Scarcity without Leviathan: The Violent Effects of Cocaine Supply Shortages in the Mexican Drug War

Juan Camilo Castillo, Daniel Mejía, and Pascual Restrepo

Abstract

Using the case of the cocaine trade in Mexico as a relevant and salient example, this paper shows that scarcity leads to violence in markets without third party enforcement. We construct a model in which supply shortages increase total revenue when demand is inelastic. If property rights over revenues are not well defined because of the lack of reliable third party enforcement, the incentives to prey on others and avoid predation by exercising violence increase with scarcity, thus increasing violence. We test our model and the proposed channel using data for the cocaine trade in Mexico. We found that exogenous supply shocks originated in changes in the amount of cocaine seized in Colombia (Mexico's main cocaine supplier) create scarcity and increase drug-related violence in Mexico.

In accordance with our model, the effect of cocaine scarcity on violence is larger near US entry points; in locations contested by several cartels; and where, due to high support for the PAN party, crackdowns on the cocaine trade have been more frequent. Our estimates suggest that, for the period 2006-2010, scarcity created by more efficient interdiction policies in Colombia may account for 21.2% and 46% of the increase in homicides and drug-related homicides, respectively, experienced in the north of the country. At least in the short run, scarcity created by Colombian supply reduction efforts has had negative spillovers in the form of more violence in Mexico under the so-called War on Drugs.

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Foreword by Michael Clemens

The 2,000 mile border between the US and Mexico is an economic cliff, the largest GDP per capita differential at any land border on earth. Across this fault-line, the two nations continue a deep and centuries-old exchange of goods, services, investment, labor, culture, and ideas.

Some of those interactions happen through flourishing, transnational illicit markets—such as for drugs, arms, and labor—with major economic and social effects for both sides. The political economy of these markets is complex and poorly understood. It is shaped by a policy approach that is today dominated by unilateral, domestic law enforcement.

This paper was commissioned by CGD's Beyond the Fence study group. Castillo, Mejía and Restrepo provide a rigorous new evidence of the ripple effects of enforcement policy via transnational illicit markets. First, they measure for the first time how antinarcotics interdiction in Colombia affects cocaine prices far away—in Mexico. Second, they show how the resulting change in cocaine prices leads to violence in Mexico, above and beyond violence caused by local enforcement efforts. This transnational mechanism can explain roughly one fifth of the stunning rise in murders in Mexico after 2006.

CGD created Beyond the Fence in 2013 to generate rigorous new research on how policy decisions on one side of the border ripple to the other side through illicit markets, and to inform a policy debate on more bilateral approaches to innovative regulation. The group brings together some of the world's leading social scientists and policy innovators. The dual meaning of the name represents a desire for researchers to investigate the effects of policy that cross the fence, and for policymakers to reach beyond unilateral enforcement approaches.

"Hereby it is manifest that during the time men live without a common power to keep them all in awe, they are in that condition which is called war; and such a war as is of every man against every man. [. . .] In such condition there is no place for industry [. . .] ; no account of time; no arts; no letters; no society; and which is worst of all, continual fear, and danger of violent death; and the life of man, solitary, poor, nasty, brutish, and short."

Thomas Hobbes, 1651
Leviathan
Book I, chapter XIII

1 Introduction

According to Thomas Hobbes, in a world without the rule of law, in which the state does not have the monopoly of violence and where no reliable third party can enforce laws and contracts, the life of man becomes "nasty, brutish and short" (Hobbes, 1651). The rule of law and monopoly of violence by a central authority—the Leviathan—are essential requirements for the absence of conflict and violence. Contemporary writers like Steven Pinker have also argued that the rise of the Leviathan was one of the main driving forces behind the decline in violence that has been observed during the last millennium (see Pinker, 2011). The logic behind this observation is simple: Outside the rule of law there is no reliable third party enforcement and property rights are poorly defined; wealth and assets can be appropriated by others through the use of force, and violence becomes the only rational choice. Not only does the exercise of violence allow people to prey on others; it also protects them from potential predators. In such an environment appropriation and protection become what Hirshleifer (2001) has termed "the dark side of the force".

Despite the great expansion of the state and its monopoly of violence since Hobbes' time, there are still many regions, markets, and moments, both past and present, that lie outside the scope of the Leviathan, and in which violent appropriation and private protection are the rule rather than the exception. In many developing countries there are large areas with no state presence, where the monopoly of violence is disputed among local strongmen (see Acemoglu et al., 2013; Fearon and Laitin, 2003; Sánchez de la Sierra, 2014). This creates large conflicts between warlords over the extraction and control of valuable resources and their rents (see Skaperdas, 2002). Markets for illegal goods are another important example, where illegality precludes the possibility of using the state as a source of third-party enforcement. Contemporaneous illegal drug markets in Colombia, Mexico, and Afghanistan are all ruled by illegal armed groups that frequently resort to violence in order to solve disputes and protect (*de facto*) property rights. The scale and salience of violence may vary, but other markets with poorly defined property rights are constantly subject to violence as well, independently of the type of goods transacted. For instance, a recent piece in The New York Times describes the use of violence by fisherman involved in the banned sea cucumber trade in Mexico[1].

But examples are not limited to developing nations. In Sicily, the violent mafia started as a dual organization that specialized both in extortion and offering protection for the explotation of sulfur mines (see Buonanno et al., 2012). The mafia's business model was only profitable because of the weak law enforcement institutions in the Italian South. Later, the mafia diversified and started selling protection in other trades. There was demand for private protection only because the Leviathan was absent in such environments (see Gambetta, 1996). During the settlement of the American West, Scots-Irish herders developed a "culture of honor", in which people were expected to respond with violence against any threat (see Nisbett and Cohen, 1996; Grosjean, 2013). These cultural norms are a violent substitute for a third party that settles disputes among herders and punishes those attempting to steal herds.

In this paper we analyze the role of scarcity in environments that lack reliable third party enforcement. By third party enforcement we mean that market participants are subject to the state's monopoly of violence—the rule of law, which is used to enforce property rights and enforce contracts in an impartial and reliable way. As our discussion above underscores, the intensity and salience of violence varies from example to example. Thus, it becomes important to understand its determinants. We study the role of scarcity—or supply shortages—as one important factor that can potentially exacerbate the use of violence in market environments without third party enforcement. Our basic intuition is that scarcity increases violence if the demand for certain goods whose market is illegal is inelastic. In this case, a decrease in supply causes a larger increase in prices, therefore increasing total revenues and the stakes. This leads to more predation and violence.

We study this question in the context of Mexico and the cocaine trade. Mexico has witnessed a dramatic increase in violence: The homicide rate in 2010 was almost

[1]Because sea cucumbers are extracted from the bottom of the ocean, they do not have properly defined property rights, and this has caused fights among neighboring fisherman communities. See the full story here: http://www.nytimes.com/2013/03/20/world/americas/quest-for-illegal-gain-at-the-sea-bottom-divides-fishing-communities.html?_r=0.

three times that of 2005 (see figure 1). Most of the surge in violence in Mexico can be attributed to confrontations between Drug Trafficking Organizations (DTOs), or cartels, and between DTOs and Mexican authorities. In fact, since 2006, there have been more than 60,000 drug related killings in Mexico, which is a larger death toll than that observed in Afghanistan since 2001 (estimated to be between 30,000 to 45,000 since 2001) (see Crawford, 2011). These numbers emphasize the relevance and importance of the Mexican case by itself. It is therefore a worthy task to document the role that cocaine scarcity may have played in the surge in violence witnessed by Mexico in the last few years.

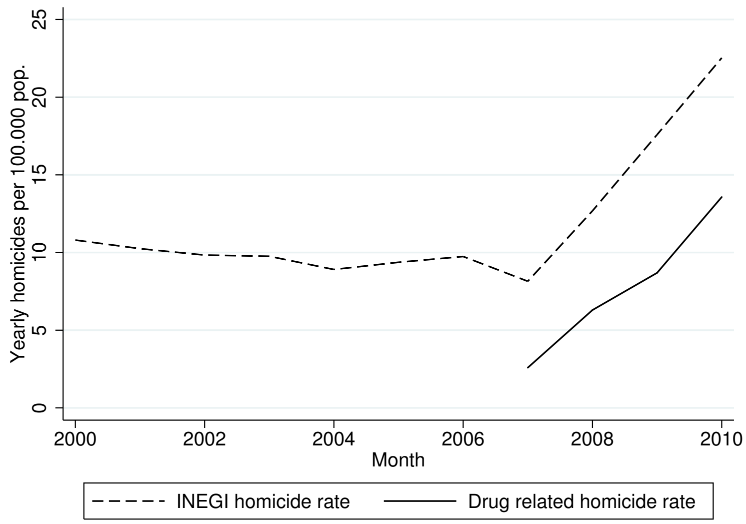


Figure 1: Homicide rate in Mexico.The total homicide rate shows the data provided by INEGI. The drug-related homicide rate was published by the President's Office. This data is only available starting in December 2006.

Besides our interest in the Mexican case, documenting the role of scarcity in markets without reliable third party enforcement is important for two main reasons. First, it sheds light on the nature of the associated violence. If violence responds to economic incentives in the way economic theory predicts, we learn that violence is a rational choice made by agents motivated by profit, or greed. This helps us differentiate the economic explanation, based on the opportunity to appropriate and the necessity to defend, from other explanations that emphasize culture or the socioeconomic environment, suggesting different courses of action to reduce violence.

A second reason is that many policies could increase scarcity in markets with poorly defined property rights, and, through this mechanism, increase violence. For instance, limits on formal mineral extraction—of gold or diamonds, for example—create scarcity and increase prices, making illegal extraction more likely to become violent. Supply reduction policies in drug markets create scarcity and may end up inducing more violence. Commercial restrictions to trade in some resource-abundant countries with poor institutions could increase rents and violence. Moreover, violence would persist in these environments as long as unprotected revenues are high, so that the stakes remain attractive and the use of violence becomes a profitable strategy. The fact that scarcity increases violence by raising revenues suggests that policies that reduce revenue and limit the incentives to prey become the best alternative to actually enforcing property rights adequately. Thus, recognizing the nature of violence in markets without third party enforcement and the effect of market forces on its extent, would enable policy makers to design better policies to prevent it or cope with it.

We construct a simple model that provides insights that apply generally, although it is motivated by the recent Mexican case. In our model, exogenous (negative) supply shocks in cocaine markets cause increases in wholesale prices that are larger than the fall in quantities. Thus, the total revenue from cocaine trafficking activities increases, and the higher stakes spur more violence. An important assumption for this to hold is that demand for cocaine is inelastic, as has been documented by various sources such as Becker et al. (2006)[2]. The reasoning behind the assumption is that, since cocaine is an addictive substance, consumers must buy their personal dose regardless of price, implying an inelastic demand.

In our model, drug cartels fight each other and use violence to be able to extract more of the higher rents. The use of violence increases when the stakes are higher. For example, when revenue from the cocaine trade increases, toll collector cartels can extract greater rents, and thus become more willing to use violence to control a given territory suitable for the drug trade. In turn, other cartels will also be more likely to use violence in response, in order to avoid being extorted or preyed upon. When there are more cocaine rents in the system, there is more cash and assets that can be appropriated by other cartels, or even by the very members of the same cartel (if it is not fully cohesive). Rapacity and violence emerge as a consequence. Unlike participants in well functioning legal markets, cartels do not have reliable third party enforcement to protect their property and revenue streams from others, or to protect them from extortion. Violence does not only become an opportunistic strategy to prey on others; it also becomes a necessity to protect one's own position and the control of the trade. Our model shows that the effect of cocaine shortages on violence is larger in places with more competing organizations (i.e., rival cartels), in places where there is more turnover and hence informal cooperation arrangements cannot sustain less violent outcomes (i.e.,

[2]We further discuss the validity of this assumption when we present the model.

due to higher arrest rates of cartel leaders), and in places where drug trafficking is more intense (e.g., the north of Mexico).

We test our model using monthly data from Mexican municipalities from December 2006 to 2010, a period that coincides with what has been called the "Mexican Drug War". The Mexican cocaine trade fits perfectly our purposes for several reasons. First, because cocaine production takes place in the Andes, and most notably in Colombia during our period of study, we can use changes in interdiction policies in Colombia as exogenous sources of variation in the supply of cocaine. Second, cocaine demand has been estimated to be inelastic, especially in the short run[3]. Third, the illegal nature of this market precludes the existence of any formal source of third party enforcement, thus forcing market participants to operate outside the scope of the rule of law, and forcing market participants to enforce property rights and contracts by themselves.

We focus on high frequency monthly variation in the supply of cocaine from Colombia as a source of shocks to scarcity in cocaine markets in Mexico. This variation is created by month to month changes in seizures in Colombia, which are arguably exogenous to the Mexican environment. We only focus on high frequency relations because we believe year to year variation is likely to confound trends in Mexican and Colombian policies that may be spuriously correlated over time (for instance, Calderón's war on drugs, and a shift towards more interdiction efforts in Colombia, both of which increased steadily since 2006). The key identifying assumptions are, first, that the potential relationship between policies in Mexico and Colombia breaks down at higher frequencies once we control flexibly for long term time trends, and second, that other determinants of violence in Mexico are not correlated with interdiction efforts in Colombia at higher frequencies.

We find that violence increases in Mexico during months with supply shortages caused by seizures in Colombia. Moreover, violence increases especially in the north, and within the north, specifically in places close to U.S. entry points, as predicted by our model. Also, violence increases more in northern municipalities that have historically voted for PAN, President Felipe Calderón's party (whose term lasted from December 2006 until November 2012). Because these municipalities were more likely to support federal government efforts against cartels in their area (see Dell, 2012), the turnover of cartel leaders was higher. Finally, violence increases more in places with cartel presence, especially in places with two or more cartels or with two or more rival cartels operating at the time of the supply shock. The fact that the effect of scarcity is mediated by all these variables does not only further validate our model, but also shows a wide range of

[3] Once again, see our detailed discussion about the elasticity of demand in section 4.

empirical facts consistent with our proposed mechanism through which scarcity breeds violence.

Our interpretation of the results is that Colombian supply shocks—which became larger and more frequent since 2006—have created scarcity, raised prices and contributed to the increase in violence in Mexico. Our preferred estimates suggest that a 10 metric ton (mt) decrease in the Colombian supply in a given month (Colombia produced around 43.5 mt per month in 2006) increases the overall homicide rate during that month by 1.2 log points in all Mexico, by 3.5 log points in the 40% municipalities closest to the U.S., and by 5.1 log points in the 20% municipalities closest to the U.S. border. Our estimated effects are even larger as one gets closer to U.S. entry points. More precisely, our estimated impact is about 14 log points larger near the Mexico-U.S. border.[4] Assuming the size of this effect is the same in the long run, we would conclude that the reduction in the net cocaine supply from Colombia experienced between 2007 and 2010 (from 43.5 mt to 16.6 mt each month) accounts for about 37 log points of the 174.5 log point increase of the homicide rate in northern Mexico. Our estimates suggest that, for the period 2006-2010, scarcity created by more efficient interdiction policies in Colombia may account for 21.2% and 46% of the increase in homicides and drug related homicides (see section 6 for the calculations involved for these estimates), respectively, experienced in the north of the country. At least in the short run, scarcity created by Colombian supply reduction efforts has had negative spillovers in the form of more violence in Mexico.

Although our evidence comes from a particular context, we believe that the economic forces modeled are present in many commodity markets without reliable third party enforcement, at least in the short run, if demand is inelastic. Our evidence suggests that scarcity can have larger effects in markets with several rival participants (monopolies could thus reduce rapacity and violence), in places where the trade is particularly important (i.e., near places that are abundant in resources required for the production and transportation of the commodity), and in places with large turnover among market participants, which precludes the formation of informal arrangements to enforce property rights. Illegal drug markets are special in that they are illegal, and hence the lack of reliable third party enforcement becomes a more serious issue than in markets with weak central state presence. Thus, the magnitude of the effects we analyze might be smaller in other contexts, but we believe that the economic forces highlighted in this paper would still operate.

This paper is organized as follows. Section 2 outlines the related literature and

[4] This is the average effect among the 5% municipalities closest to the U.S.

explains our contribution to the literature. In section 3 we revisit the Mexican context and describe its environment. Section 4 presents a simple model to understand the effects of scarcity on violence in illegal drug markets and derives some testable predictions. Section 5 presents our estimation strategy, data and empirical results. Section 6 concludes.

2 Related literature

Our paper is related to at least three branches of literature. First, it is related to the broad literature on property rights and violence. The fact that interpersonal violence emerges when the state lacks the monopoly of violence is a classic theme in the social sciences at least since Hobbes (1651), and it has been treated more recently by Elias (2000) and Pinker (2011). The possibility of using force or the threat of force to appropriate resources, in contrast to ordinary market transactions, has been present in the economic literature since Grossman (1991) and Hirshleifer (1991, 1994, 2001). When property rights are weak, or institutions—such as the rule of law—dysfunctional, conflict over the access and control of valuable resources could end up increasing violence through rapacity. This is a variant of the resource curse, in which the presence of valuable commodities ends up increasing violence by intensifying rapacity, i.e., the temptation to prey on others and the necessity to defend from potential predators.

Skaperdas (2002) argues that when there is no monopoly of violence, warlords compete for turf, which allows them to extract rents from valuable resources. When the value of these resources increases so does conflict among warlords. In a similar vein, Gambetta (1996) argues that the combination of valuable resources with poorly defined property rights can lead to the emergence of mafia-type organizations that offer private protection from predation by others or from the mafia itself (i.e., extortion). Collier and Hoeffler (2004) show that resource booms could be used to finance insurgencies, or could induce a greedy insurgency to start a civil war in order to control the rents from these resources (see also Grossman, 1999). However, weak property rights or lack of reliable third party enforcement are not sufficient for the rapacity channel to be observed. For instance, resource booms could also increase wages, and hence the opportunity cost of people to engage in violence, outweighing the effects of rapacity (see Becker, 1968; Grossman, 1991).

Just as with the ambiguous theoretical predictions, the empirical findings regarding the effect of an increase in resource revenues—caused by either scarcity or demand increases—is mixed. For instance, Collier and Hoeffler (2004) find that exports of commodities have a strong positive effect on the risk of conflict. However, Fearon (2005) shows that this result is fragile, and that only oil production appears to be an important determinant of conflict onset after a resource boom. His interpretation is that oil produces an easy source of financing for rebel groups, rather than oil rents being contested by armed groups. On the other hand, using a panel of African countries, Miguel et al. (1994) show that higher national income, instrumented using rainfall, reduces the likelihood of conflict, probably because the opportunity cost channel dominates in this case. Brückner and Ciccone (2010) reach a similar conclusion using variation in commodity prices. Dube and Vargas (2013) find that coffee booms– which are likely to increase wages–reduce violence in Colombia, while oil booms– which are not likely to increase wages– increase violence.

A paper that is very closely related to ours is Buonanno et al. (2012). They find that mafia-type organizations were more likely to appear in Sicilian municipalities with sulfur extraction, a valuable commodity with poorly defined property rights. The timing of the emergence of these organizations coincided with a large boom in sulfur prices. On a similar vein, Couttenier et al. (2013) show that, during the U.S. gold rush, interpersonal violence increased near mineral discoveries, but only when there was no state presence at the time of the discovery. They refer to this violence as a variant of the resource curse. Both papers support the view advanced here that scarcity—understood as low demand relative to supply that triggers an increase in prices and revenues—increases violence in commodity markets with poorly defined property rights through a rapacity channel. A full review of this literature is beyond the scope of our paper, but the interested reader is referred to Ross (2004).[5]

We contribute to this literature by studying the role of rapacity in the context of an illegal commodity. Illegal commodities are, in our view, one natural example in which rapacity—or the willingness to appropriate—should be strong, given that their illegal character precludes market participants from the possibility of relying on a third party to enforce property rights and fulfill contracts. When property rights are not centrally enforced, the temptation to prey and the need to protect from others make violence a natural outcome. Consistent with this view, we show that scarcity has an

[5]Another branch of literature does not focus on the role of commodities but on the emergence of violence when property rights are weak. Grosjean (2013) studies the emergence of the culture of honor in the U.S. South, and finds that places with more herding during the settlement period were, and still remain, more violent. Moreover, this only occurs in the Deep South, where institutions were weak and property rights over herds were poorly enforced by a central authority, suggesting that the rapacity channel might have been in place. She interprets these findings as supporting Nisbett and Cohen's hypothesis that the lack of property rights over herds led to the use of inter-personal violence as a costly substitute.

effect on violence through the rapacity channel by increasing total revenue if demand is inelastic. The fact that violence increases differentially in areas that are more important for cocaine trafficking, when there are more cartels contesting these areas, or when there is large turnover further suggest that the specific channel through which scarcity increases violence is rapacity. We cannot rule out the presence of the opportunity cost channel, but it appears to be dominated in this particular market, which is the case as long as the labor share of the Mexican cocaine trade is small relative to the whole economy (see Dal Bó and Dal Bó, 2011).[6]

Our paper is also related to literature on violence in illegal markets, and more particularly to violence in drug markets. This literature started with the classification of drug related violence by Goldstein (1985), according to which drug markets can breed violence through three different channels: First, through *pharmacological violence* consuming drugs may lead users to a mental state in which they are more prone to aggressive behaviors and violence; second, through *economic compulsive violence* drug consumers may engage in property crime in order to be able to sustain their costly habit. These two channels are unrelated to the supply side of drug markets that we study in this paper. The third channel is *systemic violence* among suppliers, and is caused by the fact that illegal markets lack reliable third party enforcement, and their participants are pushed outside of the scope of the rule of law. Thus, systemic violence is exactly the type of violence we have discussed so far, which occurs when property rights are poorly defined and the temptation to appropriate others' resources arises.

