The Pearson Institute Discussion Paper No. 40

Economic shocks and rebel tactics

Austin L. Wright

2016

Working paper

THE PEARSON INSTITUTE
FOR THE STUDY AND RESOLUTION OF GLOBAL CONFLICTS

ECONOMIC SHOCKS AND REBEL TACTICS*

Austin L. Wright†

May 10, 2016

Abstract

Why do rebels vary their tactics? Some insurgents employ terrorism and hit-and run attacks; others wage conventional wars against state rivals. I argue rebels' tactical choices reflect three constraints: economic opportunities of non-combatants, state strength, and rebel capacity. I test the argument with microdata on rebel violence in Colombia and exploit plausibly random shocks to local income. I find evidence that local economic shocks substantially affect rebel tactics. Specifically, when government forces benefit from local windfalls and economic opportunities for civilians improve, insurgents favor irregular tactics. Alternatively, when rebels are strengthened, they favor conventional tactics. These results are robust to accounting for numerous potential sources of bias, including atmospheric dispersion of illicit crop herbicides, violence spillovers from drug trafficking, and foreign military aid shocks. The main findings challenge prominent theories of insurgency, and are relevant to the comparative study of political violence, with important implications for scholars and policy makers.

JEL Codes: D74, Q17, F16, J30, O13

*For extensive comments, I thank Faisal Ahmed, Ryan Brutger, Joanne Gowa, Guy Grossman, Raymond Hicks, Richard Jordan, Amanda Kennard, Ben Lessing, Saurabh Pant, Amanda Rizkallah, Tsering Shawa, Emily West, and Joseph Young. I also thank seminar and workshop participants at the following institutions: American University SIS, Chicago Harris, Connecticut College, New York University, Princeton University, University of Iowa PS/IIHR, University of Minnesota, UCLA, UC Riverside, University of Southern California SIR/SSI, and Vanderbilt University. Iván Bornacelly, Oeindrilla Dube, Manuel Fernández, Karina Gonzalez, Daniel Mejía, Pascual Restrepo, and Luis Reyes generously shared data and the staff of *Revista Criminalidad Policía Nacional* granted access to their historical archives. John Mejía and Bob Dattore provided excellent guidance regarding historical climate data. David Thau and the Google Earth Engine program provided access to vital cloud-based supercomputer resources. Special debts of gratitude are owed to David Carter, Kris Ramsay, Jacob Shapiro, and Juan Vargas; each advanced this project immeasurably. This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. 2012152169. Supporting materials are available at **www.austinlwright.com/rebel_tactics**. All errors remain my own.

†Harris School of Public Policy, The University of Chicago, 1155 East 60th Street, Chicago, Illinois 60637.

1 Introduction

Rebel tactics vary significantly within conflicts, across time and geographic space. Popular histories of the American civil war, for example, portray battles between highly disciplined Union and Confederate armies. Yet a closer study of this conflict reveals that Southern tactics differed radically throughout West Virginia, Tennessee, and North Carolina, where civilians were systematically targeted and irregular skirmishes were more common than battlefield engagements (Kalyvas, 2006; Lockyer, 2010). In Missouri, the character of rebel violence stood in stark contrast to the conventional warfare of the battles at Gettysburg, Fort Sumter, and First Manassas. "This was", Fellman (1989, 23) writes about Missouri, "a war of stealth and raid, without a front, without formal organization, with almost no division between the civilian and the warrior." Similarly, in Vietnam, Vietcong forces employed tactics that ranged from heavy weapon battles with French, American, and local forces to orchestrated ambushes and non-combatant massacres.[1] More recently, Boko Haram and the Islamic State of Iraq and Syria (ISIS) have varied their tactics widely, attacking civilians, razing villages and border crossing outposts and fielding trained fighters to seize contested territories from local and national military forces.[2]

Although recent research investigates how and why the technologies of rebellion differ *across* insurgencies (Kalyvas and Balcells, 2010), we still know little about the conditions under which rebels vary tactics *within* conflicts, from irregular violence to conventional tactics and vice versa.[3] This is due, as Findley and Young (2012), Bueno de Mesquita (2013), and Carter (2015) note, to a tendency in current scholarship to study models of terrorism, guerrilla warfare, and conventional tactics in isolation.[4]

