	23,436	23,436	23,436
Municipios	1,116	1,116	1,116	1,116	1,116	1,116	1,116	1,116
	Panel C: Results by Ruggedness							
Ruggedness	*Below Median*	*Above Median*	*Below Median*	*Above Median*	*Below Median*	*Above Median*	*Below Median*	*Above Median*
MAIZE x PRICE	-0.003	-0.076***	-0.003	-0.050***	-0.011	-0.123***	-0.000	-0.011***
	(0.006)	(0.011)	(0.005)	(0.009)	(0.014)	(0.026)	(0.001)	(0.003)
Observations	23,436	23,436	23,436	23,436	23,436	23,436	23,436	23,436
Municipios	1,116	1,116	1,116	1,116	1,116	1,116	1,116	1,116

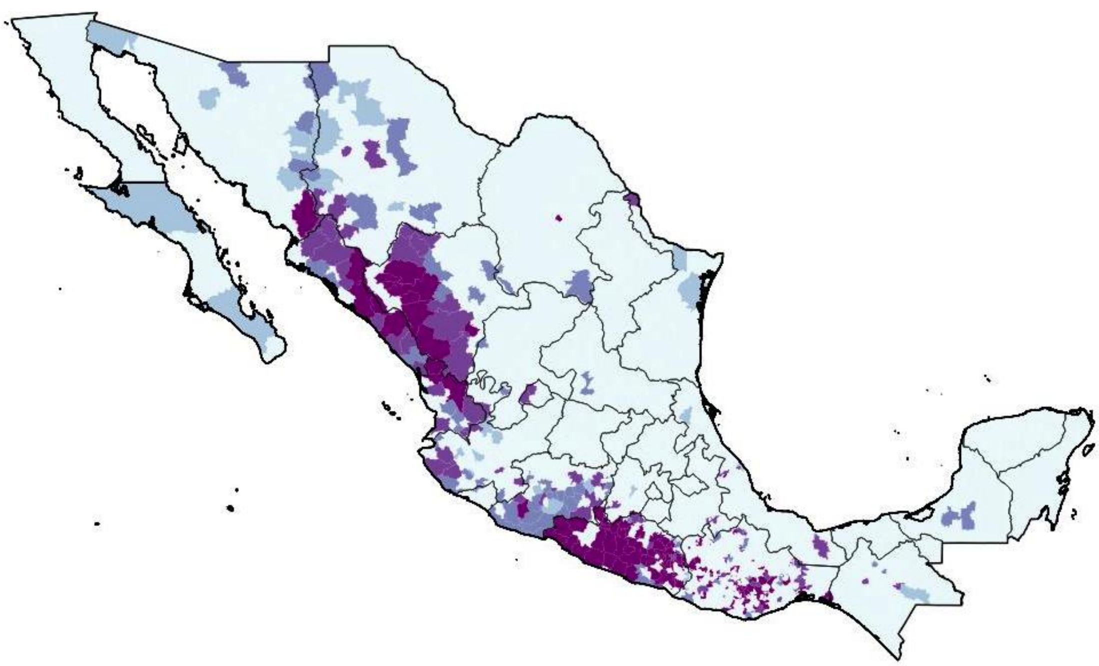
Notes. Robust standard errors clustered at the municipal level are shown in parentheses. Variables not shown include municipio fixed effects and log population in all columns. In addition, all regressions control for temperature and rainfall conditions in Mexican municipios, land quality interacted with year effects, trends by average agricultural income in 1990, the fraction of agricultural workers, major highway presence, distance to the U.S. border, and distance to the nearest security station. The interaction of maize suitability and the log national maize price is instrumented with the interaction of maize suitability and the lagged rainfall and temperature deviations in the major maize producing U.S. states and the log export volume of China, France and Argentina. Log marijuana and poppy eradication are measured as log of area eradicated per 10,000 hectares plus 1. *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