Several papers have studied the correlation between violence and the supply side of drug markets with some mixed findings. We will only focus on those which, in our view, have taken seriously the endogeneity issues that arise when trying to estimate the causal effect of illegal drug markets on systemic violence. Angrist and Kugler (2008) exploit a large upsurge in coca cultivation in Colombia caused by an exogenous change in Peruvian policy that deterred cocaine cultivation in Peru during the first half of the 1990s. As a consequence, violence increased in Colombia, especially in states that already produced coca leaves by 1994. Mejía and Restrepo (2013) also study the case of Colombia. They construct an index of suitability for coca cultivation at the municipal level, and show that its interaction with different demand shocks for Colombian cocaine predicts within-municipality variation in the extent of coca cultivation. They use this index as an exogenous source of variation to set up an instrumental variables estimator

[6]Levitt and Venkatesh (2000) offer some evidence suggesting a small labor share in the drug dealing business. They find that wages for gang members are barely above the minimum wage. Their data comes from a gang involved in drug dealing in an anonymous American city, so their findings do not necessarily apply to Mexican cartels.

and conclude that increases in coca cultivation cause more violence. The interpretation of their results relies on the fact that illegal armed groups fight each other (and the government) over the control of territories suitable for coca cultivation and cocaine production.

Some other works focus on illegal goods other than drugs. Owens (2011a) finds no effect of dry laws on homicides and argues that demographics were the main driving force behind the increase in crime during the alcohol prohibition period. However, in a subsequent study, Owens (2011b) shows that the Temperance movement did increase violence among young people, who were more likely to be involved in the supply side of alcohol distribution than older people. Likewise, García-Jimeno (2012) shows that alcohol prohibition, especially the intensity of enforcement, caused an increase in crime in U.S. cities. The relation between illegal markets and violence, however, is not limited to addictive goods. Chimeli and Soares (2010) explore how illegality itself generates violence in a completely different market: mahogany exploitation in the Brazilian Amazon. Mahogany trade in Brazil was initially legal, but it was suddenly prohibited in a short period of time, between March 1999 and October 2001. The authors use a difference in difference approach and conclude that violence increased differentially due to prohibition in places where mahogany extraction was a natural phenomenon.

Our paper contributes to this literature by identifying systemic violence, and characterizing how it changes with scarcity in the context of the Mexican drug war. In particular, we document how drug related violence in the Mexican cocaine trade behaves as predicted in a model in which violence follows a profit maximizing logic. In particular, violence in Mexico responds to economic incentives and to variations in the value of the drug trade created by supply shocks in Colombia. This is the defining characteristic of systemic violence. Thus, although we are not directly estimating the contribution of drug trafficking to violence, we are showing that to a large extent, the nature of drug related violence in Mexico is related to profit incentives and rapacity effects, and not to other social or cultural explanations. Our paper adds to the increasing body of evidence suggesting that participants in illegal drug markets rely on violence to prey on others and protect themselves because of lack of reliable third party enforcement. The resulting systemic violence in the supply side of drug markets is, in our opinion, the largest cost of the war on drugs. Our paper also contributes to this literature by showing that supply reduction policies may increase violence by increasing total revenue, and create strong spillovers whereby policy changes in one country affect security in other countries (see Castillo (2013) and Mejía and Restrepo (2013) for similar theoretical and empirical results).

Finally, our paper is related to an ongoing debate about the causes of the large upsurge in violence observed in Mexico since 2006. Many observers have pointed fingers at president Calderón's strategy as the main reason for the increase in homicides observed in the last years. More precisely, many observers and security analysts have argued that Calderón's strategy of frontally attacking drug cartels, especially targeting their leaders, has been the main force behind the surge in homicides since 2007. They argue that Calderón's strategy of beheading drug cartels, either by killing or capturing their leaders, has led to internal disputes over the control of this illegal business by competing cartels or by lower ranked members of the same drug trafficking organizations. Also, critics argue, the strategy led to the splitting of major cartels into smaller ones[7]. Some studies supporting this position are Guerrero (2010, 2011a) and Merino (2011). Some other studies defend the government's actions, such as Poiré and Martínez (2011), who argue that the strategy of capturing or killing cartel leaders does not increase violence, and Villalobos (2012), who supports Calderón's strategy arguing that in order to eliminate drug related violence, a period of higher levels of violence was necessary before homicide rates start going down.

More recent papers have addressed this question taking endogeneity issues seriously when trying to estimate the effect of Calderón's policies against drug cartels on the levels of violence. Dell (2012) uses a regression discontinuity design, comparing those municipalities where the PAN, Calderón's party, won the local elections by a small margin *vis-à-vis* those municipalities in which the PAN lost by a small margin, expecting more violence where the PAN won. The intuition behind her identification strategy is that it was easier for the Federal Government to intervene in municipalities with a PAN mayor, thus making Calderón's war on drugs more intense in these places. The study concludes that frontal actions against DTOs have caused an important increase in the levels of violence and created spillovers in neighboring municipalities. On the other hand, another study by Calderón et al. (2012) combines a difference in differences methodology with synthetic control groups and shows that Calderón's intervention did have an effect on the levels of violence, but it was only a temporal effect (contrary to what Guerrero (2011a) argues). In a different vein, Dube et al. (2012) shift the focus to U.S. gun control policies. In particular, they find that violence in Mexico increased as a consequence of the 2004 expiration of the U.S. Federal Assault Weapons Ban, which created a positive shock of gun availability in Mexico. In another paper, Dube et al. (2013) show that negative agricultural shocks contributed to the rise of the Mexican

[7]Grillo (2011) and Valdés (2013) provide thorough reviews of the history of drug trafficking in Mexico and its nexus with crime and violence

drug sector. The authors also find that, consistent with our findings, violence increased as a consequence.

Our paper contributes to this literature by showing that besides U.S. assault guns, negative agricultural shocks and Calderón's policies spearheaded at the municipal level by PAN mayors, Colombian anti-drug policies also played a role in the increase of Mexican violence since 2006. Our paper emphasizes the role of cross-country spillovers, but the logic is different from Dube et al. (2012). In particular, as we show in the paper, increases in interdiction rates in Colombia created cocaine shortages in downstream markets and increase revenue. As the following section shows, drug seizures increased dramatically in Colombia since 2006, and large seizures took place more frequently than before, creating large and frequent shortages in the Mexican cocaine market. According to our econometric results, this translates into more frequent and larger violence surges in Mexico since 2006. We do not see this as an alternative explanation for the increase in violence in Mexico, but rather as a complementary one. As we show in the empirical section, the effect of cocaine shortages is amplified in municipalities that have been historically more pro-PAN and which, following the logic outlined in Dell (2012), would fight cartels more aggressively. Thus, at least in the short run, Calderón's policies interacted with cocaine shortages to create the conditions for rapacity to spur violence, rather than providing an environment of tacit cooperation among cartels in which scarcity caused less rapacity and violence.

3 Mexican institutional background and Colombian cocaine shortage

During the last few years, Mexico has witnessed a dramatic increase in violence. The homicide rate in 2010 was almost three times that of 2005 (see figure 1). Most of the surge in violence in Mexico can be attributed to drug related violence. In 2007, there were 8,686 homicides, out of which 2,760 were estimated to be drug related. On the other hand, in 2010 there were 25,329 homicides; according to official figures, 15,258 of these were drug related. This means that the drug related homicide rate increased by 161 log points between 2007 and 2010, whereas the overall homicide rate increased by 98 log points during the same period.

Mexico has been the main point of entry of drugs into the U.S. since, at least, the turn of the century. Illicit drugs produced in the Andean countries, most importantly cocaine, used to be shipped to North American markets through the Caribbean, but with the blocking of the Caribbean route after the installation of several radars and other monitoring mechanisms controlled by U.S. authorities, Colombian and Mexican drug traffickers began to use the Mexican route more intensively to smuggle drugs into the U.S. Since then, struggles between DTOs striving to control drug trafficking routes became a major source of violence in Mexico. However, as shown by the data, the total number of homicides in Mexico was still low by Latin American standards until 2006. After this year it began to increase, mainly driven by drug related homicide rates.

The vast majority of cocaine flowing from the Andes to the U.S. is trafficked by Mexican cartels, who purchase cocaine from Colombian producers and, to a lesser extent, from Peru and Bolivia, and then smuggle it across the U.S. border using a variety of imaginative techniques.[8] Colombia became the main supplier of cocaine to downstream cartels in Mexico, and its role as a direct trafficker into the U.S. has fallen over time. Since Mexico does not produce cocaine, the cocaine industry behaves like a vertical market, with upstream producers of cocaine in Colombia who then sell it to Mexican cartels, which in turn traffic it across the U.S. border to distribute it. Although Mexico also produces drugs such as cannabis, heroin and ATS (Amphetamine-type stimulants), a large proportion of profits (between 50 and 60%) obtained by Mexican DTOs are generated by drug-trafficking activities, especially of cocaine, and not by drug production (see Kilmer et al., 2010).

We ask whether the increase in Mexican homicides and large episodes of drug related violence in Mexico after 2006 are related to dramatic and frequent cocaine shortages in Mexican drug markets caused by successful interdiction efforts in Colombia, especially after 2006. In that year the Colombian government redefined the anti-drug strategy, deemphasizing attacks on those parts of the drug production chain that produce lower value added (coca crops) and focusing more attention on the interdiction of drug shipments and the detection and destruction of cocaine processing labs. This change in the anti-drug strategy can be confirmed in the data, which shows a large increase in cocaine seizures. While the number of hectares of coca crops aerially sprayed with herbicides went down from 172,000 per year in 2006 to about 104,000 in 2009, cocaine seizures went up from 127 metric tons (mt) in 2006 to 203 mt in 2009, and the number of cocaine-processing labs detected and destroyed increased from about 2,300 to about 2,900 during the same period. These changes in strategy resulted in an important reduction in the supply of Colombian cocaine[9]. If we take UNODC figures on potential

[8]For instance, the Sinaloa Cartel used catapults to throw drug packages across the U.S. border, so that his men could pick them up on the other side of the border (Valdés, 2013).

[9]Mejía and Restrepo (2008) explain why this shift towards interdiction reduced supply.

cocaine production in Colombia and subtract from them the amount of cocaine seized in Colombia each year, the average monthly supply from Colombia decreased sharply from 43.5 to 16.6 metric tons. This negative supply shock was noticeable throughout the region and even in cocaine street prices in U.S. retail markets. The available evidence on cocaine prices suggests that the price per pure gram went up from about $135 in 2006 to about $185 in 2009 for purchases of two grams or less, and from $40 to $68 for wholesale purchases between 10 and 50 grams during the same period (according to the DEA's STRIDE database[10]).

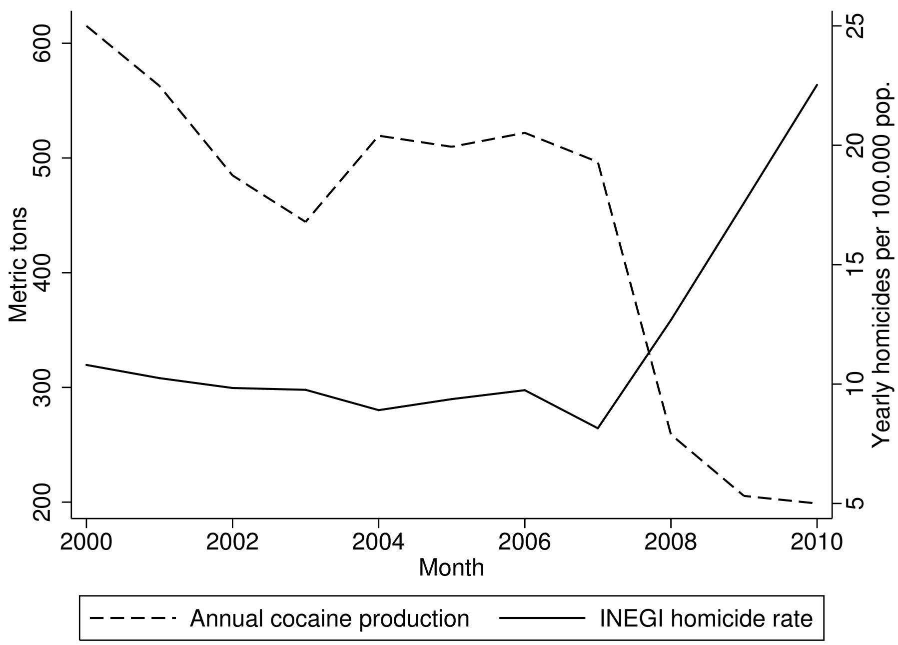


Figure 2: Net cocaine production in Colombia (in metric tons, left axis) and overall homicide rate in Mexico since 2000 (per 100.000 inhabitants, right axis). Net production is defined as potential production minus seizures and computed from UNODC cultivation and productivity figures, and official seizures statistics.

As figure 2 shows, the negative supply shock in wholesale cocaine markets starts in 2006, at the same time that the overall homicide rate in Mexico started increasing (there is no data for drug related homicides before 2006, but we suspect they follow a similar pattern). However, it would be inadequate to interpret this as evidence of a causal effect from cocaine shortages originating in producer countries such as Colombia on violence in Mexico. In particular, this correlation could be spurious and it could simply capture the fact that Calderón's term started in 2006 and at the same time

[10]The System to Retrieve Information from Drug Evidence (STRIDE) is a database of drug exhibits sent to Drug Enforcement Administration (DEA) laboratories for analysis (see: http://www.justice.gov/dea/resource-center/stride-data.shtml).

Colombia modified its anti-drug strategy. The fact that violence in Mexico trends upwards (especially in the north) since 2006, as well as seizures in Colombia, is what led us to focus on high frequency variation after controlling for these trends. The evidence obtained from monthly variation after flexibly controlling for trends is reliable and can be interpreted as causal, since there is no reason to expect monthly variation in seizures—which creates the variation in the supply of Colombian cocaine—to be correlated with Calderón's policies in Mexico or any other determinant of violence.

4 A model of scarcity and violence

In this section we present a model that guides and motivates our empirical analysis. Our model adds structure to the intuition outlined above and provides a richer set of implications to test. We start with a static model and then introduce some dynamic elements to analyze the role of informal cooperation arrangements and their interaction with enforcement and negative supply shocks in wholesale cocaine markets. Denote a municipality by i, with $i \in \{1, 2, \ldots, I\}$, and let s_i be its relative importance in cocaine trafficking. Here, s_i is the share of total revenue from the cocaine trade that is disputed in this municipality. Intuitively, municipalities close to U.S. entry points would have a large s_i since most of the trafficking activities will take place there, and control of these locations commands a larger share of total cocaine revenue.

Let Q^s be the supply of Colombian cocaine. We simplify the analysis and assume that Colombia is the only supplier of cocaine to Mexican cartels. This assumption does not change our results as long as Peru and Bolivia (the other two cocaine producer countries) do not have a perfectly elastic supply. We assume there is an iceberg cost, $1 - h$, of trafficking, so that the final supply of cocaine reaching the U.S. is hQ^s. This iceberg cost is shaped, among other things, by law enforcement and, especially, interdiction policies in Mexico. Drugs are sold at a final price P, so that the total revenue of the cocaine trade is hPQ^s. The demand for drugs is given by the inverse demand function $P^d(hQ^s)$, which we assume is inelastic throughout. This assumption implies that revenue increases as supply falls.

We assume that only a fraction $1-\eta$ of the total cocaine trade revenue is vulnerable to appropriation by other cartels and must be contested and defended through violence. Thus, $\eta < 1$ is a measure of how well protected property rights are, and it captures the presence of reliable third party enforcement. The above assumptions imply that the total drug revenue in municipality i that is vulnerable to appropriation by others is

$$(1-\eta)s_i hPQ^s. \tag{1}$$

There are N cartels, indexed by $c \in \{1, 2, \dots, N\}$. Let N_i be the set of cartels operating in municipality i. All cartels are rivals and we assume that within cartels there is perfect cohesion. Thus, this model only focuses on inter-cartel violence, but cartels without perfect cohesion or breakups can be easily incorporated by treating them as different cartels.[11] Our model assumes that cartels are unable to coordinate their actions to restrict supply and take advantage of the low elasticity of demand to increase profits. Also, we assume that cartels' location is exogenous, which we think is the right assumption when we look at high frequency variation in these markets. There may be entry or exit of cartels, but this does not occur at monthly frequencies. Let I_c be the set of municipalities in which a cartel operates. Finally, cartels are price takers in our model.[12] Even if there were some level of collusion, all we need is the degree of competition to be high enough that residual demands are elastic while market demand is inelastic.

The timing and full description of events is as follows:

1. Nature draws Q^s randomly from some distribution F with support $[0, \infty)$. In our empirical application the random nature of Q^s is created by enforcement changes in Colombia and month to month fluctuations in seizure rates.

2. Participants observe Q^s. Each cartel buys Q^s_c units of cocaine at a price P^s, traffics it and sells it at a price $P = P^d(hQ^s)$, with P^d being the inverse demand function. There is a variable convex cost $C(Q^s_c)$ of running the cartel operations that satisfies the usual Inada conditions. At this point, the cartel has already paid $P^sQ^s_c$ to Colombian producers and $C(Q^s_c)$ in operating costs. The total revenue generated by cocaine trafficking is hQ^sP. We assume demand is inelastic so that revenue increases when Q^s falls. We will show that the amounts determined at this stage, Q^s_c and P^s, have no incidence in the conflict or in the level of violence,

[11] We have also explored alternative models of moral hazard within cartels based on Acemoglu and Wolitsky (2011). In these models, cartels use more violence and coercion against their own members to induce effort when revenue is higher. Thus, intra-cartel violence could also increase as a consequence.

[12] The term cartel is therefore misleading, but for historical reasons it has been the name used by Latin American drug trafficking organizations, so we will stick to it. The powerful Colombian drug trafficking organizations of the 1980s and 1990s (especially those from Medellín and Cali) started calling themselves *carteles* in order to emphasize that they were a few organizations that controlled the whole trade, even though they did not collude to increase prices. The name stuck, and present-day Mexican organizations use the same name (see Gonzalbo, 2012).

but we still model this stage for the completeness of our analysis and to show that the effects we explore arise after an equilibrium in this market.

3. In order to appropriate or defend revenue, cartels engage in conflict against each other in the municipalities where they operate. They invest $g_{c,i}$ in weapons, personnel, recruitment, and training in municipality i. By doing so, cartel c is able to obtain a fraction $q_{c,i}$ of the total revenue being contested in municipality i, where $q_{c,i}$ is determined endogenously according to the following contest succcess function:[13]

$$q_{c,i} = \frac{g_{c,i}}{\sum_{c' \in N_i} g_{c,i}} \tag{2}$$

The aggregate level of drug related violence in municipality i is given by:

$$v_i = \sum_{c \in N_i} g_{c,i}. \tag{3}$$

4. Payoffs are realized. More specifically, cartel c obtains profits

$$-P^s Q^s_c - C(Q^s_c) + \eta h P Q^s_c + \sum_{i \in I_c} \left(q_{c,i}(1-\eta) s_i h P \sum_{c} Q^s_c - g_{c,i} \right) \tag{4}$$

Given the exogenous supply of drugs from Colombia, Q^s, which is drawn from a probability distribution, an equilibrium consists of market clearing prices and quantities in the U.S., $P(Q^s)$ and $Q(Q^s)$, a market clearing price for cocaine supplied by Colombia $P^s(Q^s)$, and conflict strategies $g_{c,i}(Q^s)$, such that they are a Nash equilibrium of the sub-game in which cartels fight over the rents in municipality i. We now characterize the equilibrium and some important properties.