In this paper, I argue that internal and external constraints shape the incentives and opportunities for armed rebel groups to shift their tactics from irregular, hit-and-run attacks to conventional, frontal assaults. Three constraints bind rebels' tactical choices: economic opportunities of non-combatants, state strength, and rebel capacity. Because the severity of these constraints may be shaped by conflict dynamics, I study plausibly random shocks to the economic foundation of each constraint. The observable implications of my argument are straightforward. When governments benefit from local windfalls and economic conditions improve for civilians, insurgents favor irregular tactics. When rebels are strengthened by revenue booms, they favor conventional tactics.

[1] Respectively, Dien Bien Phu, Bien Hoa Air Base, Chon Thanh, Battle of Ong Thanh, and Massacre at Hue.

[2] Respectively, Borno, Adamawe, and Yobe; Derna (Libya), Bumar, Wana (Iraq), Atmeh, Azaz (Syria).

[3] As Kalyvas and Balcells (2010) point out, from 1944-1990, 66% of civil wars were characterized by irregular violence, while 28% were fought by conventional means. The dominant "technology of rebellion" shifted after the end of the Cold War, favoring conventional tactics over asymmetric violence. Although system polarity may explain these trends, a more granular theory is required to explain when rebels substitute one tactic for another or combine irregular *and* conventional violence.

[4] Bueno de Mesquita (2013), for example, studies the dominant tactic employed by rebels at the onset of civil war, although he does not model portfolio allocation between different tactics within ongoing conflict.

I test the argument with microdata on rebel violence and plausibly exogenous shocks to local income in Colombia. The conflict data I analyze distinguish ambush, sabotage, and hit-and-run style attacks from intentional, armed clashes between rebels and state forces (Restrepo, Spagat and Vargas, 2006). Consistent with the historical record of other insurgencies, rebel tactics in Colombia varied significantly over time and across municipalities. To study if civilian outside options, state capabilities and rebel capacity explain this variation, I analyze municipal-year data on income shocks to three goods: coffee, oil and coca. These commodities are at the core of the constraints that I theorize bind rebel strategy. When coffee productivity is high and prices rise, non-combatants have economic options outside of participating in rebellion. As local oil income grows, counterinsurgent capacity increases directly—through the allocation of royalties and tax income to fighting effort—and through secondary support—contracts with multinational firms to protect wells and pipelines.[5] As cultivation of coca bushes expands and market prices for cocaine rise, local rebel income surges, permitting subunits to better arm and recruit fighters. Naturally, income shocks can also be negative, diminishing economic opportunities for civilians, tempering government capacity and curtailing the strength of rebels.

I use an instrumental variables approach, leveraging plausibly exogenous variation in world prices and supply, and novel climatic data to identify shocks to local income.[6] I focus on three robust results. First, negative shocks to local coffee income lead rebels to shift their tactics substantially. A one standard deviation decline in municipal income from coffee is associated with an 8% increase in the use of conventional tactics over irregular violence. Second, positive shocks to government revenue from oil cause insurgents shift to irregular, hit-and-run attacks on state forces. For oil income, a one standard deviation gain is associated with a 6% shift from direct engagements to indirect fighting. Third, negative shocks to rebel rents from coca production lead resource-constrained rebels to avoid direct engagements with state forces and employ guerrilla and terrorist tactics instead. When coca income experiences a one standard deviation fall, rebels allocate 4% more effort to irregular violence.

This paper advances the study of internal conflict in four ways. First, scholarship has focused predominantly on isolated forms of violence. Thus, the coincidence of conventional violence against state forces and other, "lesser" forms of violence has largely been ignored (Tarrow, 2007). "While this overlap may seem evident to some," write Findley and Young (2012, 286), "it is puzzling that most scholars continue to ignore these connections." This is unfortunate since non-state actors use a variety of violence, ranging from sabotage and ambushes to pitched engagements with state forces. Rebels also mix their tactics, allocating some effort to conventional

[5]In addition to funding units of the national military and police, British Petroleum retained private contractors to train local Colombian forces in counterinsurgent tactics (1997).