Figure 1: Drug Crop Eradication in Mexico

<u>Panel A:</u> ***Average Eradication of Marijuana in Mexican Municipios***

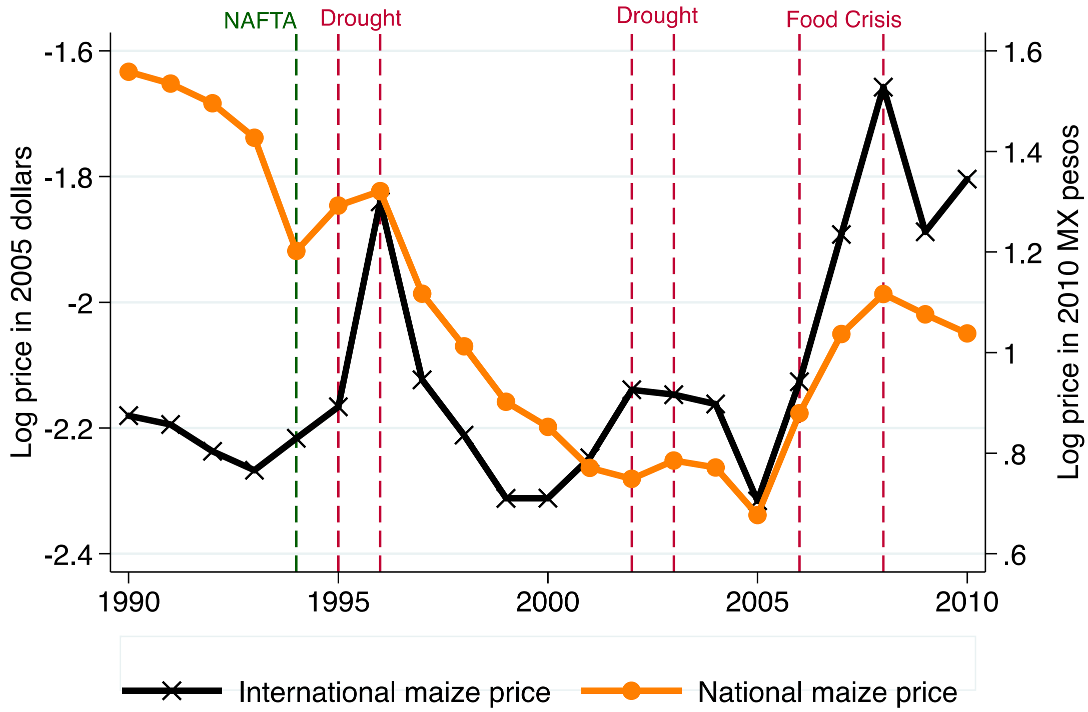


<u>Panel B:</u> ***Average Eradication of Poppy in Mexican Municipios***



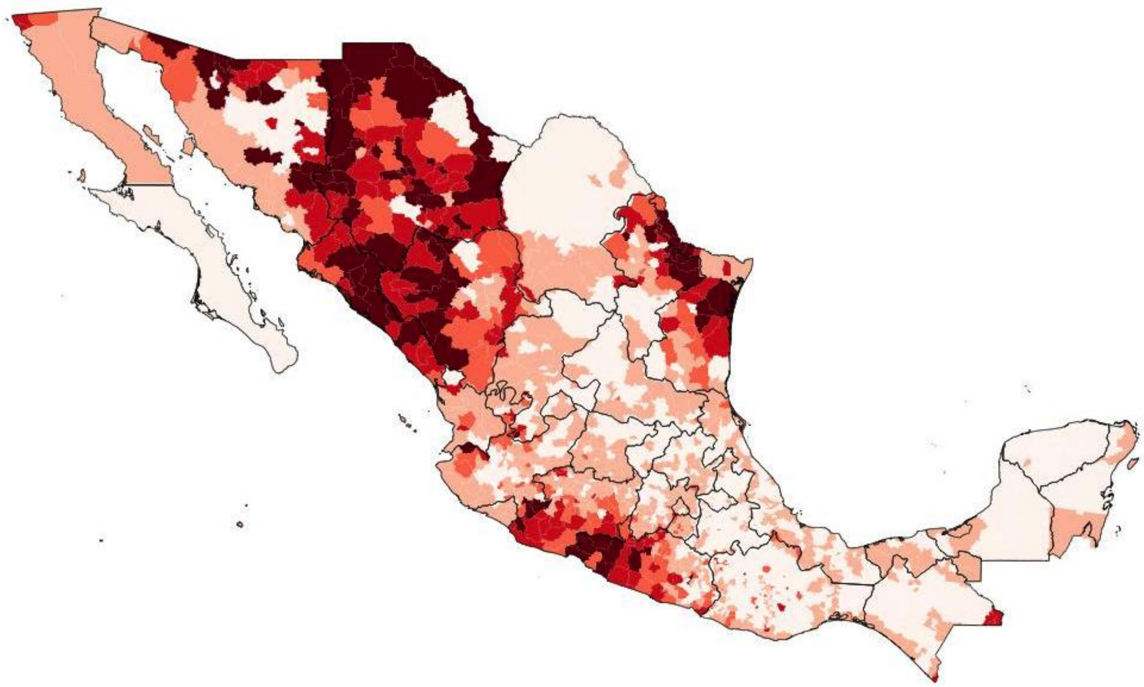
Notes. This figure shows annual averages of marijuana (Panel A) and poppy (Panel B) eradicated per 100,000 hectares in each Mexican municipio between 1990 and 2010. The data were obtained from SEDENA. Darker colors denote higher levels of eradication.