The objective of cartels is to choose the amount of Colombian cocaine that they will intend to traffic, Q^s_c, and their conflict strategies $g_{c,i}$ to maximize profits. This problem is greatly simplified by noticing that the supply in the U.S. is simply hQ^s. Market clearing implies that the final price of cocaine is given by:

$$P(Q^s) = P^d(hQ^s). \tag{5}$$

Let $R(Q^s)$ be the total cocaine trade revenue generated by Mexican cartels. The above observation shows that this is equal to $R(Q^s) = hP^d(hQ^s)Q^s$, which increases

[13]A contest success function (CSF) is a technology wherein some or all contenders for resources incur costs as they attempt to weaken or disable competitors (see Hirshleifer, 1991). Also see Skaperdas (1996) and Hirshleifer (1989) for a detailed explanation of the different functional forms of CSFs.

when Q^s falls since demand is inelastic.[14] In equilibrium, the revenue disputed in municipality i only depends on Q^s, and is given by $(1-\eta)s_i R(Q^s)$. Thus, when choosing their conflict efforts, cartels simply face a series of independent problems in each municipality they operate. Cartel i's maximization problem is given by:

$$\max_{g_{c,i}} q_{c,i}(1-\eta)s_i R(Q^s) - g_{c,i}. \tag{6}$$

Notice that the choices over Q^s_c do not have to be taken into account when determining conflict efforts, since market clearing conditions impose a particular structure on equilibrium revenues, and because payments to Colombian cartels are treated as bygones (i.e., they are not contested).[15] The unique Nash equilibrium among cartels operating in municipality i is symmetric and given by:

$$g_{c,i}(Q^s) = \frac{|N_i|-1}{|N_i|^2}(1-\eta)s_i R(Q^s). \tag{9}$$

The above expressions fully characterize the level of violence in municipality i as

$$v_i(Q^s) = \frac{|N_i|-1}{|N_i|}(1-\eta)s_i R(Q^s). \tag{10}$$

This expression gives us our main proposition.

Proposition 1. *Suppose demand is inelastic, so that revenue $R(Q^s)$ is decreasing in Q^s. A decrease in the Colombian supply of cocaine, Q^s, increases revenue and leads to more violence (on average) in all Mexico. The increase in violence is larger when:*

[14]Mathematically, $\frac{\partial \log R}{\partial \log Q^s} = \left(1 - \frac{1}{|\epsilon^d|}\right)$, which is positive if and only if $|\epsilon^d| > 1$, i.e., whenever demand is inelastic.

[15] The model can still be fully solved as follows: Plugging the optimal choice of $g_{c,i}$ on the cartel's objective function yields

$$-P^s Q^s_c - C(Q^s_c) + \eta h P Q^s_c + \sum_{i \in I_c} \frac{1}{|N_i|^2}(1-\eta)s_i h P \sum_{c \in N} Q^s_c. \tag{7}$$

Therefore, the optimal choice of $Q^s_c \geq 0$ solves

$$P^s + C'(Q^s_c) \geq \eta h P + \sum_{i \in I_c} \frac{1}{|N_i|^2}(1-\eta)s_i h P, \tag{8}$$

with equality if $Q^s_c > 0$. The convex cost C satisfying the Inada conditions was introduced so that it is possible for this equation to have a solution for more than one cartel. Otherwise one cartel– the one having presence on the best locations– would buy all drugs and the others would simply prey from it. We do not think this alternative situation is unrealistic, as many cartels are toll collectors and simply prey on others, while not involved in cocaine trafficking directly. In fact, even with the convex cost it is possible for some cartels to specialize in preying on others while not trafficking at all. Here, P^s and P are taken as given by the cartel. The equilibrium prices $P(Q^s), P^s(Q^s)$ are the only prices that guarantee market clearing.

- *Third party enforcement is absent or weak, so that η is small.*

- *s_i is higher. That is, in municipalities that are more important for cocaine trafficking.*

- *There are more cartels $|N_i|$. In particular, the model predicts that violence would increase only if there are at least two rival cartels operating in the same municipality. Violence would remain unchanged if there is only one or no cartels (although there could be other sources of violence unrelated to the model).*

Proof. The proof follows simply from differentiating equation 10 to obtain comparative statics on the level of violence. The key observation is that expenditures on conflict increase with total revenue in a municipality, and total revenue increases when supply falls because demand is inelastic. □

In our empirical application we will analyze if the data supports this proposition. The first part of the proposition suggests that in the time series at the monthly level we should observe that months with low cocaine production in Colombia due to higher seizures should be months of higher violence in Mexico. There are several empirical counterparts to s_i that one can think of, but in our empirical application we focus on distance to entry points to the U.S. as an inverse measure of s_i. Clearly, municipalities that are closer to U.S. entry points will be more important for trafficking and cartels that control them would be able to extract more resources from the cocaine trade. Thus, it seems reasonable to associate these municipalities with a high value of s_i. Our model not only predicts that we should find a relation between scarcity and violence on average; there should also be a gradient, with violence increasing more in municipalities near U.S. entry points, and with the effect fading out as we move away from the frontier. Finally, the model suggests that it "takes two to tango". That is, violence should increase as a consequence of scarcity only in places with at least two cartels. Moreover, as the number of cartels operating in a municipality keeps increasing, the model predicts that scarcity will have a bigger effect on violence. We will test this implication by estimating the differential effect of cocaine shortages in municipalities with different numbers of cartels present at the time of the supply shock.

Before continuing with the dynamic extension of the model, we make some comments on its setup. First, note that shocks to Colombian supply Q^s are exogenous, as they will be in our econometric application. Second, note that s_i is an exogenous variable that captures, in a reduced form, how intensively drug trafficking uses routes, labor and resources in general from municipality i. The assumption is that in municipalities that are important for the cocaine trade, more revenue will be disputed. In a more complete model one would like to determine s_i from the production structure and technology, and study how this relates to more rents being present in a municipality. However, this suffices for the purposes of our model.[16] In our model, we think of cartels as trafficking cocaine across the U.S. border, so s_i does not capture the potential of a municipality for consumption. This interpretation could be easily accommodated, and, in fact, it would not change our interpretation or results, but the main source of profits from the cocaine trade are exports to the U.S. (see Kilmer et al., 2010), so we stick to the idea of cartels as smugglers that take drugs to the U.S.

Our model also assumes that cartels fight over the share of revenue that is vulnerable to appropriation. What they fight over is revenue and not profits, because payments to Colombian cartels are sunk costs. Thus, cartels are the full residual claimants of the rents they appropriate and protect from others. A slightly more complex version of our model would yield the same results as long as there is no perfect risk sharing between cartels and suppliers in Colombia. For instance, if cartels and suppliers were able to establish complex contracts, one could have a situation in which cartel payments to suppliers depend on its conflict success, and cartels could end up fighting over profits, rather than revenue. We believe that the absence of third party enforcement precludes these vertical relationships, and payments to Colombian suppliers can be treated as bygones.[17] Operating costs, C, are also bygones. This convex cost simply smooths the equilibrium and guarantees that it is possible to have more than one cartel operating in the cocaine trade and not simply preying on others. (For details, see footnote 15).

We assume an inelastic demand so that revenue increases as supply tightens. This is widely believed to be the case for drugs, especially for cocaine, since it is a psychoactive substance that is highly addictive: consumers buy their daily dose regardless of the market price, which means that demand does not respond largely to prices. Becker et al. (2006) mention an elasticity of less than 1 for most drugs, with a central tendency towards 1/2, especially in the short run. The relevant value for our model is the short run elasticity of demand, which is considerably smaller than in the long run, since a

[16]For instance, one could follow Dell (2013) and pose a model in which s_i is determined by the road network and enforcement in municipalities, and where the objective of cartels is to transport drugs to entry points to the U.S. minimizing transportation costs. In this model, municipalities that are along the faster drug routes would command a high s_i because they are helpful for production, and provide more rents to the cartels controlling them.

[17]However, other alternative models yield similar results. In Mejia and Restrepo (2013) scarcity increases conflict over the control of routes as long as the elasticity of demand is larger than the elasticity of substitution between drugs and routes. Castillo (2013) also provides conditions over the elasticity of demand that make enforcement increase profits.

short term spike in prices affects only a fraction of the present value of payments a consumer has to make to keep a drug habit (see Becker and Murphy (1988) for the full theoretical argument and Becker et al. (1994) for evidence from cigarette consumption).

Early attempts to measure the elasticity of demand of drugs estimated inelastic demands but focused mainly on marijuana and heroin. See, for instance, Nisbet and Vakil (1972) for Marijuana among UCLA students, Roumasset and Hadreas (1977) for heroin in Oakland, and Silverman and Spruill (1977) for heroin in Detroit. Wasserman et al. (1991) and Becker et al. (1994) find demand elasticities between -0.4 and -0.75 for cigarette consumption in the short run, which supports the idea that the demand for addictive substances is price inelastic. For cocaine, more recent studies typically estimate inelastic demands as well. Bachman et al. (1990) find no evidence of increasing availability of cocaine leading to more consumption among high school students. DiNardo (1993) finds no link between consumption and variation in enforcement. Both studies are consistent with an inelastic demand. Saffer and Chaloupka (1999) estimate a price elasticity of demand for cocaine of -0.28 (their estimates for alcohol and heroin are -.3 and -.98 respectively). Caulkins (1995) reaches a different conclusion using the fraction of arrestees testing positive for drugs to construct a measure of the elasticity of demand for cocaine and heroin: he finds elasticities for cocaine between -1.5 and -2.0. However, his methodology relies on the assumption that prices do not affect arrest rates, as well as other modeling choices, and only identifies a local elasticity among a particular group. Despite this single work that contradicts our assumption, we will maintain that cocaine demand is inelastic, as it is supported by our results. If demand were elastic, cocaine shortages would decrease violence, which is the opposite of what we actually find.

Finally, the contest success function in equation 2 is standard in the conflict literature and is not essential for our results (see Skaperdas (2002) for more on contest success functions). All we need for our results is that the function be concave in $g_{c,i}$, satisfy the Inada conditions, and exhibit either increasing differences in the vector of $g_{c,i}$, or small cross-derivatives if they are negative. This implies that the stakes at play increase violence, which is what one would intuitively expect. The conflict function is a reduced form representation of all strategies available to cartels to appropriate drug rents. For instance, cartels can act as toll collectors, and extort other cartels operating in municipality i that have cash, cocaine, or assets at this municipality due to its trafficking importance. They could also fight for turf in order to use routes and labor for their trafficking activities. They could prey on each other by violently stealing cash, weapons, assets or other resources, or they could eliminate competition from key municipalities, which could increase their market share. There are also non-violent ways in which cartels could compete for the rents of the cocaine trade obtained from controlling municipality i. For instance, they could bribe public officials, or even engage in the provision of goods to the community to gain popular support. We are not modeling these alternatives, which intuitively are more relevant in a longer planning horizon than in the monthly frequency we are considering in this paper. Using violence is an equilibrium even if these alternatives are available, and intuitively, it is the first order margin of response in the short run, when opportunities to prey become available and rapacity intensifies.

Having clarified these aspects of the model we move to a dynamic setup. We have repeatedly argued that our empirical strategy measures the response of violence to high frequency supply shocks in order to make sure that we do not measure spurious correlations. Thus, our model must also show that the results of proposition 1 hold when supply shocks last for a short time. We will follow Rothemberg and Saloner (1986), Abreu et al. (1990) and Castillo (2013). The dynamics allow us to focus on Subgame Perfect Equilibria (SPE) of the repeated game in which cartels fight each other for the control of revenue. We think this is a natural extension because in a world without third party enforcement, participants rely not only on violence, but also on informal arrangements sustained under the threat of retaliation, and SPE captures this possibility. The dynamic model allows us to understand the effect of supply shortages when such informal cooperative arrangements are in place, and more importantly, how they interact when government policies are aimed at capturing or killing cartel leaders, greatly reducing the scope of such arrangements.

In particular, we are interested in understanding the effect of enforcement during Calderón's war on drugs, and how it affected inter-cartel conflict. During our period of analysis, the war on drugs was spearheaded by the PAN party. As shown by Dell (2012), municipalities with PAN mayors were more likely to crack down on the drug trade. Calderón's strategy did not take the form of increasing seizures. In fact, cocaine seizure rates in Mexico varied little over time before and after Calderón took office. The real focus of Calderón's war on drugs was on arresting drug kingpins (see Guerrero, 2011a). This task was easier in municipalities with PAN mayors or large PAN support. Thus, we model the role of PAN by letting municipalities have an idiosyncratic arrest probability a_i which is higher when there is popular support for PAN actions. There are many other ways in which enforcement could affect our model of inter-cartel violence. For instance, η could be municipality-specific, with higher enforcement municipalities having a lower η, because a tighter enforcement of drug markets destroys property rights. Or h could be lower in municipalities with more enforcement if this is directed at seizing drugs, but as we argued above, we do not think this is what the anti-drug strategy on Mexico has focused on, at least during our period of analysis.

In the dynamic model, the same game described above is played repeatedly, with an independent draw of Q_t^s in each period. At the end of the period, nature reveals which cartel leaders are arrested. A cartel leader in municipality i is arrested with probability a_i and then replaced by a new one. We assume leaders take all decisions maximizing the cartel profits with their own discount rate $(1-a_i)\beta$, and not with the "market" discount rate β they would have if the incentives of the leaders and the cartel "shareholders" were aligned. In other words, arrests make cartel leaders behave more impatiently than they otherwise would, so, unlike what happens with traditional firms, the discount rate of the CEO—the leader—matters. The idea is that once a cartel leader is arrested or killed, the next leader cannot credibly compensate him for long term investments, which also stems from the lack of enforceable contracts in environments without third party enforcement. An alternative is to assume that with probability a_i the cartel is dismantled in municipality i, but casual observation suggest that Calderón's policy has been mostly to behead leaders who are quickly replaced (at least in the short run), which fits our model well. It is possible that some cartels will be dismantled on the long run, as suggested by some supporters of Calderón's policies, but we believe this is not the case at the monthly frequency we are focusing on.

Formally, at time t_0 a cartel maximizes

$$E_{t_0} \sum_{t \geq t_0} \beta^{t-t_0} (1-a_i)^{t-t_0} \left[-C(Q_{c,t}^s) - P_t^s Q_{c,t}^s + \eta h P_t Q_{c,t}^s + \sum_{i \in I_c} \left(q_{c,i,t} (1-\eta) s_i h P_t Q_t^s - g_{c,i,t} \right) \right], \tag{11}$$

where we have added a time subscript to all variables that change in time. The intra-period timing is as defined above. To simplify things we assume that cartels cannot condition their actions on past choices of quantities or cannot punish by demanding different quantities. Also, we assume that actions in municipality i can only be conditioned on past actions in this municipality. This greatly simplifies the characterization of Subgame Perfect Equilibria, while still allowing for some natural degree of cooperation maintained through the threat of retaliation. This assumption implies that quantities will be chosen as in the static problem, and we can treat the conflict in each municipality as a separate problem. For all cartel leaders in municipality i, we have a repeated game that we can study separately. Just as in the static problem, the amount paid for drugs $P_t^s Q_{c,t}^2$, the cost of running the cartel operation $C(Q_{c,t}^s)$, and the revenues that are not subject to appropriation $\eta h P_t Q^s_{c,t}$ are bygones. Thus, during each period they choose $g_{c,i,t}$ to maximize their expected payoffs

$$E_{t_0} \sum_{t \geq t_0} \beta^{t-t_0}(1-a_i)^{t-t_0} q_{c,i,t}(1-\eta) s_i R(Q^s_t) - g_{c,i,t}. \tag{12}$$

The unique Markov Perfect Equilibirum (MPE) of the dynamic game coincides with the repeated static equilibrium described above. However, we are interested in other Subgame Perfect Equilibria (SPE) which allow for more cooperation and punishments. Since the contribution of our paper is not at the theoretical level, we focus on the simplest SPE that allows for some degree of self-enforcing commitment. In particular, let $g^N(Q^s)$ be the symmetric static Nash equilibrium when supply is Q^s, which coincides with the solution to the static model. We consider a recursive equilibrium with all cartels spending $g^C(a_i, Q^s) \in [0, g^N(Q^s))$, and reverting to $g^N(Q^s)$ if anyone deviates. This may not be the most cooperative SPE but it is the simplest one and it helps us illustrate our point. The equilibrium is characterized in the following proposition:

Proposition 2. *Suppose demand is inelastic, so that $R(Q^s)$ is decreasing in Q^s. The equilibrium sustaining more cooperation through reversion to the static Nash MPE is recursive and involves $g_{c,i} = g^C(a_i, Q^s) \in [0, g^N(Q^s))$. The function g^C satisfies the following properties:*

- *Suppose revenue is unbounded from below. Then, for $Q^s \geq \overline{Q}(a_i)$, $g^N(a_i, Q^s) = 0$. Thus, for any arrest probability, there is no violence if revenue is sufficiently low. Moreover, $\overline{Q}(a_i)$ is increasing in a_i.*

- *Suppose revenue is unbounded from above. Then $g^N(a_i, Q^s) > 0$ for Q^s sufficiently small, even if $\beta(1-a_i) \to 1$. If revenue is bounded as $Q^s \to 0$, then a fully cooperative equilibrium with $g^N(a_i, Q^s) = 0$ $\forall Q^s$ can be sustained if $\beta(1-a_i) > \overline{\beta}$, for some $\overline{\beta}$.*

- *g^N is increasing in a_i, decreasing in Q^s and the cross partial is negative. Thus, supply shortages have a larger impact on violence in municipalities with a higher arrest rate, specially in those that are important for drug trafficking.*

Proof. The proof follows Rothemberg and Saloner (1986), and is presented in appendix B. □

The key intuition from this proposition is that in the absence of third party enforcement, there is room for some *de facto* protection of property rights created by the threat of future retaliation. In fact, cartels may behave less violent if they know that predatory behavior would trigger a reversion to the violent and costly static Nash equilibrium. Notice that when a_i is low and β high, an equilibrium with no violence can be sustained, where predation does not occur on the equilibrium path. This is a variant of the Folk theorem. However, as the effective discount rate decreases, participants value the future less and some level of predation has to be allowed in the SPE, especially when supply is tight and revenue is high. The reason is twofold: the temptation to prey is higher, and future revenues are also smaller on average, so future retaliation seems less severe. The arrest rate makes future punishments look even less severe by reducing the value of future payoffs, and an even larger level of violence must be allowed in the present when supply is tight. This logic explains the negative cross partial derivative of the function $g^C(a_i, Q^s)$. The allowed level of violence keeps down the incentives to deviate because it makes harder for other cartels to prey on others, given their current level of expenditure on weapons; but also because the incremental gain from exerting more violence is reduced.

One important point from the proposition is that informal arrangements based on dynamic threats are not enough to eliminate the consequences of supply shortages on violence as long as the future is significantly discounted. Thus, scarcity leads to violence even in the presence of informal cooperative arrangements because of the reasons outlined above. Informal arrangements are not only limited by the fact that revenue can be high today and small in the future, but also by a higher discounting among participants created by other policies.

The empirical content of this proposition is that supply shocks should have a larger effect in northern municipalities with high turnover of cartel leaders. Following Dell (2013), the effect of supply shortages should be especially large in the north, and in places where there is massive support for the PAN, which is the party that spearheaded the war on drugs in Mexico. In these municipalities there is more cooperation with federal authorities and Calderón's policy of arresting or killing cartel leaders decreases the effective discount rate more than in less pro-PAN municipalities.

The rest of the paper describes our empirical work in which we test the main predictions of our model and investigate the role of scarcity mediated by several factors, including the number of participants, the importance of the location for the commodity trade, and enforcement in the form of a higher probability of arrests or killing of participants.

5 Empirical strategy and data

In order to test our model, we need exogenous supply shocks to proxy for changes in Q^s. The Mexican setting, in which cocaine trafficked by cartels is purchased from Andean countries, suggests that we can use fluctuations in the Colombian supply of cocaine as our source of exogenous variation in scarcity. Though cartels may compensate by purchasing more cocaine from other sources, it would still be the case that final prices would rise by more than the fall in quantities as long as demand is inelastic.

To get a clean identification of the effect of scarcity, we focus on high frequency supply shocks at the monthly level. Monthly supply from Colombia is constructed by taking annual production and transforming it to monthly figures, and then subtracting monthly seizures. Using high frequency variation in the Colombian supply also has additional advantages. First, since we remove the low frequency component, long term trends that are spuriously correlated do not confound our estimates. More specifically, there is a downward trend in Colombian supply and an upward trend in crackdowns in Mexico since president Calderón took office at the end of 2006. This implies that there is a correlation at the yearly level that is likely to be spurious. The key identifying assumption is that this correlation breaks down at higher frequencies once trends are partialed out. The resulting monthly variation is arguably exogenous to other phenomena determining violence in Mexico or other secular trends. The second advantage is that this variation is mostly driven by changes in seizures, since monthly production by construction does not vary a lot at this high frequency. This can be seen from the high correlation between seizures and net supply in figure 3. Thus, our variation does not reflect the possibility that supply may be responding to changes in the Mexican market that could directly affect violence. In fact, results using seizures directly as the independent variable are very similar, suggesting that all our estimations are driven by the monthly variation in seizures in Colombia. Finally, the short run nature of these shocks implies that prices are more responsive, since there is less room for substitution, and other source countries cannot rapidly increase their supply.