[6]My use of weather variation to study income shocks builds on and contributes to an emerging literature in the political economy of conflict (Rana, 2014; Blakeslee and Fishman, 2014; Brückner and Ciccone, 2011; Dube and Vargas, 2013; Hidalgo et al., 2010; Mejía and Restrepo, 2014; Nunn and Qian, 2014; Adano et al., 2012; Fjelde and von Uexkull, 2012; Mares, 90; Sarsons, Forthcoming)

means while also using irregular tactics. Understanding the factors that drive these tactical choices has important implications for scholars and policy makers. I bridge the analytical distinction between irregular violence and conventional tactics by studying how and why rebels vary their use of both technologies of rebellion.

Second, my core findings highlight variation in rebel violence unexplained by existing theories of insurgency. Theories of contestation suggest that rebels use violence to signal resolve (Hultman, 2012; Fearon, 1995). For violence to be a credible signal of rebels' willingness to continue the insurgency, it must convey strength (Walter, 2009, 249). Rebels, accordingly, invest heavily in sophisticated attacks when they are least capable of carrying them out. I find, however, that rebels do the opposite. As their relative capabilities degrade, rebels revert to irregular violence, allocating scarce resources to limited engagements with police and military units, and, relatedly, violence against civilians.[7] Theories of control differentiate zones governed by insurgents and state actors and claim that the character of violence changes with the degree of political sovereignty (Kalyvas, 2006). Contrary to these claims, I find that violence *within* zones of control can vary substantially. Within a small geographic space, rebels produce a variety of violence, and the character of this violence cannot be explained by the degree of political sovereignty alone.[8] Variation in rebel institutions also cannot explain these results. Theories of organization anticipate that the character of violence perpetrated by rebel groups will be consistent across regions and over time within a given conflict (Weinstein, 2007, 217-219). The institutional endowments of rebels shape their violence, independent of variation in group and state capacity, and persistence of organization in insurgency translates into consistency in rebel tactics. Thus, Colombia's civil conflict represents a least-likely setting for observing tactical substitution. Yet, as I demonstrate, the portfolio of violence used by rebels is highly variable, despite continuity in the microlevel institutions governing rebellion during the period of study.

Third, this study addresses a notable empirical gap in the study of civil conflict. As Blattman and Miguel (2010) point out, few studies have convincingly demonstrated the microfoundations of the political economy of civil war. Indeed, the lion's share of research on substate conflict investigates country-level panel data, including prominent contributions like Fearon and Laitin (2003), Collier and Hoeffler (2004), Miguel, Satyanath and Sergenti (2004), Humphreys (2005) and, more recently, Hsiang, Meng and Cane (2011) and Bazzi and Blattman (2014).[9] In their influential study of internal violence in Colombia, Dube and Vargas (2013) present microlevel evidence that commodity price shocks increase the severity of rebel violence in some municipal-

[7] This finding is anticipated by Laitin and Shapiro (2008). They argue that irregular violence is meaningful because it reveals group capacity is low.

[8] Staniland (2012) presents an well-conceptualized extension of this argument, noting that violence in a number of historical cases is shaped by political geography *and* informal/formal agreements between rebels and states to cooperate. While persuasive, my findings do not reflect the emergence of wartime political orders.

[9] For related contributions, see Ross (2004); Buhaug (2010); Burke et al. (2009, 2010); Collier, Hoeffler and Soderbom (2004); Hegre and Sambanis (2006); Hsiang (2010); Miguel and Satyanath (2011).

ities but not others. Fjelde (2015), Jia (2014) and Vanden Eynde (2015) similarly investigate the relationship between subnational income shocks and political violence. I build on this micropolitical turn in the study of insurgency by presenting robust empirical evidence linking local economic shocks and tactical choice by rebels.

Finally, I bring rebel capacity back into the study of insurgent violence, theoretically and empirically. I situate rebel capacity within a theoretical framework that incorporates outside options and state strength. Previous scholarship has held at least one of these factors constant in order to gain leverage on another. Bueno de Mesquita (2013), for example, focuses on the economic opportunities of civilians outside of rebel mobilization while Carter (2015) studies state capacity. Similarly, Butler and Gates (2009) and Lockyer (2010) emphasize the balance of military strength but largely ignore outside options. Studying these three constraints together allows us to explore how each plays a distinct yet vital role in shaping the violence rebel groups employ.