Figure 2: Maize Prices



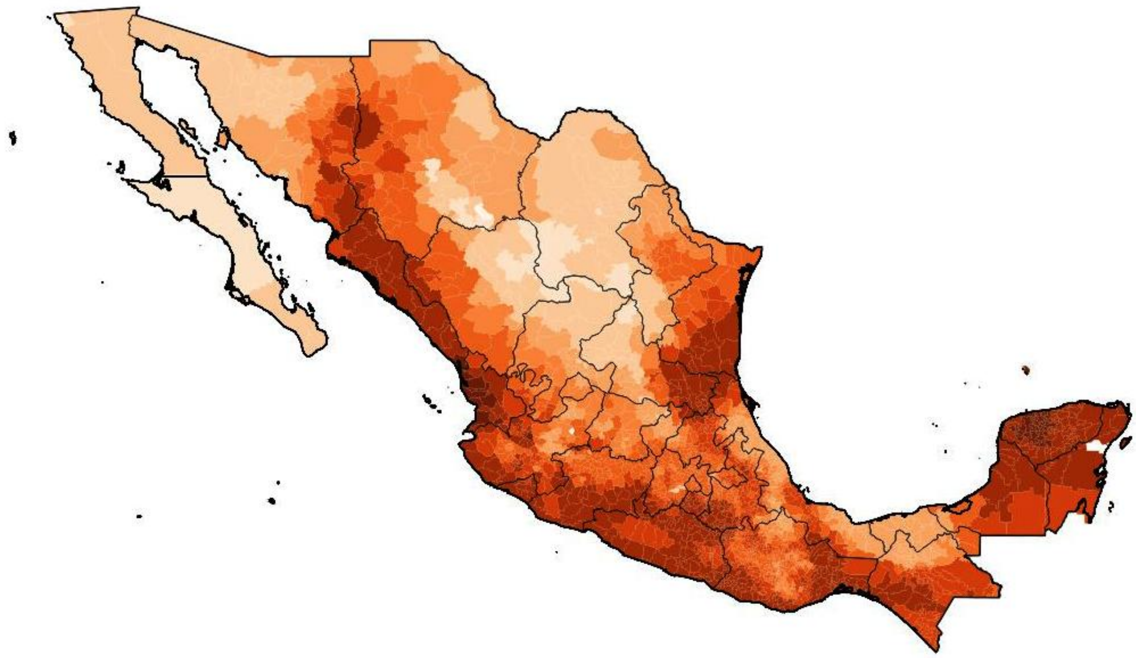
Notes. This figure shows the international maize price and Mexican maize price over the 1990-2010 period. The data for the international price comes from the World Bank. The data for the national price comes from the Servicio de Información Agroalimentaria y Pesquera (SIAP), in the Mexican Ministry of Agriculture. The green line marks the introduction of NAFTA in 1994. The red lines denote U.S. droughts and the international food crisis.