These advantages of using high frequency shocks allow us to estimate the causal effect of short run fluctuations in scarcity due to exogenous conditions, and obtain a clean identification of its effect on violence. We are confident that the month to month variation in seizures that we exploit is mostly driven by luck (i.e., one military or police operation turned out to be successful in detecting and interdicting a cocaine shipment), or by factors that are exogenous to Mexico (i.e., politics or funding in Colombia). Figure 3 plots the monthly variation in the Colombian supply from 2000 to 2010 after removing time trends using a cubic polynomial (in the months) and year dummies.

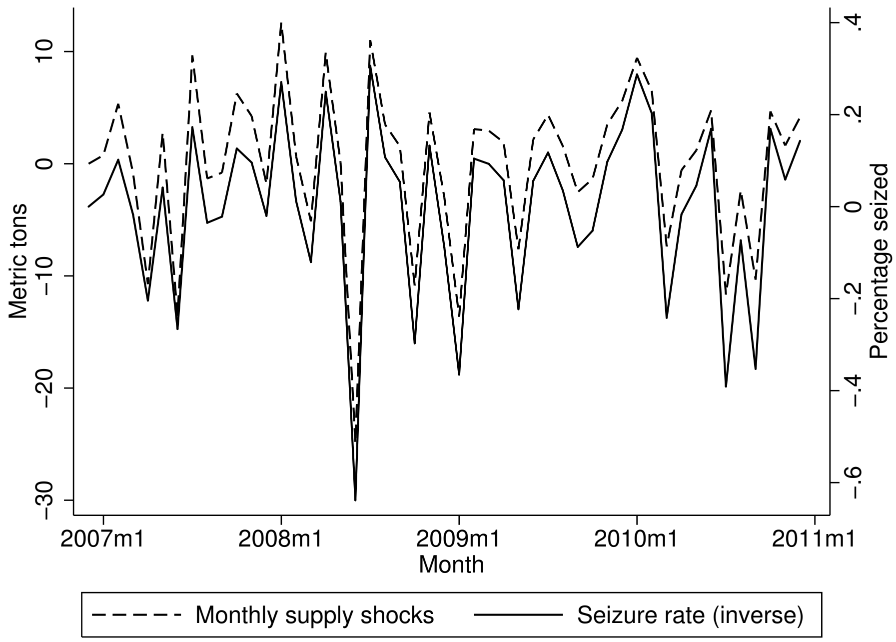


Figure 3: The figure shows the production of Colombian cocaine at a monthly level net of seizures (in metric tons, left axis). We plot the residual component after partialing out a cubic polynomial in the month. We plot the inverse of the monthly seizure rate on the right axis (data from the Colombian National Police).

We study the time series effect of these shocks on violence by estimating the model

$$h_{i,t} = \lambda_i + \beta c_t + S_t(\gamma) + \theta X'_{i,t} + \varepsilon_{i,t} \tag{13}$$

where $h_{i,t}$ is a monotone transformation of the homicide rate in municipality i at time t, c_t is the net cocaine production in Colombia in month t, and $\varepsilon_{i,t}$ is an error term. The term $S_t(\gamma) = \sum_{n=0}^{3} \gamma_n t^n + y_t$ includes both a cubic polynomial and year dummies that control flexibly for time trends. It therefore guarantees that we exploit only the high frequency component of cocaine production plotted in figure 3, which is driven by the exogenous variation in seizures in Colombia. In particular, this term eliminates all year to year variation and smooths longer term variation that may confound our estimates. Our results do not change if instead of a cubic polynomial we use a quadratic or quartic polynomial to detrend our data (see appendix A). Finally, X'_{it} is a vector with additional controls. This is essentially a time series exercise which exploits efficiently all the municipality data and controls for compositional changes. Our model suggests that $\beta < 0$, and we focus on this hypothesis in this case. The identifying assumption is that the high frequency component of cocaine production in Colombia, c_t, is orthogonal to $\varepsilon_{i,t}$ once time trends are flexibly controlled for. As we argued above, we believe this is the case at the monthly level.

To investigate the other predictions of our theoretical model, we estimate regressions of the form

$$h_{i,t} = \lambda_i + \delta_t + \beta c_t \alpha_i + \alpha_i S_t(\gamma) + \theta X'_{i,t} + \varepsilon_{i,t} \tag{14}$$

for different interaction variables α_i. In these models we test for heterogeneous effects of supply shocks on violence depending on municipality characteristics. Since in these models we focus on the differential effects of scarcity depending on municipality characteristics, we control for a full set of month dummies. The interaction term $c_t\alpha_i$ provides within municipality variation that allows us to identify the heterogeneous effect of cocaine shortages on violence. We explore heterogeneity by distance to U.S. entry points, which is our proxy for a municipality's importance in the cocaine tarde, s_i. On top of these interactions we will add another layer and investigate heterogeneity by the number of cartels operating in a municipality and by support for the PAN party. The conditions required to give our estimates a causal interpretation will be discussed when we present each set of results. One key aspect is that the term $\alpha_i S_t(\gamma)$ (with $S_t(\gamma) = \sum_{n=0}^{3} \gamma_n t^n + y_t$, just as in equation (13)) flexibly controls for differential trends and year to year variation in homicides that varies systematically with the interaction variable α_i. This gives us a sharper identification, since the effect of the interaction is obtained from a comparison between short term fluctuations in violence in municipalities with different α_i during a supply shock. Before moving to our estimation we present our data.

5.1 Data

Our main dataset is a monthly panel of 2,438 Mexican municipalities from December 2006 until December 2010. Our dependent variables are measures of the monthly homicide rate in a municipality. We use two main sources. Our first source is the monthly homicide rate from INEGI (Mexico's Instituto Nacional de Estadística y Geografía[18]). This data is available from 1990 to 2010 and includes all homicides (not only those related to drug trafficking). Our second source is the data on drug related homicides that was published by the Mexican Presidency, and includes the number of monthly casualties from December 2006 until December 2010.[19] This dataset only includes homicides

[18]The data can be downloaded from INEGI's website, `www.inegi.org.mx`

[19]Unfortunately, the new Mexican government of Enrique PeÃ±a Nieto, who took office in December 2012, stopped publishing these homicide rates, which were previously available online.

that, according to local authorities, had a relation with the illegal drug trade. Drug related homicides are divided into three broad categories: (1) executions, which involve targeted assassinations by DTOs; (2) confrontations, which are the result of battles either between competing DTOs or between DTOs and government authorities; and (3) aggressions, which are targeted homicides caused by DTOs attacking government forces. However, there is an ongoing debate about the reliability of this classification.[20] Thus we also show all of our results using the INEGI measure of the overall homicide rate. Another advantage of the INEGI measure is that it covers a longer time period, which will be useful in some of our empirical exercises. Finally, in our robustness exercises we also use the homicide rates reported by the SINAIS[21], which gathers the information from public health records.

We compute monthly homicide rates (normalized at a yearly basis) using census population counts. Given the high skewness in homicide rates, we follow literature on crime and use a logarithmic transformation. However, this is problematic at a monthly frequency because there is a high probability of having no homicides. We address this issues by estimating our models with different transformations of the homicide rate. In particular, for any homicide rate we use

$$h_{i,t} = \log(r_{i,t} + p_{90}), \tag{15}$$

with p_{90} being the 90th percentile of the homicide rate in our sample. This transformation is increasing in $r_{i,t}$, and is well defined. Our results hold for a variety of alternative transformations shifting the homicide rates by different amount (such as the 50th or the 10th percentile); for Poisson or negative binomial models; or for a dummy that takes the value of 1 when there is a homicide recorded (see appendix A). The reason why we choose the 90th percentile in our preferred estimate is that it is the transformation that results in errors that are closest to normal.

To interpret results obtained with this transformation, notice that the approximation

$$\Delta \log(r_{i,t} + p_{90}) \approx \frac{r_{i,t}}{r_{i,t} + p_{90}} \Delta \log r_{i,t}, \tag{16}$$

holds. The sample average of $\frac{r_it+p_90}{r_it}$ is 10.07 for the INEGI homicide rate and 21.12 for drug related homicides. Thus, an easy rule of thumb to transform our estimates into log points is to multiply them by 10 when the dependent variable is the INEGI homicide rate and by 20 when the dependent variable is the drug related homicide

[20] For some of the articles that criticize the data, see Lizárraga (2012) and Proceso (2012).

[21] Sistema Nacional de Información en Salud - `http://www.sinais.salud.gob.mx/`

rate.[22] We will use this simple rule of thumb when discussing the economic significance of our results. Of course, the approximation does not hold for larger changes in policies and in those cases we will compute the exact implied changes in homicides rates under counterfactual scenarios.

As explained above, we explore the effect of scarcity mediated by the trafficking importance, the number of cartels and the political power of the PAN party. We use the distance to the nearest U.S. entry point as our proxy for trafficking importance. This is computed as the distance from the centroid of each municipality to the closest U.S. entry point. The centroids are obtained from INEGI and the entry points from Google Earth. To explore heterogeneity by the number of participants or cartels, we use the measure of presence of drug cartels proposed by Coscia and Ríos (2012), who, based on web content such as blogs and news, build a yearly panel that tells whether each cartel was present in each municipality during each year. The dataset covers the period from 1990 until 2010 and contains information about the seven most important Mexican drug cartels in this period (Cartel de los Hermanos Beltrán Leyva, Familia Michoacana, Cartel del Golfo, Cartel de Juárez, Cartel de Sinaloa, Cartel de Tijuana and Los Zetas), as well as about the presence of other smaller DTOs. Finally, to explore heterogeneity by PAN political power, we use historical voting shares for PAN municipal mayors in the municipality.

Our variation in scarcity comes from high frequency changes in the supply of Colombian cocaine induced by interdiction efforts. We construct a monthly measure of the net supply of Colombian cocaine as follows: First, we compute annual cocaine production figures from UNODC and convert them to a monthly basis by extrapolating with a third-order spline of the logarithm of production. We then subtract from each month's estimated production cocaine seizures within Colombia during that month. Seizures are obtained from data provided by the Colombian Ministry of Defense covering all months in our sample (the detrended component of these series was presented in figure 3). When giving an idea of the size of our estimates, we will compute the effect of a 10mt decrease in the monthly net Colombian supply of cocaine. This is roughly the standard deviation of this series and about 1/5th of the average monthly production of Colombian cocaine in 2006.

We also include some additional municipality covariates in some of our estimations, all of which were obtained from INEGI. First, we include municipality income, which varies at the yearly level. We also include some measures of state presence, which include

[22] The corresponding adjustment factors for executions, confrontations and aggressions are 19.8, 47.84 and 32.30, respectively.

social security personnel per capita (both from the Mexican Institute or Social Security (IMSS) and from the Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado (ISSSTE)) and middle and high school teachers per capita. Again, these variables only vary at a yearly level, so they control for longer term socioeconomic phenomena when added as covariates. In our time series exercises we control for the INEGI national unemployment rate at the monthly level and for the IGAE, a measure of economic activity that is available on a monthly basis, and which is highly correlated with the GDP.

Table 1 summarizes our data. The table presents statistics separately for all Mexico, for the 40% closest municipalities to U.S. entry points (quintiles 1 and 2 of the distance), and for the 20% closest municipalities (the first distance quintile). Note that the Mexican population is skewed towards municipalities that are closer to the U.S.: The first distance quintile includes 24.9% of the national population, and quintiles 1 and 2 include 60%. Many of our results focus on these two quintiles, which include the majority of the Mexican population.

The top panel summarizes time varying variables. For each group it reports statistics for all months or for the growth of the variable between 2007 and 2010 (recall that our first month is December 2006). The bottom panel reports fixed municipality characteristics. As the table shows, the north of Mexico (Quintiles 1 and 2) is more violent as measured by the INEGI homicide rate and drug related homicides. Not only were quintiles 1 and 2 more violent in 2007, but violence also increased disproportionally in the north. The homicide rate in Mexico increased by 98 log points, while it increased by 119 log points in quintiles 1 and 2, and by 164 log points in the first quintile. A similar pattern emerges for drug related crimes. Interestingly, the data shows that the vast majority of homicides in the north are drug related, whereas homicides in other areas of the country are less so. In consistency with the intuition that the north of Mexico is more important for cocaine trafficking, we see a higher cartel presence in quintiles 1 and 2 than in the country as a whole. In particular, the average number of cartels per municipality was 0.86 in the first quintile, and 0.47 in Mexico as a whole. Furthermore, most homicides in our data took place in these two quintiles: they include 55% of all homicides committed in 2006, and 75% of homicides committed in 2010. The growth in cartel presence during this period has been more homogeneous along the country. Finally, northern municipalities are historically more likely to support the PAN, as captured by the PAN vote share during 1990-2000.

Table 1: Summary statistics.

Panel A: Panel variables							
		First quintile		Quintiles 1 and 2		All of Mexico	
		All years	Change 2007-2010 (log points)	All years	Change 2007-2010 (log points)	All years	Change 2007-2010 (log points)
INEGI homicides	Mean	1.17	169	1.04	123	0.60	103
	St. Dev.	(10.2)	(9.8)	(7.92)	(6.7)	(5.13)	(5.17)
	Observations	24,108		48,216		120,442	
INEGI homicide rate	Mean	25.4	164	16.4	119	14.8	98
	St. Dev.	(56.7)	(6.05)	(37.8)	(5.35)	(35.2)	(3.33)
	Observations	24,108		48,216		120,345	
Drug-related homicides	Mean	0.778	221	0.556	181	0.292	166
	St. Dev.	(8.21)	(10.1)	(6.06)	(7.78)	(3.91)	(6.15)
	Observations	24,108		48,216		120,442	
Drug-related homicide rate	Mean	16.9	216	8.81	176	7.28	161
	St. Dev.	(65.7)	(15.5)	(42.2)	(15.8)	(36.1)	(7.94)
	Observations	24,108		48,216		120,345	
Number of cartels	Mean	0.861	61	.695	75.6	.471	78
	St. Dev.	(1.27)	(2.03)	(1.19)	(1.67)	(1.02)	(1.33)
	Observations	2,458		4,916		12,290	
Municipal income (Mexican pesos)[23]	Mean	2,658	27.1	1,960	27.6	2,136	26.6
	St. Dev.	(1,113)	(1.69)	(1,403)	(1.44%)	(1,420)	(0.768)
	Observations	2,458		4,916		12,290	
State healthcare personnel / 1,000 inh.	Mean	0.969	2.33	0.793	2.67	0.748	0.95
	St. Dev.	(0.727)	(1.05)	(0.693)	(0.877)	(0.705)	(0.584)
	Observations	2,458		4,916		12,290	
State teachers / 1,000 inh.	Mean	13	0.785	11.5	-1.15	12.3	-1.5
	St. Dev.	(2.65)	(0.468)	(4.63)	(0.39)	(4.21)	(0.253)
	Observations	2,458		4,916		12,290	

Panel B: Cross-sectional variables				
		First quintile	Quintiles 1 and 2	All of Mexico
Population	Mean	57,438	77,906	50,182
	St. Dev.	154,383	332,115	225,021
Distance to U.S. border	Mean	331	508	758
	St. Dev.	(184)	(220)	(267)
Historic voting for PAN, 1990-2000	Mean	0.280	0.256	0.176
	St. Dev.	(0.140)	(0.149)	(0.161)
Observations		492	984	2,458

[23]The exchange rate was around 12 Mexican pesos for each U.S. dollar during the whole period of analysis.

6 Results

In this section we present our results. We estimate most of our models separately for all the municipalities in our sample and for a subsample that contains municipalities in the first two quintiles of the distribution of distance to the U.S. border. We do this because cocaine trafficking, and the economic forces that we want to test, are particularly important in the north of Mexico. As shown above, quintiles 1 and 2 encompass a large share of the population. The predominant role of cocaine trafficking in the north is evident from the larger share of homicides, especially drug related homicides, as well as cartel presence.

6.1 Time series results

We start by providing evidence in favor of the main prediction in proposition 1, namely that violence increases in Mexico when cocaine becomes scarce due to low supply from Colombia. Figure 4 plots monthly supply production in Colombia against the average drug related homicide rate in Mexico. Both series are detrended using a cubic polynomial in the month and year dummies, so that we only focus on their high frequency relationship. The figure suggests a high negative correlation between supply in Colombia and violence at the monthly frequency in Mexico. The negative correlation between both series is high (-0.20), and becomes higher if we only focus on quintiles 1 and 2 (-0.35). This provides *prima facie* evidence for the mechanism proposed in this paper.

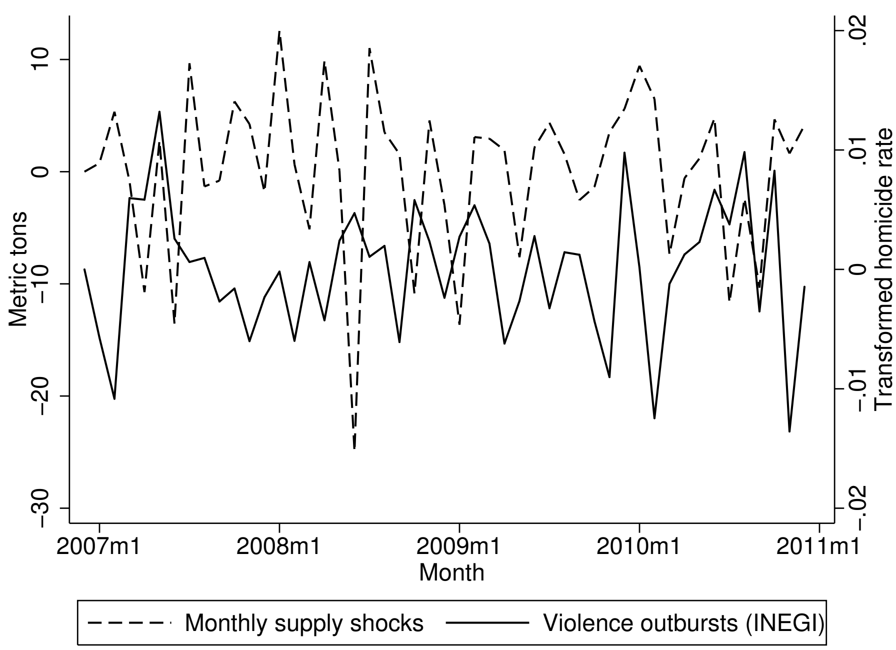


Figure 4: The figure shows the production of Colombian cocaine at the monthly level net of seizures (in metric tons, left axis). We plot the residual component after partialing out a cubic polynomial in the month. The right axis plots the detrended component of the INEGI homicide rate.

To provide further evidence, we estimate some variations of the model in equation

13. Table 2 presents our results. The table has five panels, each one with a different dependent variable: the shifted log of the INEGI homicide rate, the drug related homicide rate, the rate of drug related executions, the rate of drug related confrontations, and the rate of aggressions. Columns 1 and 2 focus on the first distance quintile, columns 3 and 4 on quintiles 1 and 2, and columns 5 and 6 on all Mexico. Even columns add time series controls varying at the monthly level, including the unemployment rate and and a measure of economic activity (IGAE). Though we regard these controls as endogenous and favor our estimates without them, it is reassuring to see that our main results hold after their inclusion. We do not report these coefficients to save space. As expected from our model and the intuition provided above, all estimates are uniformly negative except for drug related aggressions. There is a robust and significant time series effect of lower cocaine supply in Colombia on higher levels of violence in Mexico. According to all measures of violence, the relationship is stronger in northern municipalities belonging to distance quintiles 1 and 2, and even stronger for the first distance quintile. This is reasonable since cocaine trafficking is concentrated mostly in the north of Mexico (with the states of Michoacán and Guerrero being the most important exceptions). The dynamics of violence in the rest of the country respond to different forces, explaining why we find weaker effects when we estimate the model for Mexico as a whole.

Under each estimate we report two types of standard errors. The first one assumes there are no aggregate time shocks in the error term, but allows for arbitrary serial correlation within municipalities. The second one allows for serial correlation across observations in a given month and estimates the standard errors following the two-way clustering procedure by Cameron et al. (2011) and Thompson (2011). The asterisks indicate the significance level obtained for the first set of standard errors. The second set of standard errors are higher in most cases, suggesting the presence of correlated shocks in time, and in some specifications our estimates lose significance at traditional levels when using these standard errors to draw inferences. However, our estimates using the INEGI homicide rate or the drug related homicide rate remain significant—especially for the first two quintiles—and our estimates using the total drug related homicide rate now have p-values that are only slightly larger than 0.1.

If we look in detail at the subcategories of the drug related homicide rate, we find effects consistent with our theory for executions and confrontations. On the other hand, the effect of scarcity on aggressions is a precisely estimated zero. We think this is informative as well. Aggressions, which are targeted homicides caused by DTOs attacking government forces, are not related to the theoretical mechanism emphasized

Table 2: Effects of cocaine shortages on average violence in Mexico.

	All Mexico		Quintiles 1 and 2		First quintile	
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: INEGI homicide rate.					
Net cocaine supply from Colombia	-0.012*	-0.010	-0.035***	-0.033***	-0.051***	-0.046**
	(0.006)	(0.006)	(0.010)	(0.010)	(0.017)	(0.018)
	(0.005)	(0.005)	(0.008)	(0.009)	(0.015)	(0.016)
Observations	120296	120296	48167	48167	24108	24108
R-squared	0.004	0.004	0.013	0.013	0.021	0.022
	Dependent variable: Drug related homicide rate.					
Net cocaine supply from Colombia	-0.009**	-0.008**	-0.023***	-0.020**	-0.039**	-0.034**
	(0.004)	(0.004)	(0.008)	(0.009)	(0.015)	(0.016)
	(0.007)	(0.007)	(0.013)	(0.013)	(0.025)	(0.025)
Observations	120296	120296	48167	48167	24108	24108
R-squared	0.007	0.007	0.012	0.012	0.020	0.021
	Dependent variable: Drug related executions.					
Net cocaine supply from Colombia	-0.006	-0.006	-0.017**	-0.015**	-0.026*	-0.023
	(0.004)	(0.004)	(0.007)	(0.008)	(0.013)	(0.014)
	(0.005)	(0.005)	(0.010)	(0.011)	(0.021)	(0.022)
Observations	120296	120296	48167	48167	24108	24108
R-squared	0.006	0.006	0.011	0.011	0.017	0.017
	Dependent variable: Drug related confrontations.					
Net cocaine supply from Colombia	-0.004**	-0.004**	-0.009**	-0.008**	-0.017**	-0.017**
	(0.002)	(0.002)	(0.004)	(0.004)	(0.007)	(0.008)
	(0.002)	(0.002)	(0.005)	(0.005)	(0.009)	(0.010)
Observations	120296	120296	48167	48167	24108	24108
R-squared	0.001	0.002	0.003	0.003	0.006	0.006
	Dependent variable: Drug related aggressions.					
Net cocaine supply from Colombia	-0.004**	-0.004**	-0.009**	-0.008**	-0.017**	-0.017**
	(0.002)	(0.002)	(0.004)	(0.004)	(0.007)	(0.008)
	(0.002)	(0.002)	(0.005)	(0.005)	(0.009)	(0.010)
Observations	120296	120296	48167	48167	24108	24108
R-squared	0.001	0.002	0.003	0.003	0.006	0.006
Time series controls:						
Unemployment rate		✓		✓		✓
IGAE		✓		✓		✓

Note.- The table presents estimates of the effect of supply shortages (measured at the monthly level in hundreds of metric tons) on violence in Mexico. The dependent variable is the shifted log of the homicide rate indicated in each panel. Even columns add unemployment and a measure of economic activity as controls. Columns 1 and 2 present estimates for the whole Mexican territory; Columns 3 and 4 for quintiles 1 and 2; and Columns 5 and 6 for the first quintile. Two sets of standard errors are reported in parenthesis below each estimate. The first is robust to heteroskedasticity and serial correlation within municipalities. The second also allows for correlated time shocks across municipalities. Coefficients with *** are significant at the 1% level, with ** are only significant at the 5% level and with * are only significant at the 10% level using the first set of standard errors.

in our model, especially at such high frequencies. Targeted homicides of government officials seem to be part of a more long run strategy of intimidation rather than a reaction to current short term economic incentives. By contrast, our model emphasizes inter-cartel violence or confrontations resulting as a fast reaction to temporal shocks. This type of violence is better captured by executions– which includes assassinations of other (or own) cartel members– and confrontations.

We now discuss the quantitative implications of our estimates. The estimates in columns 1, 3 and 5, which are our preferred specifications, suggest that a 10 mt reduction in the Colombian supply during a given month—which coincides roughly with its standard deviation—increases violence as measured by the INEGI homicide rate by 5.1 log points in municipalities in the first quintile in Mexico (s.e=1.5-1.7); 3.5 log points in Municipalities in quintiles 1 and 2 (s.e=0.8-1.0); and 1.2 log points in municipalities in all Mexico (s.e=0.5-0.6). These numbers are obtained by multiplying the reported coefficients and standard errors by 0.1 (since 10 mt are 0.1 hundreds of a metric ton), and then multiplying them by 10–the rule of thumb adjustment to interpret changes in shifted logs in terms of percentage changes. Likewise, the same supply reduction increases the drug related homicide rate by 7.8 log points in municipalities in the first quintile in Mexico (s.e=3.0-5.0); 4.6 log points in municipalities in quintiles 1 and 2 (s.e=1.6-2.6); and 1.8 log points in municipalities in all Mexico (s.e=0.8-1.4). In this case, the rule of thumb adjustment factor is 20 as discussed in the data section.

Similar calculations can be done for executions, confrontations, and aggressions, with adjustment factors of 20, 50, and 30, respectively. A supply reduction of 10 mt causes increases in executions of 1.2 log points in all Mexico, 3.4 log points in quintiles 1 and 2, and 5.2 log points in the first quintile. The same supply reduction causes an increase in confrontations of 2 log points in all Mexico, 4.5 log points in the first two quintiles, and 8.5 log points in the first quintile. The effect on aggressions is a precisely estimated zero, so we do not discuss it. As stated earlier, our model only predicts changes in executions and confrontations, so these numbers validate our theoretical results. Furthermore, it is reasonable to expect larger increases in confrontations than in executions, since confrontations are directly related to battles for turf of the type that would be created when rapacity increases, whereas executions are more directly linked to vendettas and other types of violence—which would anyway increase as a consequence of rapacity, at least due to spillover effects.

Based on this numbers, let us now make a calculation of the magnitude of the effect of Colombian supply reduction on Mexican violence in the last few years. Since these numbers are not small anymore, we will not use the rule of thumb that works for small changes. Instead, we make the exact calculation. This calculation requires the important assumption that the short run effects we have identified apply over longer periods, since the supply reduction in Colombia from 2006 to 2010, unlike the shocks used in our econometric strategy, is a more permanent phenomenon. Using the INEGI figures, our estimates suggest that the 26.9 mt fall in monthly cocaine supply from Colombia during 2006-2010 caused an increase of 3.2 log points in violence in all of Mexico, which accounts for 2.9% of the total increase, and an increase of 13.0 log points in the first quintile, which accounts for 7.7% of the total increase in northern Mexico. Though sizable, there are important caveats to the assumption underlying this calculation. First, demand may be more elastic over the long run, implying smaller effects. Likewise, supply from other Andean countries may adjust slowly, implying smaller effects in the long run as these adjust. Second, our theoretical discussion highlights that temporary shocks have a larger effect than permanent ones. The reason is that a temporal shortage that is soon reversed implies large revenues today and low revenues tomorrow. Therefore, future punishments look less severe, and higher violence must be allowed today. In contrast, permanent shocks also raise the deterrence power of future punishments, so they raise violence less. Despite these caveats, we offer these calculations as a useful benchmark. In any case, large and temporal cocaine shortages caused by interdiction policies in Colombia since 2006 have created large outbursts of violence in Mexico, at least in the short run according to our evidence.

Now, we study the full dynamic effect of supply shocks in an event study setting. To do so, we estimate the full dynamics of the homicide rate in a window of six months before and after a supply shock in Colombia. In particular, we estimate the model

$$h_{i,t} = \lambda_i + \sum_{j=-6}^{6} \beta_j c_{t+j} + S_t(\gamma) + \theta X'_{i,t} + \varepsilon_{i,t}. \tag{17}$$

The estimates of β_j are then used to find the behavior of the homicide rate around a reduction of 10 metric tons in the monthly cocaine production in Colombia at time 0. Figure 5 shows the dynamics of the INEGI homicide rate around such a reduction in the Colombian supply. The average level before the shock is normalized to zero for comparability. The left panel shows the effect on quintiles 1 and 2, and the right panel in all Mexico.[24] In consistency with the previous results we see that violence, as measured by the INEGI overall homicide rate, increases exactly during the cocaine shortage and then decays back to its pre-shock level. The magnitudes are re-scaled so

[24]The effect on the first quintile follows a similar path but its bigger and less precisely estimated. It is not presented here to save space.

that the vertical axis measures the change in log points of the homicide rate. The peak in homicides for quintiles 1 and 2, which occurs exactly at the time of the supply shock, is close to the 3.5 log point effect estimated in Table 2. The estimated pattern for all Mexico is less clear and less precise, but also suggests a peak effect at the time of the supply shock close to the 1.2 log points estimated previously.[25]

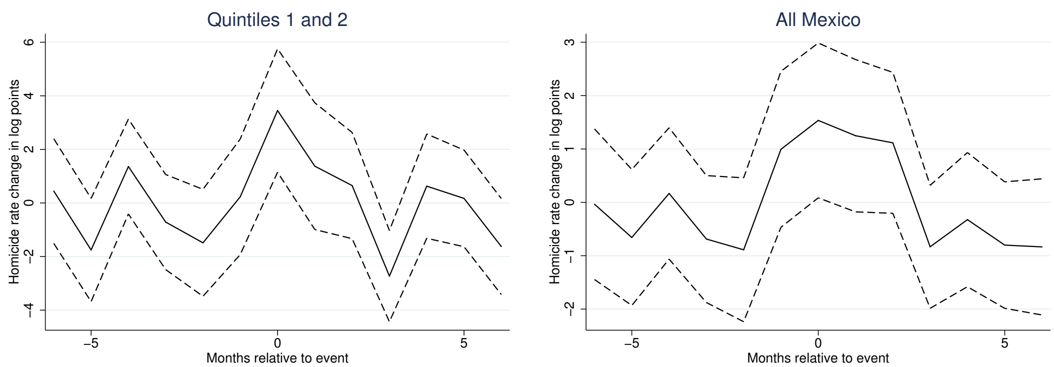


Figure 5: The figure shows the path of the INEGI homicide rate around a 10 metric ton reduction in cocaine production from Colombia at time 0. The solid line plots our estimates, with the pre-shock level of homicides normalized to zero. The 95% confidence interval is plotted in dashed lines.

Figure 6 presents analogous plots constructed using the drug related homicide rate. The dynamics are very similar and suggest that drug related homicides also increase during the shortage and then recover, with no significant pre-trends. The peak of the effect again coincides with the timing of the supply shock, though the size of the peak is slightly larger than the corresponding estimates in Table 2. We do not present figures separately for confrontations and executions, but they all show the same consistent picture, namely that violence increases significantly, peaking at the time of the negative supply shock, with no significant pre-trends, and going back to its pre-shock level afterwards. All these features are consistent with our model and also provide support for our empirical strategy.

So far, we have presented results that show that net cocaine production in Colombia, which is mostly driven in the short term by cocaine seizures, has an effect on the levels of violence in Mexico. We argued that this occurs through an increase in cocaine revenues, which is the case as long as demand is inelastic. Unfortunately, we cannot measure the amount of drug related rents that are being contested in a municipality, or the amount of drug revenue in Mexico on a monthly basis.[26] Rather, we provide some reality checks

[25]The fact that homicides were high the month before– though not at a significant level– could be caused by the possibility that interdiction operations take a while to succeed. During their implementation, they may disrupt supply even before the final seizures are coded.

[26]The general problem is that we lack reliable data on cocaine prices, specially at such high frequency.

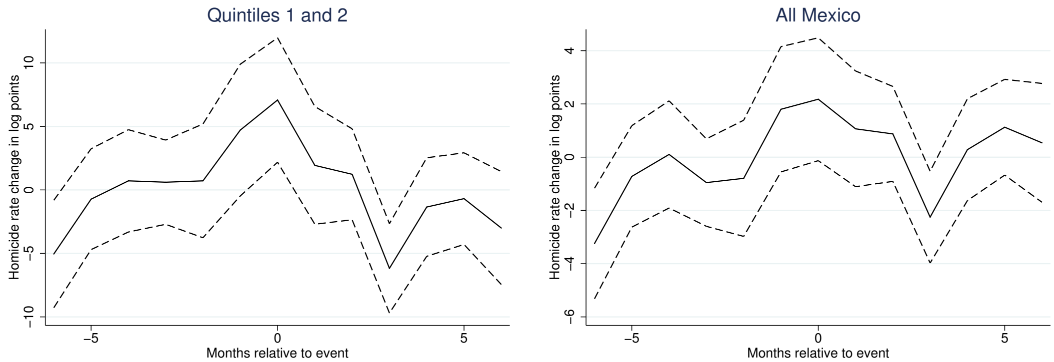


Figure 6: The figure shows the path of the drug-related homicide rate around a 10 metric ton reduction in cocaine production from Colombia at time 0. The solid line plots our estimates, with the pre-shock level of homicides normalized to zero. The 95% confidence interval is plotted in dashed lines.

suggesting that cocaine shortages in Colombia seem to have increased revenues focusing on longer term variation. Figure 7, shows that wholesale cocaine prices have increased dramatically from 2007 until 2010, as the Colombian supply declined. In particular, while net cocaine production in Colombia went down from about 470 MT per year in 2007 to about 207 MT in 2009 (a 55% decline), the price per pure gram of cocaine in the streets of the U.S. went up from about $135 in 2006 to about $185 in 2009 for purchases of two grams or less (a 40% increase), and from $40 to $68 for purchases between 10 and 50 grams during the same period (a 70% increase). Taking into account the net production from Peru and Bolivia, total gross drug trade revenue measured using wholesale prices in the U.S.—which are the ones perceived by Mexican cartels—increased by about 7% between 2006 and 2009, suggesting an inelastic demand even at lower frequencies.[27] Even though this calculation is done by comparing variation across several years, which is different from the variation we exploit in our empirical exercise, it provides some suggestive evidence that cocaine shortages indeed increase revenues for Mexican cartels as required by our mechanism. The fact that retail prices rose only for cocaine during this period, and not for the three other drugs that flow through Mexico (heroin, marijuana and methamphetamine), further increases our confidence

UNODC reports yearly prices, and quarterly prices can be constructed using STRIDE undercover purchases reports. However, there are sizable doubts about the quality of such data and how to interpret its variation in time and across locations. This becomes especially worrying when relying on the smaller samples used to construct quarterly series (see Horowitz (2001), and Arkes et al. (2008), for a reply arguing that there is some information in the STRIDE data especially for estimating price trends). These concerns and the fact that we only have 12 quarters of data preclude any reasonable econometric exercise.

[27]Part of this revenue corresponds to routes other than the Mexican one. Peru and Bolivia have to be taken into account because cartels may substitute towards this sources, and this would also add to their revenue stream.

that increases in Colombian cocaine seizures had an effect on violence in Mexico through the increase in cocaine prices and rents associated to the cocaine market.

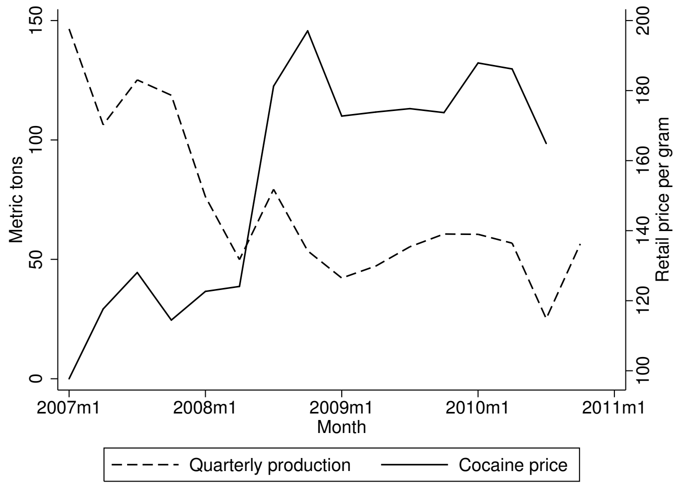
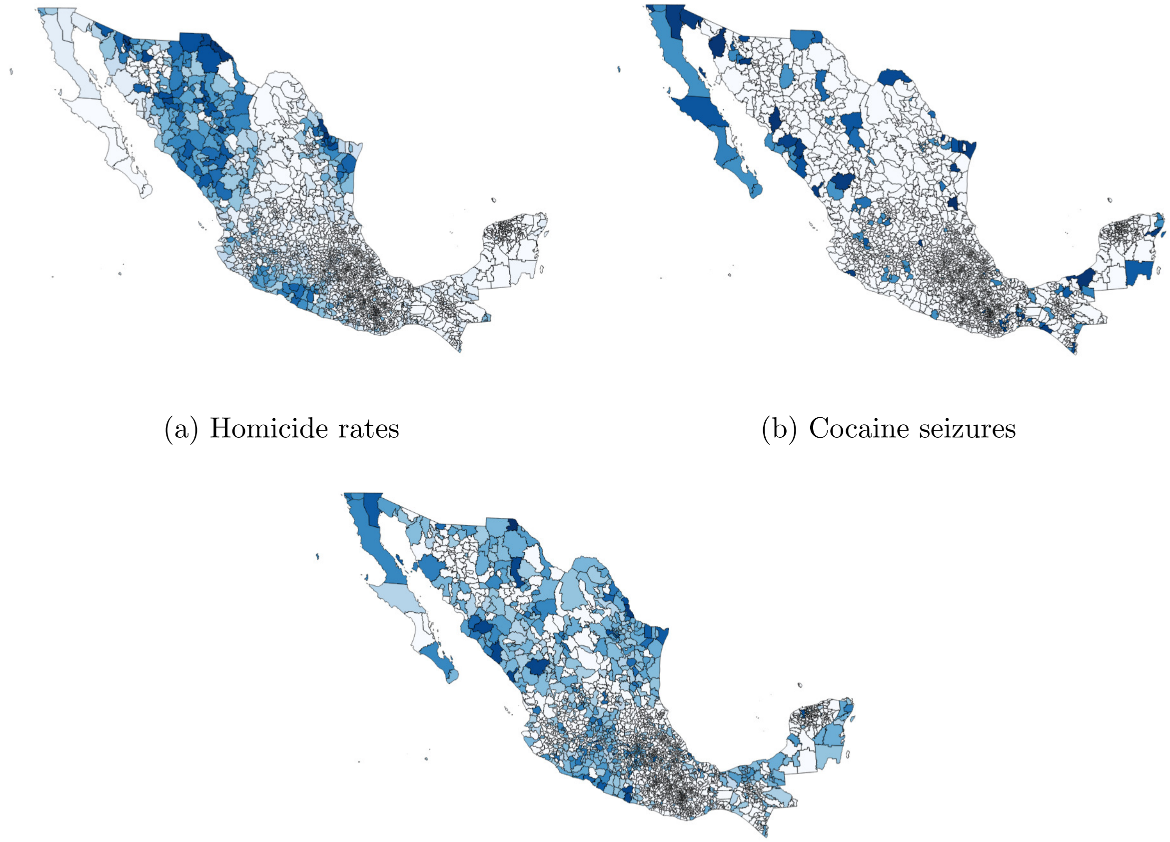


Figure 7: The figure shows the quarterly cocaine production in Colombia net of seizures (left axis) and the quarterly cocaine prices reported by STRIDE (right axis). Prices are per dollar for pure gram in wholesale transactions, while production is in hundred metric tons per quarter.

6.2 Heterogeneity by importance for trafficking

In this section we investigate the prediction in proposition 1 regarding the importance of a municipality for trafficking. Casual observation suggests that municipalities that are closer to entry points in the U.S.-Mexico border will be more important for cocaine trafficking. Unlike heroin or cannabis, cocaine is not produced in Mexico, so the strategic position of a municipality in terms of trafficking determines its importance. Figure 8 presents maps of Mexico showing that drug trafficking has a clear spatial allocation, with drug related homicides, cocaine seizures by Mexican authorities and cartel presence concentrated on the northeast region, close to the Gulf of Mexico and next to the U.S. border, the northwest of the country, and the Pacific region southwest of Mexico City, especially in the states of Michoacán and Guerrero. These maps thus show that, in broad terms, the regions where drug trafficking and violence are more intense tend to be located either close to U.S. entry points (because of their importance for smuggling) or near the ports in the southwest of Mexico, which are important points of entry of cocaine from Colombia. We focus on the distance to the U.S. as our main measure of importance for trafficking because drug related activities in the Pacific seem to be unique to two states (Michoacán and Guerrero), while they are more widespread in the north. Distance to the U.S. entry points is therefore our preferred proxy for the importance of a municipality for the cocaine trade.



(a) Homicide rates

(b) Cocaine seizures

(c) Number of cartels

Figure 8: Maps of Mexico by municipality. Figure 8a shows the average homicide rate, figure 8b shows average cocaine seizures, and figure 8c shows the average number of cartels. All maps show averages for the 2007-2010 period.