Figure 3: Drug-related Killings



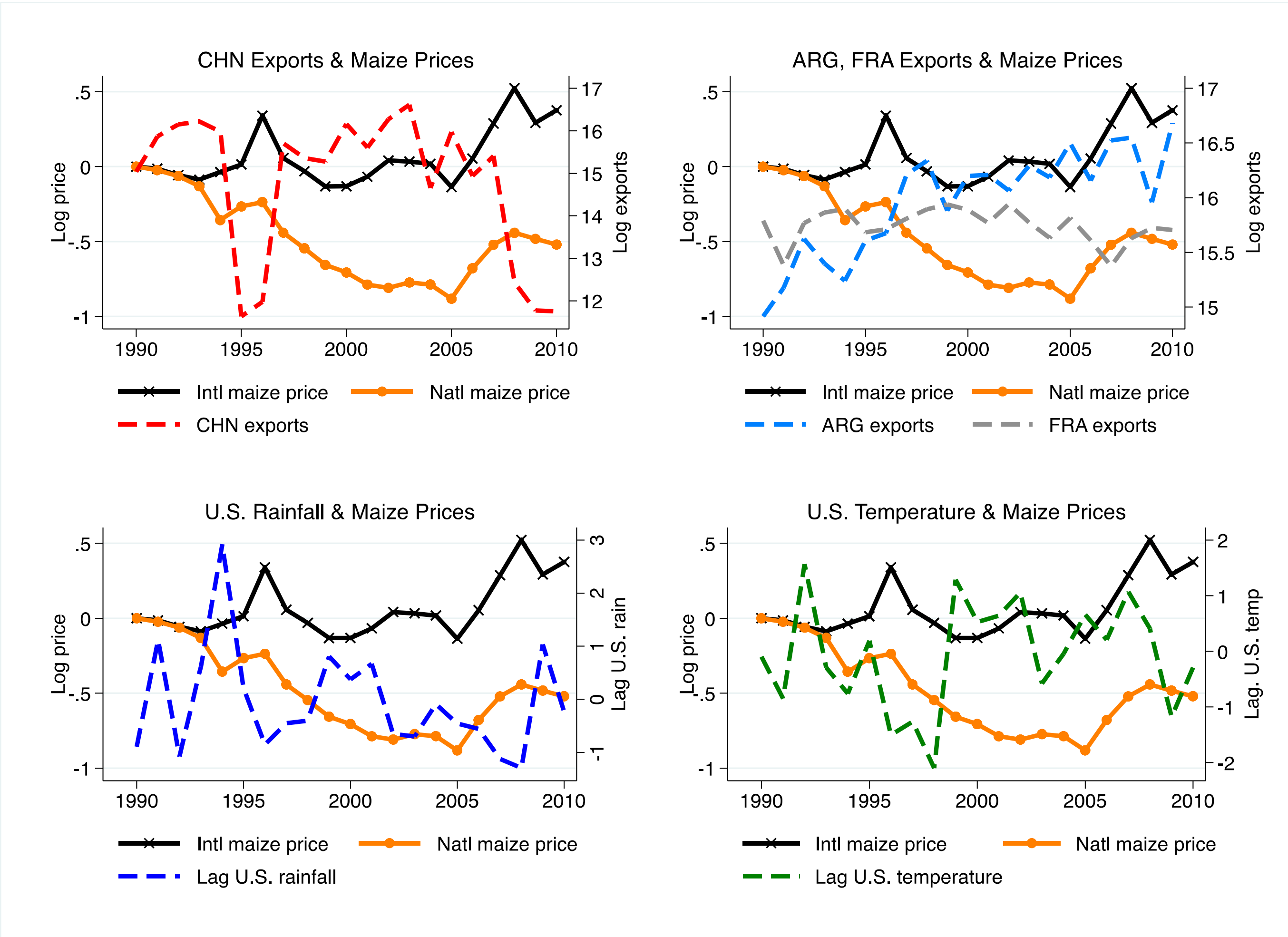
Notes. This map shows the annual average of drug-related killings per 10,000 people in each Mexican municipio. The data come from the Mexican National Security Council, and are available for the 2007-2010 period. Darker colors denote higher levels of drug-related killings.