To start investigating this prediction, we estimate the time series equation (equation 13) separately for groups of municipalities in 191 moving windows each one covering 5 percent of the observations and starting from the 5 percent closest to Mexico. Thus, we obtain estimates for the group of municipalities between the distance percentiles 0th to 5th, 0.5th to 5.5th, and so on until the distance percentiles 95th to 100th. For each window we obtain an estimate, a 95% confidence interval and an average distance to the U.S. among municipalities in the group. These are used to construct the effect of a 10mt fall in the supply of Colombian cocaine during a month as a function of the distance to the U.S. in each window. We normalize the effect in terms of log point changes using the rule of thumb described in the data section.[28]

[28]For each group of municipalities we compute the average adjustment factor and use it, since the

Figure 9 plots all the estimated effects and their confidence intervals as a function of the distance to the U.S. border. In most of the Mexican territory, homicide rates increase in response to negative supply shocks originated in higher seizures in Colombia, but the effect is much stronger and significant in municipalities close to the U.S. border. In fact, there is significant heterogeneity, with the effect near the Mexico-U.S. border being close to a 15 log points increase in the homicide rate. These plots suggest that cocaine shortages have a larger effect on violence in municipalities that are more important for trafficking, as proxied by how close they are to U.S. entry points. The evidence here is also consistent with our findings in the previous section, which showed larger effects in distance quintiles 1 and 2 and smaller effects for Mexico as a whole. We also believe that the fact that there is no effect for municipalities far from the Mexican-U.S. border is telling. Since cocaine trafficking activities are mostly negligible for these municipalities, our model suggests that we should observe no effect.

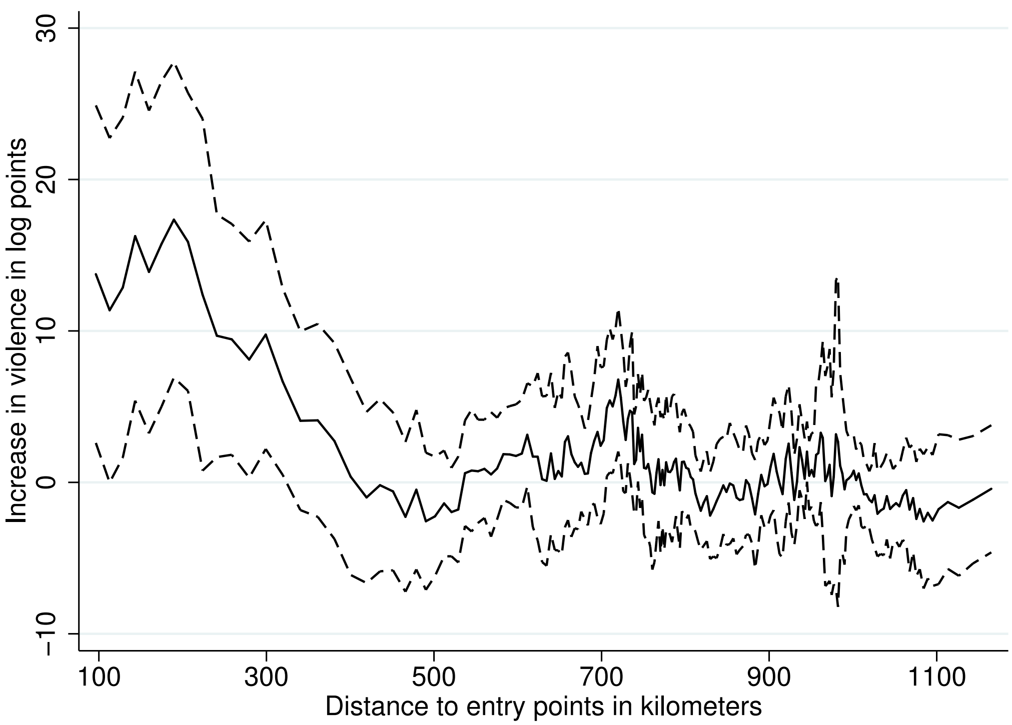


Figure 9: Effect of net cocaine production in Colombia on overall homicide rates in Mexico as a function of the distance to the U.S. nearest entry point. The left axis shows the percent increase in violence caused by a 10mt fall in Colombian supply during one month. The horizontal axis plots the distance to the nearest entry point measured in kilometers.

The results using the drug-related homicide rate show a similar pattern but with a

sample varies.

larger differential increase of violence in the north. Figure 10 shows the large differential effects of a temporal reduction of 10 metric tons in supply in the north of Mexico. Drug related homicides may increase by up to 40 log points following a 10mt negative supply shock, which is a large and significant number.

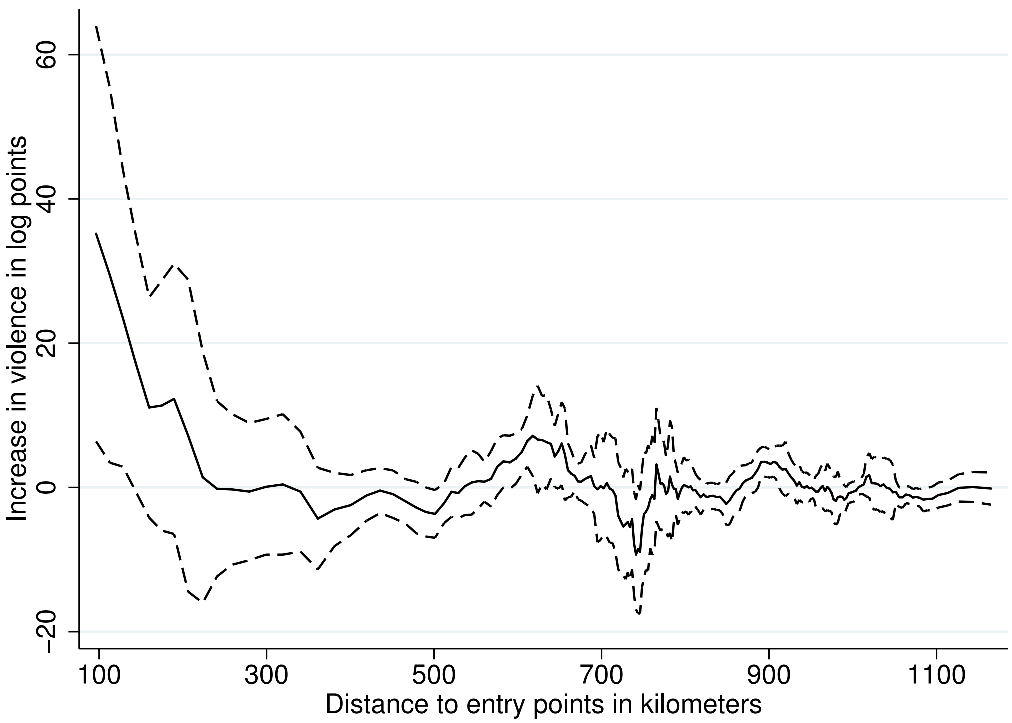


Figure 10: Effect of net cocaine production in Colombia on drug-related homicide rates in Mexico as a function of the distance to the U.S. nearest entry point. The left axis shows the percent increase in violence caused by a 10mt fall in Colombian supply during one month. The horizontal axis plots the distance to the nearest entry point measured in kilometers.

We now turn to study the evidence more systematically in a regression framework. Let d_i be the distance from municipality i to the U.S. nearest entry point. We estimate the following model:

$$h_{i,t} = \lambda_i + \delta_t + \beta c_t d_i + d_i S_t(\gamma) + \theta X'_{i,t} + \varepsilon_{i,t} \tag{18}$$

We are interested in the interaction term $c_t d_i$, which identifies the differential effect of cocaine scarcity on violence depending on the importance of the municipality for trafficking. Theory suggests that $\beta > 0$, meaning that violence increases disproportionally in municipalities close to the U.S. when there is a negative supply shock in Colombia, and as anticipated in the previous figure.

This model does not only test one of the precise statements of proposition 1, but also provides another broad test of our mechanism. In particular, the effect of scarcity should be stronger in places where the cocaine trade and trafficking are more intense. Thus, finding that shortages increase violence in these places relative to the average municipality provides additional evidence for our mechanism, which exploits both the time series and the cross sectional dimensions of our data. In other words, we regard this exercise as providing within municipality evidence of our mechanism, exploiting the fact that the importance of a municipality for trafficking varies cross sectionally. In contrast, the previous section focused on the pure time series evidence of our mechanism. We believe that our estimates of β in equation 18 can be interpreted as causal because distance is exogenous once we condition on fixed effects and control for any secular trends in homicides that vary by distance—using the controls $d_i S_t(\gamma)$. Thus, our estimates do not exploit the fact that the north was becoming more violent over time, but the fact that during months with negative supply shocks in Colombia, violence in municipalities located closer to entry points deviates differentially from its trend behavior. The coefficient β captures this differential short run response.

Table 3 presents our estimation results for different dependent variables. The top panel presents results using the transformed INEGI homicide rate as the dependent variable; while the other panels present results for the drug related homicide rate and its components. Columns 1 to 4 estimate equation 18 for all Mexican municipalities; while columns 5 to 8 restrict the sample to municipalities in distance quintiles 1 and 2. As before, we restrict ourselves to the closest quintiles to focus on the north of Mexico, where we believe drug trafficking and our model has more predictive power for violence, and because municipalities close to U.S. entry points can be expected to be more similar to each other, making our comparisons more accurate (there are many reasons to believe that municipalities in the north of Mexico are systematically different from municipalities in the south). All municipalities in this group have experienced the consequences of drug trafficking more severely than the rest of the country, so focusing on these municipalities provides a cleaner experiment. We only report estimates for the effect of the interaction term, since the main effect of shortages is not identified once we include month fixed effects.

Columns 1 and 5 present results controlling only for a differential cubic trend by distance to the U.S. (that is, when $S_t(\gamma)$ includes a cubic polynomial and year dummies). The results vary little if we use higher order polynomials, so we stick to a cubic polynomial throughout.[29] The results using the INEGI homicide rate suggest that a

[29]Table 8 in the appendix shows that the estimates do not vary significantly for polynomials of degree two or higher.

Table 3: Differential effects of cocaine shortages on average violence in Mexico by distance to U.S. entry points.

	All Mexico				Quintiles 1 and 2			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: INEGI homicide rate.							
Colombian supply × Distance to U.S.	0.101***	0.101***	0.108***	0.089***	0.156***	0.157***	0.166***	0.164***
	(0.029)	(0.029)	(0.029)	(0.031)	(0.054)	(0.055)	(0.055)	(0.056)
Observations	120296	118527	115305	115305	48167	47351	46273	46273
R-squared	0.011	0.011	0.012	0.012	0.027	0.028	0.030	0.031
	Dependent variable: Drug related homicide rate.							
Colombian supply × Distance to U.S.	0.083***	0.083***	0.088***	0.088***	0.182***	0.184***	0.188***	0.186***
	(0.026)	(0.026)	(0.027)	(0.028)	(0.058)	(0.059)	(0.059)	(0.059)
Observations	120296	118527	115305	115305	48167	47351	46273	46273
R-squared	0.020	0.021	0.021	0.022	0.033	0.034	0.035	0.036
	Dependent variable: Drug related executions.							
Colombian supply × Distance to U.S.	0.061***	0.061***	0.066***	0.065***	0.125**	0.126**	0.129**	0.127**
	(0.023)	(0.023)	(0.023)	(0.024)	(0.050)	(0.051)	(0.051)	(0.051)
Observations	120296	118527	115305	115305	48167	47351	46273	46273
R-squared	0.016	0.016	0.017	0.018	0.026	0.027	0.028	0.029
	Dependent variable: Drug related confrontations.							
Colombian supply × Distance to U.S.	0.031**	0.031**	0.032**	0.033**	0.073**	0.074**	0.076**	0.075**
	(0.014)	(0.014)	(0.014)	(0.015)	(0.033)	(0.033)	(0.034)	(0.033)
Observations	120296	118527	115305	115305	48167	47351	46273	46273
R-squared	0.007	0.007	0.008	0.009	0.012	0.013	0.014	0.015
	Dependent variable: Drug related aggressions.							
Colombian supply × Distance to U.S.	-0.001	-0.001	-0.001	0.000	-0.001	-0.000	-0.000	0.001
	(0.003)	(0.003)	(0.004)	(0.003)	(0.008)	(0.008)	(0.008)	(0.007)
Observations	120296	118527	115305	115305	48167	47351	46273	46273
R-squared	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.004
Covariates:								
Income and state presence		✓	✓	✓		✓	✓	✓
Differential trend by PAN support			✓	✓			✓	✓
Time dummies × PAN support			✓	✓			✓	✓

Note.- The table presents estimates of the interaction between supply shortages (measured at the monthly level in hundreds of metric tons) and distance to U.S. entry points (measured in 1000km) on violence in Mexico. The dependent variable is the shifted log of the homicide rate indicated in each panel. All estimates include a full set of Municipality and time fixed effects as well as a differential cubic trend by distance to U.S. entry points. Additional covariates are indicated in the bottom of the table. Columns 1 to 4 present estimates for all Mexico; while Columns 5 to 8 for quintiles 1 and 2. Standard errors robust to heteroskedasticity and serial correlation within municipalities are reported below each estimate in parenthesis. Coefficients with *** are significant at the 1% level, with ** are only significant at the 5% level and with * are only significant at the 10% level.

10 mt reduction in the monthly cocaine supply from Colombia causes an increase in the homicide rate that is larger by 1.01 log points (s.e= 2.9) for every 100 km that one moves closer to U.S. entry points, or by 1.56 log points (s.e= 0.54) if we restrict the regression to the first two quintiles. The difference between both estimates means that not only is the increase in homicides larger the closer one moves to the U.S. entry points, but also that the differential increase with distance is larger as one gets closer to the U.S border. In Column 2 we add the annual GDP per capita and state presence controls. Since they only vary at the annual level, they are not controlling for high fre-

quency socio-economic phenomena, but for differential time trends (or lower frequency variation) in municipalities with different characteristics that could be related to their distance to the U.S. entry points. Our estimates vary little, suggesting that we are not capturing differential trends depending on income or state presence. We do not think that adding these controls creates a significant bad control problem. Even though income and state presence could be endogenous, their annual variation is less so, and simply helps us control for different longer term trends. In any case, all of our results hold without these controls as well.

In Columns 3, 4, 7, and 8 we control flexibly for enforcement policies that were being implemented during our period of analysis. As mentioned above, since 2006, the Calderón administration started an aggressive campaign of cracking down on cartels. As shown by Dell (2013) this was especially the case in municipalities with PAN mayors, where there was support for these policies and cooperation by local authorities. Instead of controlling for the presence of a PAN mayor, which we see as a bad control due to its potential endogeneity, we control for differential cubic trends by historical PAN support (vote share from 1990 to 2000) in Columns 3 and 7, or a full set of time dummies interacted with historical PAN support in Columns 4 and 8.[30] The intuition is that places in which the PAN held more political power, as captured by its historical vote share, are more likely to have PAN mayors or directly offer cooperation for Federal PAN policies. Thus, the models in these columns fully control for differential patterns of violence in more pro-PAN municipalities. Our estimates do not change much, suggesting that we are not capturing a correlation in time between our supply shocks and their differential effect on the north, and PAN policies that were intensified during our period of analysis.

The second panel presents results using the drug related homicide rate as the dependent variable. The structure is the same as the top panel. The point estimates and their significance are similar to the ones discussed above, but the implied magnitudes are different since we must use a different factor of adjustment. In particular, the results using the drug-related homicide rate suggest that a reduction of 10 metric tons in the monthly cocaine production in Colombia increases drug related homicides by 1.66 log points more (s.e=0.52) for every 100km that one moves closer to a U.S. entry point. The gradient becomes even steeper in the north: In quintiles 1 and 2, every 100km that one moves closer to the U.S. imply that the same supply shock increases violence

[30]On some results not reported here, we obtained very similar results using the presence of a PAN mayor as a control. Though endogenous, this shows that our estimates are not driven by the election of PAN mayors during the Calderón administration.

by 3.64 log points (s.e=1.16). These estimates suggest that for drug-related homicides, the differential effect on the north is even stronger relative to southern municipalities with little or no involvement in cocaine trafficking.

The bottom panels explore the categories into which drug related homicides are separated. Our findings agree with the time series results of table 2: The interaction coefficients for both executions and confrontations are positive and significant, whereas the coefficients for aggressions are small and not significant. The effect for confrontations is larger than the effect for executions (remember that the adjustment factor for confrontations is 50, whereas the adjustment factor for executions is 20). These results further support our model, which predicts differential increases in violence between cartels (such as executions and confrontations) in response to scarcity shocks in the north of Mexico, but it is silent about effects on violence between government authorities and cartels of the type captured by aggressions. Among violence between cartels, the type of violence that should be most strongly affected are battles for turf caused by rapacity, and homicides due to this type of battles are classified as confrontations. Our econometric results show that this type of violence increases more than the others, and does so differentially in the north of Mexico, following a supply contraction.

Our results show that the scarcity created by larger and more frequent negative supply shocks in Colombia since 2006 has contributed to the increase in violence in the north relative to the rest of the country. To get an idea of these magnitudes, consider Tijuana, which is on an entry point, and Puebla, which is in the mean distance (about 760 km away from the U.S. border). If cocaine supply from Colombia falls by 10 mt in a given month, our estimates suggest that the homicide rate increases by 11.86 log points more in Tijuana than in Puebla (in this calculation we used the coefficient for quintiles 1 and 2, since cities at the mean distance and at the U.S. border lie in this sample). Drug related homicides increase by 32 log points more in Tijuana than in Puebla. Suppose that the effect of a permanent supply fall is the same as a short run shock, with all the caveats that this assumption requires and that were already discussed. Between 2006-2010, the Colombian monthly supply of cocaine fell by 26.9 mt (from 43.5 mt to 16.6 mt). Scarcity created by Colombian policies could explain up to 20% of the differential increase in homicide rates between Tijuana and Puebla from 2006 to 2010. More generally, with the assumption above, our estimates imply that the scarcity created by Colombian policies caused a 32 log point increase in violence near U.S. border crossings relative to the mean distance. Thus, the large drop in Colombian supply could account for up to 25% of the 128 log point differential increase of violence in the north of Mexico during our period of study (in this sense, Tijuana and Puebla are similar to the sample averages). The contribution of scarcity appears to be even larger if we use the semi-parametrical estimates plotted in figures 9 and 10. In particular, our channel may explain up to 21.2% and 46% of the observed increase in overall and drug related homicides, respectively, in the 5 percent closest municipalities to the U.S., while it has no significant explanatory power in the south.

6.3 Role of cartels: It takes two to tango.

As suggested by our theoretical model, the presence of cartels in a municipality should also be important in determining whether negative supply shocks in wholesale cocaine markets breed violence, as municipalities without cartels should not see their levels of drug related violence increased as a result of supply tightenings in wholesale cocaine markets. Furthermore, the number of cartels should also be important because different theories point out that territories that are disputed between various factions should display higher levels of violence, while territories under the full control of a single faction should exhibit low levels of violence (see Grossman (2001) and Kalyvas (2006) for a similar argument). In fact, many critics of the Calderón administration have pointed out that it fragmented cohesive cartels, leading to more violence (see Guerrero (2010, 2011a) and Merino (2011)). In our model, whenever a cartel fully controls a municipality, its property rights over the revenue stream generated in that municipality are well established. In contrast, as the number of cartels increases, the rapacity effect becomes active: To secure rents, cartels must fight each other. They would like to divide the pie and not use violence, but every cartel would be tempted to deviate and use violence to appropriate a larger share of the pie. This is the classic Olson paradox in the context of inter-cartel conflict.

In order to test this hypothesis, we use the data produced by Coscia and Ríos (2012) on the presence of Mexican cartels in each municipality. Although this data is only available on a yearly basis, which means that we cannot measure how high frequency changes in the number of cartels affect violence, it allows us to measure the differential effects of supply shocks in cocaine markets depending on the number of cartels present in each municipality. We start by estimating time series results for the subsample of municipalities with no cartels, one cartel, two cartels (rival or non-rival) and two rival cartels at the time of the shock. We present our results using event study figures showing the change in the homicide rate in log points around a temporal fall of 10 metric tons at month zero (like figures 5 and 6), but the regression results are very similar. We focus on the overall homicide rate and in municipalities in quintiles 1 and

2 to save space. Results for all Mexico or using the drug related homicide rate show a similar pattern.

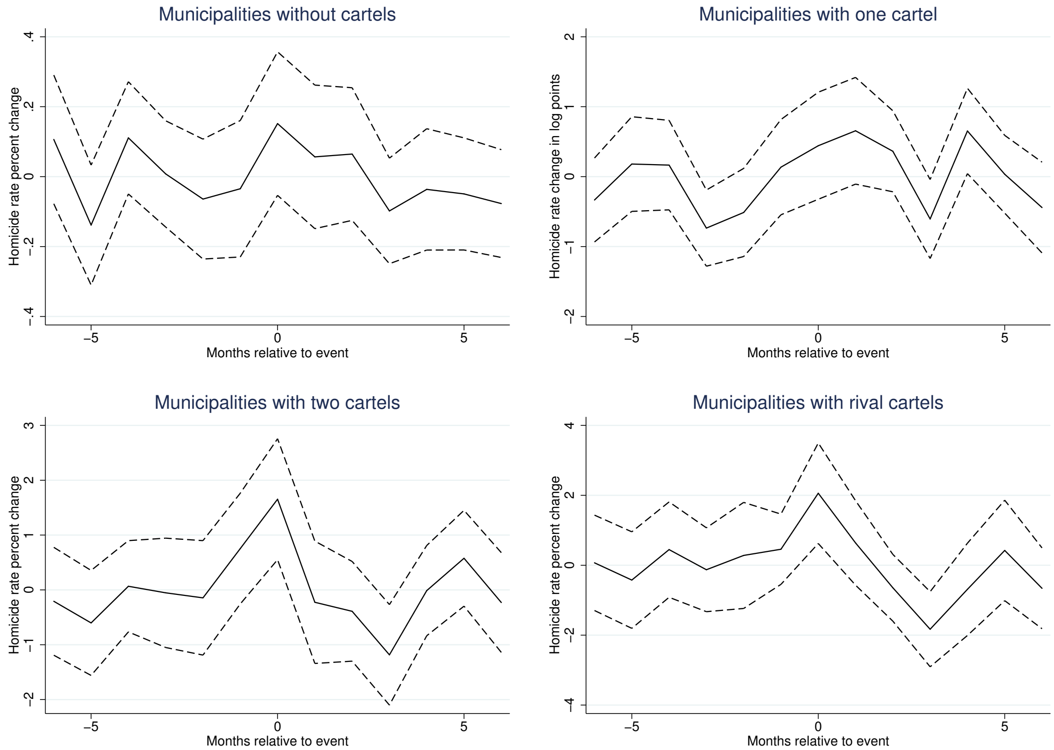


Figure 11: The figure shows the path of the drug-related homicide rate around a 10 metric ton reduction in cocaine production from Colombia at time 0 for different groups of municipalities. The solid line plots our estimates, with the pre-shock level of homicides normalized to zero. The 95% confidence interval is plotted in dashed lines.

As suggested by the figures, there is no significant change in the homicide rate around a negative supply shock in municipalities without cartels even in quintiles 1 and 2. Importantly, not only are deviations not significant, they are also small compared to effects for other municipalities. There is some non-trivial increase in homicides in municipalities with only one cartel, but this is typically not significant and small.[31] In contrast, in municipalities with two or more cartels during the year in which the shock occurs, there is a large spike in homicides coinciding with the time of the cocaine shortage. The effect is even larger if we only focus on municipalities with rival cartels, with rivalries defined following Guerrero (2011b).

To further investigate the role of cartels, we move to a regression framework to test heterogeneity by number of cartels and importance of the municipality for trafficking.

[31]As mentioned in the theory section, this can happen because cartels are not perfectly cohesive. When revenue increases, they must exercise violence or the threat of violence to solve the moral hazard problem among cartel members as in Acemoglu and Wolitzky (2011).

Let DTO_{iy} be a vector of variables related to the cartels present in municipality i during year y. This vector includes a dummy for the presence of at least one cartel, a dummy for two or more cartels, the total number of cartels and the presence of two rival cartels. To investigate how the number of cartels mediates the effect of cocaine scarcity and supply shocks, we estimate the model

$$\begin{aligned} h_{i,t} = \quad & \lambda_i + \delta_t + \beta_0 c_t d_i + \beta_1 c_t DTO_{iy} + \beta_2 c_t d_i DTO_{iy} + d_i S_t(\gamma) + \theta X'_{i,t} + \\ & \sum_{y'} \left[DTO_{iy'} S_t(\gamma_{1y'}) + d_i DTO_{i,y'} S_t(\gamma_{2y'}) \right] + \varepsilon_{i,t}. \end{aligned} \tag{19}$$

We are interested in the terms $c_t DTO_{iy}$ and $c_t d_i DTO_{iy}$, which capture heterogeneity depending on the number of cartels operating in a municipality or other measures of the number of cartels conditional also on the distance to the U.S.. Despite the fact that cartel presence varies by year, we are not exploiting this variation. In fact, the term $\sum_{y'} [DTO_{iy'} S_t(\gamma_{1y'}) + d_i DTO_{i,y'} S_t(\gamma_{2y'})]$ fully absorbs year to year variation in the number of cartels, or differential trends depending on the number of cartels at each year in our sample and distance to the U.S. Thus, concerns about the number of cartels being endogenous are ruled out since our estimates are not capturing yearly variation in the number of cartels or its heterogeneous effect in the north. Our estimator only exploits the differential short run effect of cocaine shortages in municipalities at different distances from entry points to the U.S. depending on the number of cartels present during the year in which the shock took place.

The results of this exercise are shown in table 4. The table is divided into two panels. The left-hand side of each panel (columns 1 to 3) presents results for all Mexico; and the right-hand side (columns 4 to 6) for quintiles 1 and 2. The top panel uses the shifted log of the INEGI homicide rate as the dependent variable while the bottom one uses the shifted log of the drug related homicides rate. We present the interactions between the Colombian monthly supply shocks with distance to the U.S. and cartel presence, presence of various cartels or rival cartels. We also include the triple interaction between the supply shocks, distance to the U.S. and number of cartels, which measures differential effects of supply shocks in municipalities with different number of cartels in the north. The interaction between cartels and distance to the U.S. is not identified since we are removing this variation with our controls, effectively focusing on the differential effect of shocks in municipalities with different number of cartels at the time of the shock. All effects are evaluated at the Mexican-U.S. border, and the interaction between supply shocks and distance to the U.S. is evaluated at municipalities with no cartel presence during the year in which the shock occurred.

A clear pattern emerges. There is no significant differential effect of supply shocks

Table 4: Differential effects of cocaine shortages on average violence in Mexico by distance to U.S. entry points and cartel presence.

	All Mexico			Quintiles 1 and 2		
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: INEGI homicide rate.					
Colombian supply × Distance to U.S.	0.040	0.040	0.040	0.025	0.024	0.024
	(0.039)	(0.039)	(0.039)	(0.089)	(0.090)	(0.090)
Colombian supply × Cartel presence	-0.119**	-0.023	-0.091*	-0.144**	-0.032	-0.119
	(0.050)	(0.062)	(0.055)	(0.073)	(0.084)	(0.079)
Colombian supply × Distance to U.S. × Cartel presence	0.158**	0.054	0.119*	0.231*	0.067	0.194
	(0.062)	(0.076)	(0.067)	(0.120)	(0.142)	(0.132)
Colombian supply × Various cartels		-0.146**			-0.162*	
		(0.071)			(0.085)	
Colombian supply × Distance to U.S. × Various cartels		0.151*			0.227	
		(0.091)			(0.145)	
Colombian supply × Rival cartels			-0.093			-0.077
			(0.080)			(0.094)
Colombian supply × Distance to U.S. × Rival cartels			0.133			0.104
			(0.105)			(0.156)
Observations	120296	120296	120296	48167	48167	48167
R-squared	0.014	0.015	0.016	0.033	0.035	0.037
	Dependent variable: Drug related homicide rate.					
Colombian supply × Distance to U.S.	0.026	0.026	0.026	0.070	0.069	0.069
	(0.027)	(0.027)	(0.027)	(0.072)	(0.072)	(0.072)
Colombian supply × Cartel presence	-0.111**	-0.059	-0.049	-0.126*	-0.052	-0.042
	(0.047)	(0.058)	(0.043)	(0.067)	(0.084)	(0.064)
Colombian supply × Distance to U.S. × Cartel presence	0.127**	0.043	0.036	0.190*	0.029	0.030
	(0.057)	(0.071)	(0.052)	(0.112)	(0.148)	(0.110)
Colombian supply × Various cartels		-0.079			-0.106	
		(0.075)			(0.094)	
Colombian supply × Distance to U.S. × Various cartels		0.132			0.240	
		(0.094)			(0.163)	
Colombian supply × Rival cartels			-0.208*			-0.245*
			(0.120)			(0.141)
Colombian supply × Distance to U.S. × Rival cartels			0.319**			0.458**
			(0.157)			(0.233)
Observations	120296	120296	120296	48167	48167	48167
R-squared	0.029	0.034	0.037	0.042	0.049	0.054

Note.- The table presents estimates of the interaction between supply shortages (measured at the monthly level in hundreds of metric tons), distance to U.S. entry points (measured in 1000km) and several measures of cartel presence on violence in Mexico. The dependent variable is the shifted log of the homicide rate indicated in each panel. All estimates include a full set of Municipality and time fixed effects as well as a differential cubic trend by distance to U.S. entry points and a full set of cartel measures in all years in the sample. Columns 1 to 3 present estimates for all Mexico; while Columns 4 to 6 for quintiles 1 and 2. Standard errors robust to heteroskedasticity and serial correlation within municipalities are reported below each estimate in parenthesis. Coefficients with *** are significant at the 1% level, with ** are only significant at the 5% level and with * are only significant at the 10% level.

in the north of Mexico when there are no cartels. Along municipalities with cartels, however, there is a significant differential effect on violence by distance to the U.S.. Moreover, across northern municipalities, Colombian supply shocks have a larger effect in those with cartels. For both outcomes, columns 1 and 4 indicate that supply shocks from Colombia have a larger effect on municipalities with cartel presence. For instance, our estimates using the INEGI homicide rate for all Mexico suggest that having cartels amplifies the effect of a 10 metric ton supply reduction by an additional 1.19 log points (s.e=0.5). These estimates also indicate that for every 100 km closer to the U.S., a 10 metric ton reduction in supply differentially increases violence by 1.58 log points (s.e=0.62) in municipalities with some cartel presence; while there is no significant differential effect for municipalities without cartels. This is clear evidence that the presence of cartels is necessary for violence to respond to scarcity shocks.

Column 2, 3, 5, and 6 test the statement that it "takes two to tango". In order to do so, we measure the heterogenous effect of supply shocks, mediated also by distance, when there is at least one cartel, and when there is more than one cartel operating in the municipality at the time of the shock. Columns 2 and 5 use a dummy for more than one cartel in addition to our dummy of cartel presence, while columns 3 and 6 use a dummy for rival cartels. Although we lose precision in some of the models, we see that all our previous results are driven by the presence of at least two cartels or two rival cartels. The point estimates suggest that most of the differential effect of supply shocks in municipalities with cartel presence is explained by the larger negative effects on municipalities with at least two cartels (or two rival cartels). Likewise, the results suggest that the heterogeneous effect of supply shocks by distance, which only appears in municipalities with cartels, is mostly explained by the presence of at least two cartels (or rival cartels). For instance, our estimates using the INEGI homicide rate for all Mexico (column 2), imply that the 1.19 log point differential increase in violence following a supply shock in municipalities with cartels is explained mostly by a 1.46 log point differential increase in violence in municipalities with various cartels (s.e=0.71). On the other hand, there is no significant heterogeneity among municipalities with zero or one cartel. Similarly, the additional 1.58 log points effect of a 10 metric ton reduction in supply for every 100 km closer to the U.S. are mostly explained by the additional 1.51 log points effect (s.e=0.91) for every 100 km closer to the U.S. among municipalities with at least two cartels. One noticeable feature is that, once we add interactions with the presence of at least two cartels or rival cartels, there is no significant heterogeneity between municipalities with zero or one cartel. This is a demanding exercise, and thus it comes at the cost of some loss in precision. Nevertheless, we believe it uncovers patterns that provide broad evidence for the role of cartels in our model.

6.4 Role of enforcement

As pointed out by Calderón's critics (Guerrero, 2011a; Merino, 2011; Guerrero, 2010), his actions may have been an important cause behind the rise in violence during the last years. In particular, as argued by many authors, the Calderón administration created a large emphasis on arrests and killings of kingpins, while other policies such as seizures remained unchanged. Although these policies were chosen at the federal level, local support for PAN (Calderón's party) determined how much cooperation local authorities would provide. In fact, as shown by Dell (2012), places where PAN mayors won elections were more likely to have crackdowns on drug cartels operating in the area. In a similar line, we argue that places where the PAN had more historical support, as measured by its vote share in municipal elections from 1990 to 2000, saw more intense anti-drug policies during the Calderón era. There are two potential mechanisms: First, these places are more likely to elect PAN mayors; and second, the incumbent in these places may have more pressure to cooperate with PAN national policies from its electorate. We do not use the actual election of a PAN mayor because we regard it as highly endogenous.

Since more intense anti-drug policies were specifically related to more arrests and killings of drug kingpins, our model predicts that cartel leaders in more pro-PAN municipalities should face a higher discount rate during our period of study. As a consequence we would expect a higher level of violence and a larger effect of cocaine shortages on violence. Intuitively, the large turnover of cartel leaders in these places makes it harder for them to enforce informal arrangements to cooperate and keep the levels of violence low. When the discount factor is high, the incentives to prey today become stronger, especially during a period of scarcity, even if there would be more conflict in the future. The rapacity channel gets amplified as a consequence.

We investigate this implication by estimating the model

$$\begin{aligned} h_{i,t} = &\lambda_i + \delta_t + \beta_0 c_t d_i + \beta_1 c_t PAN_i + \beta_2 c_t d_i PAN_i \\ &+ PAN_i S_t(\eta) + d_i PAN_i S_t(\mu) + d_i S_t(\gamma) + \theta X'_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{20}$$

with PAN_i being the historical support for PAN in municipality i. We are interested in terms $c_t PAN_i$ and $c_t d_i PAN_i$, which capture heterogeneity depending on PAN support in a given municipality. As before, terms $PAN_i S_t(\eta)$ and $d_i PAN_i S_t(\mu)$ control flexibly for differential trends and year to year variation in violence in places that have been more pro-PAN historically. Thus, our estimator only exploits the short run effects of cocaine shortages in municipalities at different distances from entry points to the U.S. depending on their historical support for the PAN party.

Table 5 presents these results. The top panel shows the outcome of our regressions using the INEGI homicide rate, while the bottom panel uses the drug related homicide rate. Columns 1 and 2 in each panel show estimates for all municipalities in Mexico, while columns 3 and 4 focus only on municipalities in quintiles 1 and 2 of distance to crossings to the U.S. We use two measures of historical PAN support: the vote share for PAN candidates in the municipality between 1990 and 2000, and the share between 1980 and 2000. All effects are evaluated at the Mexican-U.S. border and at the municipality with average PAN support. Consistent with our previous results, our estimates show that even in places with average PAN support, and hence, average enforcement, cocaine shortages have a stronger impact on violence closer to U.S. entry points. More importantly for our discussion about the role of PAN policies, our estimates show that the time series effect of cocaine shortages is amplified in municipalities with more PAN support, in consistency with the predictions in our theoretical model. In particular, columns 1 and 2 in the top panel show that every 10% increase in the historical PAN vote share implies an additional 5.8 log point increase in the effect of a 10 metric ton reduction of the Colombian supply on homicides. Not only are the effects of cocaine shortages larger in municipalities with larger PAN support, but they also becomes considerably stronger in the north of the country, as captured by the triple interaction, also in consistency with the ideas outlined in our theoretical model. For instance, according to the estimates in column 1 using the INEGI homicide rate as dependent variable, there is no distance gradient among municipalities with a historical PAN vote share 10% below the national mean.

To get another idea of the quantitative implications of our results, imagine two municipalities near U.S. entry points with a difference in the historical PAN vote share (between 1980 and 2000) of 5%. For instance, the historical voting for PAN in Tijuana, Baja California and Ciudad Juárez, Chihuahua was 40.1% and 41.6%, respectively, whereas it was 35.7% in Nogales, Sonora. A reduction in supply of 26.9 mt as the one observed between 2006-2010 would cause a larger increase in homicides in Nogales than in Tijuana or Ciudad Juárez by 29 log points (as measured by the INEGI overall homicide rate). The additional homicides would be explained by the consequences of more aggressive anti-drug policies that crowd out informal cooperation arrangements and lead scarcity to have larger effects on violence. In contrast, PAN policies had a less important differential effect in municipalities in the south that are less important for trafficking. In particular, such differences would not matter in municipalities at the mean distance from U.S. entry points.

To further understand the role of PAN's administration policies, we re-estimate versions of equations (13) and (18) for the whole 2003-2010 time period, including interactions of our variables of interest with the periods that fall under Calderón's war

Table 5: Differential effects of cocaine shortages on average violence in Mexico by distance to U.S. entry points and popular support for PAN policies.

	All Mexico		Quint. 1 and 2	
	(1)	(2)	(3)	(4)
	Dep. variable: INEGI homicide rate.			
Colombian supply × Distance to U.S.	0.052*	0.050	0.119**	0.117**
	(0.031)	(0.031)	(0.056)	(0.055)
Colombian supply × PAN support 1990-2000	-0.588***		-0.499**	
	(0.139)		(0.206)	
Colombian supply × Distance to the U.S. × PAN support 1990-2000	0.694***		0.906**	
	(0.174)		(0.356)	
Colombian supply × PAN support 1980-2000		-0.581***		-0.501**
		(0.155)		(0.220)
Colombian supply × Distance to the U.S. × PAN support 1980-2000		0.634***		0.835**
		(0.192)		(0.377)
Observations	117062	117797	47089	47089
R-squared	0.012	0.012	0.028	0.027
	Dep. variable: Drug related homicide rate.			
Colombian supply × Distance to U.S.	0.051*	0.044*	0.170***	0.158***
	(0.027)	(0.026)	(0.061)	(0.059)
Colombian supply × PAN support 1990-2000	-0.498***		-0.171	
	(0.128)		(0.241)	
Colombian supply × Distance to the U.S. × PAN support 1990-2000	0.651***		0.283	
	(0.157)		(0.407)	
Colombian supply × PAN support 1980-2000		-0.532***		-0.261
		(0.147)		(0.254)
Colombian supply × Distance to the U.S. × PAN support 1980-2000		0.651***		0.320
		(0.178)		(0.425)
Observations	117062	117797	47089	47089
R-squared	0.022	0.022	0.034	0.033

Note.- The table presents estimates of the interaction between supply shortages (measured at the monthly level in hundreds of metric tons), distance to U.S. entry points (measured in 1000km) and several measures of support for PAN policies. The dependent variable is the shifted log of the homicide rate indicated in each panel. All estimates include a full set of Municipality and time fixed effects as well as a differential cubic trend by distance to U.S. entry points and PAN support. Columns 1 and 2 present estimates for all Mexico; while Columns 3 and 4 for quintiles 1 and 2. Standard errors robust to heteroskedasticity and serial correlation within municipalities are reported below each estimate in parenthesis. Coefficients with *** are significant at the 1% level, with ** are only significant at the 5% level and with * are only significant at the 10% level.

on drugs (from December 2006 to December 2010, in our sample). Unfortunately, the drug related homicide data is not available for this period, so we can only present estimates using the INEGI homicide rate. Table 6 reports our findings. Columns 1 and 2 show estimates for all Mexico while Columns 3 and 4 focus on quintiles 1 and 2. The top panel reproduces the time series estimates presented in Table 2 for the whole time period, separating the effects before and during Calderón's term. Columns 2 and 4 include additional controls. We report standard errors that only cluster at the municipality level (those that also allow for aggregate shocks yield very similar results). Our estimates show that negative supply shocks only had a significant and robust effect on violence during Calderón's term. The bottom panel presents estimates for the distance gradient replicating the regressions in table 6, but computing the effects before and during Calderón's term. Columns 2 and 4 add the state presence controls as well as differential trends depending on PAN support. As can be seen, negative supply shocks only appear to have a differential effect in the north of Mexico during Calderón's term.

Table 6: Differential effects of cocaine shortages on average violence in Mexico before and during Calderón's war on drugs.

	All Mexico		Quint. 1 and 2	
	(1)	(2)	(3)	(4)
	Time series estimates.			
Colombian supply before Calderon	0.014**	0.013*	-0.001	-0.002
	(0.007)	(0.007)	(0.009)	(0.009)
Colombian supply during Calderon	-0.026***	-0.023**	-0.036**	-0.031**
	(0.010)	(0.010)	(0.014)	(0.015)
Covariates:				
Unemployment and economic activity		✓		✓
	Heterogeneity by distance to the U.S.			
Colombian supply × Distance to U.S. before Calderon	0.020	0.021	-0.063	-0.062
	(0.026)	(0.027)	(0.043)	(0.044)
Colombian supply × Distance to U.S. during Calderon	0.084**	0.090**	0.224***	0.234***
	(0.040)	(0.041)	(0.071)	(0.072)
Covariates:				
Income and state presence		✓		✓
Differential trend by PAN support		✓		✓

Note.- The dependent variable is the shifted log of the INEGI homicide rate in both panels, and the sample period goes from January, 2003 to December, 2010. The top panel presents time series results with the effect of cocaine supply before and during Calderón estimated separately. Standard errors robust to heteroskedasticity and serial correlation within municipalities are reported below each estimate in parenthesis. Similar results were obtained with standard errors that also allow for aggregate shocks. The bottom panel presents estimates of the interaction between supply shortages (measured at the monthly level in hundreds of metric tons) and distance to U.S. entry points (measured in 1000km) computed before and during Calderón separately. Standard errors robust to heteroskedasticity and serial correlation within municipalities are reported below each estimate in parenthesis. Coefficients with *** are significant at the 1% level, with ** are only significant at the 5% level and with * are only significant at the 10% level.