Figure 4: Maize Suitability



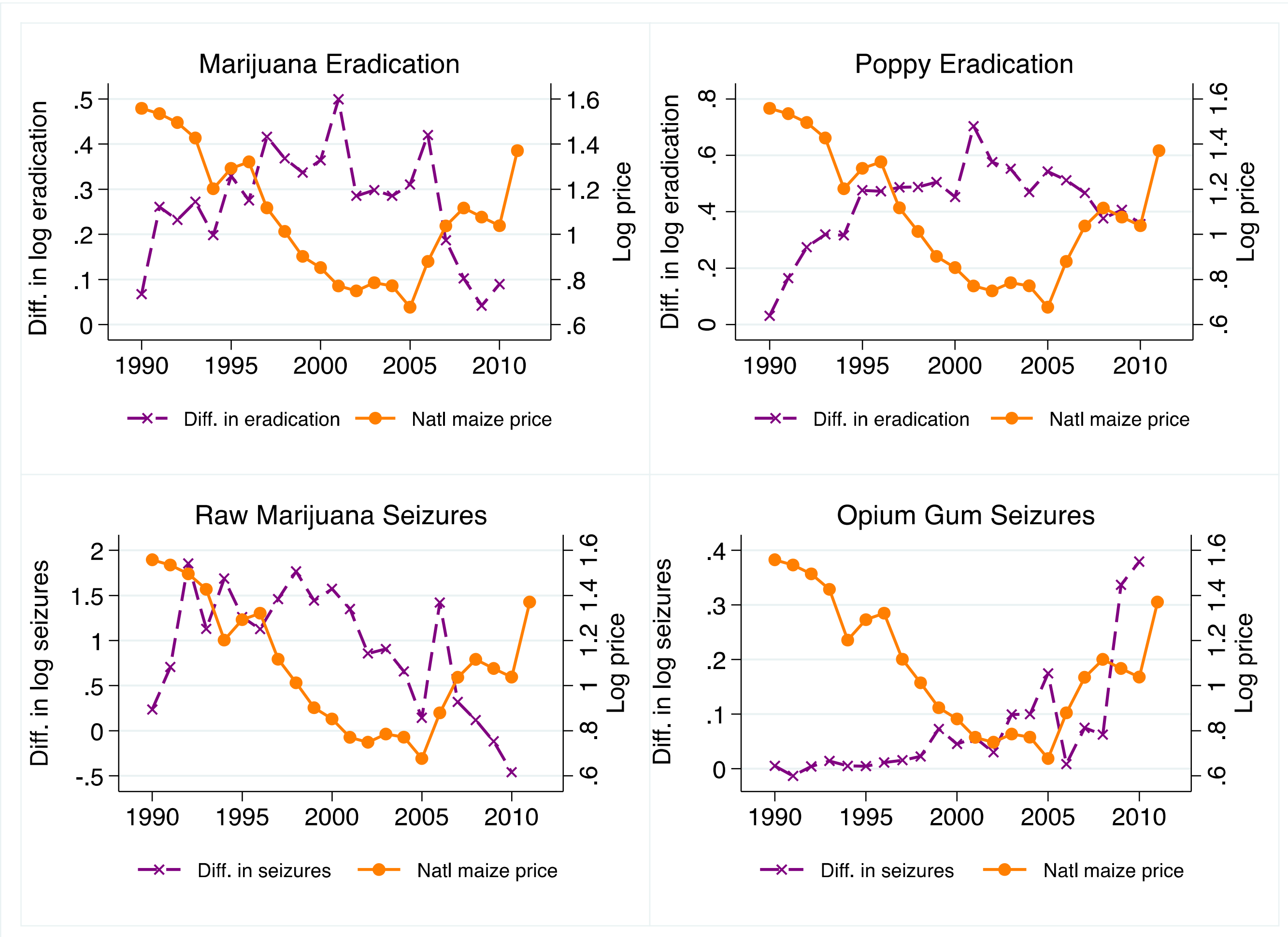
Notes. This figure shows the average agro-climatically attainable yield for maize (measured in kg DW/ha) for each Mexican municipio. This measure was constructed using 0.083-degree resolution data from the FAO's Global Agro-Ecological Zones (GAEZ v3.0). Darker colors denote higher suitability and potential yield for maize.

Figure 5: Maize Prices, Maize Exports, and U.S. Weather Shocks



Notes. The top-left panel shows the (log) volume of maize exported by China (CHN). The top-right panel shows the (log) volume of maize exported by Argentina (ARG) and France (FRA). The bottom-left panel shows the lagged annual rainfall deviation in June and July in major U.S. maize states. The bottom-right panel shows the lagged annual temperature deviation in April and May in major U.S. maize states. All panels also show the (log) national and international maize prices deviations from 1990 over the 1990-2010 period.

Figure 6: The Maize Price, Maize Suitability and Drug-Related Outcomes



Notes. The top-left panel shows the difference in (log) average marijuana eradication in municipios above and below mean maize suitability. The top-right panel shows the difference in (log) average opium poppy eradication in municipios above and below mean maize suitability. The bottom-left panel shows the difference in (log) average opium raw marijuana seizures in municipios above and below mean maize suitability. The bottom-right panel shows the difference in (log) average opium gum seizures in municipios above and below mean maize suitability. All panels also show the (log) national maize price over the 1990-2010 period.