Based on our model, we believe this is related to the special focus of the Calderón administration in killing or arresting kingpins, with the undesirable consequence of increasing discount rates and reducing the scope for informal arrangements to respect property rights. The evidence is consistent with a regime shift that followed the intensification of the war on drugs under the Calderón administration. Before 2006, there were few cartels that were very localized geographically, and with informal arrangements to respect their property. Scarcity only has a negligible effect on violence in this environment, or under some conditions no effects if full cooperation was achieved to accommodate these shocks. After 2006, cocaine shortages in Colombia found a very different environment in Mexico; one in which cartels were fragmented and their locations started overlapping. The aggressive policy of killing and arresting leaders destroyed informal arrangements that were keeping rapacity low or even absent. Our estimates suggest that Calderón's policies interacted with cocaine shortages in Colombia, at least in the short run, by creating the conditions for rapacity to be resolved with high levels of violence, instead of tacit cooperation.[32]

7 Concluding remarks

This paper investigated the role of scarcity as one potential determinant of violence in commodity markets without third party enforcement. A simple model emphasizing predation and rapacity over revenue, in the absence of well defined property rights, suggests that scarcity increases violence if demand is inelastic. Moreover, the increase is more dramatic when there are several groups contesting the unprotected revenue, in locations that are more important for the trade of the commodity, and in places where enforcement creates high turnover, making agents more shortsighted and limiting informal cooperative arrangements. Although our work is inspired by the case of the cocaine trade in Mexico, the economic forces highlighted in our model apply more generally. In particular, scarcity increases unprotected revenue, and violence increases because there are larger opportunities to prey on others and agents must resort to violence in order to avoid being preyed upon.

We test our model using monthly data from Mexican municipalities from December 2006 to 2010, a period that coincides with what has been called the "Mexican Drug War". The Mexican cocaine trade fits perfectly our purposes for several reasons: First, because cocaine is produced in the Andes, and most notably in Colombia during our period of study, we can use changes in policies in Colombia as exogenous sources of variation in the supply of cocaine. Second, cocaine demand is widely believed to be inelastic, especially in the short run. Third, the illegal nature of this market precludes the existence of any formal source of third party enforcement, and forces markets participants to operate outside the scope of the rule of law, enforcing property rights by themselves.

Using high frequency variation in the supply of cocaine created by exogenous changes

[32]The increase in cartel presence by itself cannot explain the larger effects estimated after 2006. Even if we control for the aggregate cartel presence in Mexico interacted with our variables of interest, Calderón's years appear to be especially reactive to cocaine shortages. This suggests that Calderón's policies probably had an effect beyond their impact on cartel fragmentation, presumably by increasing discount rates and destroying informal cooperative arrangements.

in Colombian enforcement, we find that violence increases in Mexico during months with supply shortages caused by seizures in Colombia. Moreover, violence increases especially in the north, and within the north specifically in places close to entry points to the U.S., as predicted by our model. Violence also increases more in northern municipalities that have historically voted for PAN, President Felipe Calderón's party, in which local authorities are more likely to support federal government efforts against cartels in their area, thus increasing the turnover of cartel leaders. Finally, violence increases more in places with cartel presence, especially in places with two cartels or with two rival cartels operating at the time of the supply shock. The fact that the effect of scarcity is mediated by all these variables as predicted by theory does not only validate our model, but also shows a wide range of empirical facts consistent with our proposed mechanism through which scarcity breeds violence. Our interpretation of the results is that Colombian supply shocks—which became larger and more frequent since 2006—created scarcity in wholesale cocaine markets, raised prices and contributed to the increase in Mexican violence. Our estimates suggest that, for the period 2006-2010, scarcity created by more efficient cocaine interdiction policies in Colombia may account for 21.2% and 46% of the increase in homicides and drug related homicides, respectively, experienced in the north of the country. Thus, at least in the short run, scarcity created by Colombian supply reduction efforts has had negative spillovers in the form of more violence in Mexico during its so-called War on Drugs.

Although our evidence comes from a particular context, it suggests that the economic forces present in our model are also present in many commodity markets without reliable third party enforcement. Higher rents in markets with poorly defined property rights may end up creating more violence, as suggested by many previous works that study the consequences of resource booms in generating rapacity. Our results also point to a considerable presence of systemic violence in the supply side of Mexican drug markets. Finally, our results suggest that supply reduction policies in Colombia interacted with the conditions created by federal policies in Mexico to create a large increase in drug related violence, especially in the north of the country.

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Appendix A Robustness and other results

We now present some robustness checks and falsifications of our findings. These results are not directly linked to the predictions of our theoretical model. Their purpose is instead to support the validity of our empirical strategy.

A.1 Different transformations of the homicide rate

In order to deal with the logarithm of homicide rates that are equal to one, we shifted the value of our dependent variable by the 90th percentile of the values in the database. The reason why we chose this percentile is that, among other choices of percentiles, it results in errors that are closest to normal. We would now like to show that our results do not depend on this precise choice of percentile, or in the form of our transformation. In order to do so, we first run our preferred regression (column 2 in table 3) by shifting homicide rates by other percentiles. The first three columns in table 7 show our coefficient of interest when shifting the homicide rate by the 90th, 50th and 10th percentile. In column 4 we use another method to deal with municipalities with zero homicides: we find homicide rates using the number of homicides plus one, and then find its logarithm. This removes the arbitrariness of the percentile level used, but it has the problem that one additional homicide is a large increase for municipalities with few inhabitants. Column 5 uses the number of homicides without any transformation as dependent variable. Columns 6 and 7 use Poisson and negative binomial models, which are commonly used with count data. Finally, column 8 uses a binomial dependent variable, which is when there are homicides in a given municipality, and zero otherwise.

Panel A shows that for all models the coefficient of interest is positive, and it is significant at a high level, except for the regressions with the number of homicides and the dummy as dependent variables, which anyway result in a coefficient that is significant at the 10% level. This is not surprising, since we believe that these models have serious flaws: the regression with the number of homicides has errors with large tails on the right, which leads to a high variance in the estimators, and the regression with the homicides dummy does not capture increases in violence in the intensive margin. For instance, municipalities with a large population, such as metropolitan zones, will almost certainly have homicides during any given month, so this regression does not capture changes in violence levels in these municipalities.

The different nature of each of the models mean that the coefficients of each of the models are not comparable to each other. We therefore show the standardized coefficients in panel B. All of them lie in the range between 0.0155 and 0.0232, except for a clear outlier, the model with the homicides dummy as a dependent variable, which, as explained above, has important flaws.

Table 7: Estimates for different transformations of the homicide rate.

	(1) Log, homicide rate plus 90th percentile	(2) Log, homicide rate plus 50th percentile	(3) Log, homicide rate plus 10th percentile	(4) Log, Homicides + 1	(5) Number of homicides	(6) Poisson	(7) Negative binomial	(8) Homicides dummy
Panel A: Non-standardized coefficients								
Colombian supply	0.1038***	0.2413***	0.4119***	0.1867***	1.4341*	1.1979***	1.2399***	0.0822*
× Distance to U.S.	(0.0299)	(0.0667)	(0.1152)	(0.0479)	(0.7366)	(0.1534)	(0.1746)	(0.0432)
Observations	118,527	118,527	118,527	118,527	118,527	96,426	96,426	118,527
R-squared	0.0110	0.0125	0.0130	0.0140	0.0150			0.0096
Panel B: Standardized coefficients								
Colombian supply	0.0232***	0.0229***	0.0155***	0.0232***	0.0202*	0.0169***	0.0175***	0.0103*
× Distance to U.S.	(0.0067)	(0.0063)	(0.0043)	(0.0060)	(0.0104)	(0.0022)	(0.0025)	(0.0054)
Observations	118,527	118,527	118,527	118,527	118,527	96,426	96,426	118,527
R-squared	0.0110	0.0125	0.0130	0.0140	0.0150			0.0096

NOTE: Robust standard errors with clustering by municipality are shown in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%. All regressions have income and state presence controls.

A.2 Degree of the polynomial trend

Our baseline regression, equation (18), includes a cubic polynomial included in the term $S_t(\gamma)$. We now explore whether the degree of this polynomial has an important effect on our results. Table 8 shows the result of using various degrees of the polynomial, and it leads to the conclusion that the degree of the polynomial is not very relevant. The main reason is that, even without the polynomial, we are already controlling for time trends by interacting year dummies with our variable of interest, so that only within-year variation remains. It is also clear that the coefficients are stable for polynomials of degree 3 or higher. This justifies our usage of a cubic polynomial throughout this paper.

Table 8: Effects of net cocaine production on homicide rate, using polynomials of different degrees as a control.

Degree of polynomial	(1) No polynomial	(2) Linear	(3) Cuadratic	(4) Cubic	(5) Cuartic	(6) Quintic
Panel A: INEGI homicide rate						
Colombian supply	-0.0120*	-0.0088	-0.0090	-0.0106	-0.0108	-0.0108
	(0.0065)	(0.0067)	(0.0068)	(0.0068)	(0.0068)	(0.0068)
Colombian supply × Distance to U.S.	0.0971***	0.0940***	0.0852***	0.1038***	0.1074***	0.1044***
	(0.0283)	(0.0289)	(0.0292)	(0.0299)	(0.0302)	(0.0301)
Observations	118,527	118,527	118,527	118,527	118,527	118,527
R-squared	0.0105	0.0105	0.0106	0.0108	0.0108	0.0108
Panel B: Drug-related homicide rate						
Colombian supply	-0.0299***	-0.0003	-0.0047	-0.0057	-0.0072*	-0.0072*
	(0.0030)	(0.0037)	(0.0039)	(0.0039)	(0.0041)	(0.0041)
Colombian supply × Distance to U.S.	0.0691***	0.0662***	0.0609**	0.0825***	0.0837***	0.0757***
	(0.0245)	(0.0254)	(0.0257)	(0.0263)	(0.0267)	(0.0259)
Observations	118,527	118,527	118,527	118,527	118,527	118,527
R-squared	0.0173	0.0187	0.0187	0.0194	0.0194	0.0195

NOTE: Robust standard errors with clustering by municipality are shown in parentheses. *** significant at 1%, ** significant at 5%, * significant at 10%.

A.3 Falsification: Effect of heroin scarcity

In order to check that the effects we measure are indeed caused by the increase in rapacity due to larger revenues in response to supply shocks, we perform a falsification test, in which we extend our baseline regression to measure whether supply shocks originated from *heroin* seizures in Colombia have an effect on violence in Mexico. Mexican cartels also obtain significant revenues from smuggling heroin across the U.S. border.

However, the large majority of the heroin they traffic is produced in Mexico (from poppy cultivated in Mexico), especially in the states of Sinaloa, Michoacán, and Guerrero. According to the UNODC (2013), the potential heroin production in Mexico is 30 times higher than in Colombia. Therefore, heroin seizures in Colombia should have no noticeable effects on the Mexican market, and thus should not increase rapacity between Mexican cartels.

Our results are shown in table 9. In this exercise we use drug seizures in Colombia instead of the net supply (as in all previous results) because there is no reliable estimate of heroin production in Colombia that we can use to construct the net supply of heroin. The coefficients should therefore have the opposite sign from the one shown in our main results if the rapacity channel is present. Panels A and B show time series effects similar to those shown in table 2 (so the coefficients should be positive), while panels B and C show the differential effect of drug shortages with distance, similar to the results in table 3 (so the coefficients should be negative). In the regressions of columns 2 and 4 we include both cocaine and heroin seizures interacted with distance to the nearest border crossing to the U.S. In all cases, coefficients for cocaine seizures remain almost the same as without heroin seizures (columns 1 and 3). Furthermore, none of the coefficients for heroin is significant, and the signs vary depending on the different regressions. We interpret this as evidence in favor of our model, since heroin seizures in Colombia cause no scarcity in Mexican drug markets that may increase violence through the rapacity channel. This helps us conclude that there is no spurious correlation between the high frequency behavior of drug seizures in Colombia and violence in Mexico—our key identifying assumption—because there is only a measurable relationship between violence and the type of drugs that would cause effects through the rapacity channel.

Appendix B Proof of proposition 2

Let $g^C(a_i, Q^s)$ be the maximum level of cooperation that can be sustained with a threat of reversion to static Nash. Here, we focus only on symmetric equilibria. Let $A(Q^s) = (1-\eta)s_i R(Q^s)$ be a random variable describing vulnerable revenue in municipality i. The incentive compatibility constraint on this level is given by

$$\frac{1}{N_i}A(Q^s) - g^C(a_i, Q^s) + \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^t (1-a_i)^t (g^N(Q^s) - g^C(a_i, Q^s))\right] \geq \max_x \frac{x}{x + (N_i - 1)g^C(a_i, Q^s)} A(Q^s) - x. \tag{21}$$

Let $\Theta(a_i) = \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^t (1-a_i)^t (g^N(Q^s) - g^C(a_i, Q^s))\right] \geq 0$. At this point, it is not clear that this amount is uniquely determined for each value of Q^s, but we will demonstrate it below. The incentive compatibility constraint simply states that the gains from

Table 9: Effect of cocaine and heroin seizures in Colombia on homicide rates.

	All Mexico		Distance quintiles 1-2	
	(1)	(2)	(3)	(4)
	Panel A: Time series effects on INEGI homicide rate			
Cocaine seizures in Colombia	0.013**	0.011*	0.039***	0.038***
	(0.007)	(0.007)	(0.010)	(0.011)
	(0.005)	(0.006)	(0.009)	(0.009)
Heroin seizures in Colombia		-0.024		-0.006
		(0.015)		(0.026)
		(0.021)		(0.037)
Observations	120296	120296	48167	48167
R-squared	0.004	0.004	0.013	0.013
	Panel B: Time series effects on drug related homicide rate			
Cocaine seizures in Colombia	0.008**	0.008**	0.021**	0.022***
	(0.004)	(0.004)	(0.008)	(0.009)
	(0.007)	(0.007)	(0.013)	(0.013)
Heroin seizures in Colombia		0.002		0.012
		(0.009)		(0.019)
		(0.011)		(0.019)
Observations	120296	120296	48167	48167
R-squared	0.007	0.007	0.012	0.012
	Panel C: Panel effects on INEGI homicide rate			
Colombian cocaine seizures	-0.1060***	-0.1096***	-0.1653***	-0.1558***
× Distance to U.S.	(0.0307)	(0.0313)	(0.0582)	(0.0590)
Colombian heroin seizures		-0.0383		0.1013
× Distance to U.S.		(0.0757)		(0.1529)
Observations	118,527	118,527	47,351	47,351
R-squared	0.0110	0.0109	0.0266	0.0266
	Panel D: Panel effects on drug related homicide rate			
Colombian cocaine seizures	-0.0800***	-0.0838***	-0.1800***	-0.1868***
× Distance to U.S.	(0.0270)	(0.0279)	(0.0602)	(0.0623)
Colombian heroin seizures		-0.0401		-0.0719
× Distance to U.S.		(0.0590)		(0.1270)
Observations	118,527	118,527	47,351	47,351
R-squared	0.0201	0.0201	0.0325	0.0325

Note.- The table presents estimates of the effect of supply shortages (measured at the monthly level in hundreds of metric tons) on violence in Mexico. The dependent variable is the shifted log of the homicide rate indicated in each panel. Columns 1 and 2 present estimates for the whole Mexican territory; Columns 3 and 4 for quintiles 1 and 2. Two sets of standard errors are reported in parenthesis below time series estimates (panels A and B). The first is robust to heteroskedasticity and serial correlation within municipalities. The second also allows for correlated time shocks across municipalities. Panel data estimates (panels C and D) include income and state presence controls. Coefficients with *** are significant at the 1% level, with ** are only significant at the 5% level and with * are only significant at the 10% level using the first set of standard errors.

a deviation to all other levels of violence x are dominated by playing the cooperative strategy $g^C(a_i, Q^s)$ and obtaining the differential continuation value $\Theta(a_i) > 0$.

Solving for x, we obtain

$$x = \sqrt{(N_i - 1)g^C(a_i, Q^s)A(Q^s)} - (N_i - 1)g^C(a_i, Q^s) \geq 0. \quad (22)$$

Plugging this value yields the incentive compatibility condition

$$\left[\frac{1}{N_i}-1\right]A(Q^s)+\Theta(a_i)\geq N_i g^C(a_i,Q^s)-2\sqrt{(N_i-1)g^C(a_i,Q^s)A(Q^s)}. \tag{23}$$

The right-hand side is decreasing for $g^C(a_i,Q^s)\in[0,g^N(Q^s)]$, and has a minimum at $g^N(Q^s)$. This implies that the above condition implies a lower bound for $g^C(a_i,Q^s)$, or the smallest possible level of conflict that can be sustained with a reversion to static Nash upon deviation.

Thus, the most cooperative equilibrium is given by the unique solution, $g^C(a_i,Q^s)\geq 0$, to the functional equation

$$\left[\frac{1}{N_i}-1\right]A(Q^s)+\Theta(a_i)\geq N_i g^C(a_i,Q^s)-2\sqrt{(N_i-1)g^C(a_i,Q^s)A(Q^s)}, \tag{24}$$

with equality if $g^C(a_i,Q^s)>0$. Let $\overline{Q}(a_i)$ be such that

$$(N_i-1)A(\overline{Q}(a_i))=N_i\Theta(a_i). \tag{25}$$

For $Q^s\geq\overline{Q}(a_i)$, we have that the above condition holds as an inequality so $g^C(a_i,Q^s)=0$ for large values of the supply Q^s as stated in the proposition. If $A(Q^s)$ is bounded, the above condition also holds as an inequality with $g^C(a_i,Q^s)=0$ when $\beta(1-a_i)\to 1$. Thus, for sufficiently low discounting there is always an equilibrium that exhibits no violence along the equilibrium path if revenue is bounded. If, on the other hand, revenue is unbounded, there is a sufficiently low Q^s such that the above condition does not hold for $g^C(a_i,Q^s)=0$, and we must have that $g^C(a_i,Q^s)>0$ for sufficiently low values of Q^s. These observations establish the first two parts of the proposition.

Before continuing, we claim that $\Theta(a_i)$ is decreasing in a_i. We have that

$$\Theta(a_i)=\frac{\beta(1-a_i)}{1-\beta(1-a_i)}\left(\frac{N_i-1}{N_i^2}\mathbb{E}[A(Q^s)]-\mathbb{E}[g^C(a_i,Q^s)]\right). \tag{26}$$

We have that for $Q^s<\overline{Q}(a_i)$,

$$g^C(a_i,Q^s)=\left(\frac{\sqrt{(N_i-1)A(Q^s)}-\sqrt{N_i\Theta(a_i)}}{N_i}\right)^2. \tag{27}$$

Plugging this in the above expression yields

$$\left(\frac{1-\beta(1-a_i)}{\beta(1-a_i)}N_i^2+N_i\right)\sqrt{\Theta(a_i)}=2\sqrt{(N_i-1)N_i}\mathbb{E}\left[\sqrt{A(Q^s)}\right]. \tag{28}$$

This expression implies that $\Theta(a_i)$ is unique (and hence the uniqueness of the solution) and also that it is decreasing in a_i as wanted. The above claim together with equation 25 also implies that $\overline{Q}(a_i)$ is increasing in a_i as mentioned in the first item of the proposition. Using the formula for $g^c(a_i, Q^s)$ derived above, this also implies that g^c is increasing in a_i as mentioned in the proposition.

Now, we focus on the role of Q^s. so

$$\frac{\partial g^C(a_i, Q^s)}{\partial Q^s} = \left(\frac{\sqrt{(N_i - 1)A(Q^s)} - \sqrt{N_i \Theta(a_i)}}{N_i} \right) \sqrt{\frac{N_i - 1}{A(Q^s)}} A'^s) < 0. \tag{29}$$

The inequality follows from observing that for $Q^s < \overline{Q}(a_i)$ we have $\sqrt{(N_i - 1)A(Q^s)} > \sqrt{N_i \Theta(a_i)}$. In the above derivation it is key to notice that $\Theta(a_i)$ does not depend on the current realization of Q^s because of the independence assumption on the draws. This shows that violence increases when supply is tighter in this equilibrium as well. Thus, informal arrangements are not enough to eliminate the impact of supply shortages on violence when there is sufficient discounting and supply is tight enough.

Moreover, we have that

$$\frac{\partial^2 g^C(a_i, Q^s)}{\partial Q^s \partial a_i} < 0, \tag{30}$$

because $\Theta(a_i)$ is decreasing in a_i. This proves the item of the proposition regarding the cross partial derivative.