Gathering data on rebel capacity is difficult. State-of-the-art research on rebel strength relies on slow-moving, aggregate measures of relative capacity.[10] The limitations of this data reflect how challenging it is to reliably track rebel forces, finances, and civilian support, even at the group-year level. I contribute to the empirical study of rebel capacity by using microlevel shocks to coca cultivation to study variation in rebel income. Rebel involvement in the Colombian drug trade is extensive and well-documented.[11] The administrative and climatic data I use to investigate shocks to rebel capacity are unparalleled in the historical study of Colombia's internal conflict and among the first in the comparative study of political violence.[12] I further contribute to the quantitative study of rebel capacity by introducing a new method for the retrospective estimation of drug production. This estimation procedure combines methodological insights from remote sensing with high resolution, historical satellite imagery to predict the extent and intensity of drug production when no such data exists. For the purposes of the present analysis, I harness this approach to study where and to what degree coca bushes were cultivated in rural municipalities. The solution is highly portable, and resolves a long-standing problem in the study of drug and agricultural production: incomplete data.

In the following sections, I outline my main argument and analyze data on local economic shocks and tactical substitution by insurgents in Colombia during the height of rebel strength and reliance on drug revenue. After presenting evidence consistent with my theory, I test the robustness of the argument and present several theoretical and empirical extensions. The results are remarkably robust. I conclude with a discussion of my findings and contributions to the study of political violence.

[10] One frequently used measure tracks how groups' military capability compares with their state rivals along a five-part scale (Cunningham, Gleditsch and Salehyan, 2013). See also Holtermann (2015)

[11] See Otis (2014) for a thorough review.

[12] See also Vanden Eynde (2015).

2 Theory & Empirical Expectations

Rebel tactics vary substantially from one region to another and as violent conflicts persist. In figure 1, I plot variation in the use of conventional and irregular tactics in 28 of Colombia's most violent municipalities. Notice that rebel tactics vary significantly. In some areas at certain times, rebels use conventional tactics. In other areas in different times, they turn to irregular violence. What explains this variation? I argue that rebels face three binding constraints on the violence they produce: the resources of their group, the strength of their state rival and the economic opportunities available to civilians outside of involvement in rebellion. These constraints can, and often do, vary at a local level. At its core, the argument is simple. To produce violence, rebels need fighters and arms. Conventional violence is appealing as a means for expanding and establishing territorial control (de la Calle and Sanchez-Cuenca, 2015), but requires more fighters and arms than irregular tactics.[13] All else equal, rebels with territorial ambitions would prefer to engage in direct fighting with state forces, but engage in irregular combat when conventional tactics are not plausible.

When combatants and weapons are scarce, groups favor irregular warfare, characterized by hit-and-run attacks on state forces and, occasionally, violence against civilians. As the group's ability to field and arm fighters increases, rebels launch conventional assaults on government forces, where they engage armed combatants in coordinated, direct combat. Although rebels may allocate their entire fighting effort to irregular *or* conventional tactics, they often mix between them. The degree to which groups focus on one tactic over another is important precisely because it reflects how severely rebel capacity, state capacity and civilian outside options constrain insurgent strategy at a local level. I clarify each of these constraints below.

Rebel capacity

Rebel organizations face resource problems that limit their ability to coordinate political activities freely or challenge state forces militarily. Resources have a multitude of potential origins. Some groups rely heavily on consensual revolutionary taxes, banditry or illegal activities like kidnapping or illicit drug production, trafficking, or protection rackets. Others are able to attract support from state sponsors, or ideologically and strategically aligned rebel groups operating in nearby conflict theaters. When rebels lack the resources to recruit, feed and arm fighters, they are less capable of engaging in conventional fighting. Instead, they rely on irregular, hit-and-run tactics, which are less taxing to execute. Even as insurgents amass arms and expand their ranks, they may continue guerrilla attacks as they prepare for large-scale conventional engagements.

[13]For most organizations whose central goal is political disruption — e.g., terrorist groups — allocation of scarce resources to conventional violence is inefficient. Although territorial and non-territorial, anti-system groups face similar constraints, the former's preference for conventional violence does not necessarily apply to the latter.

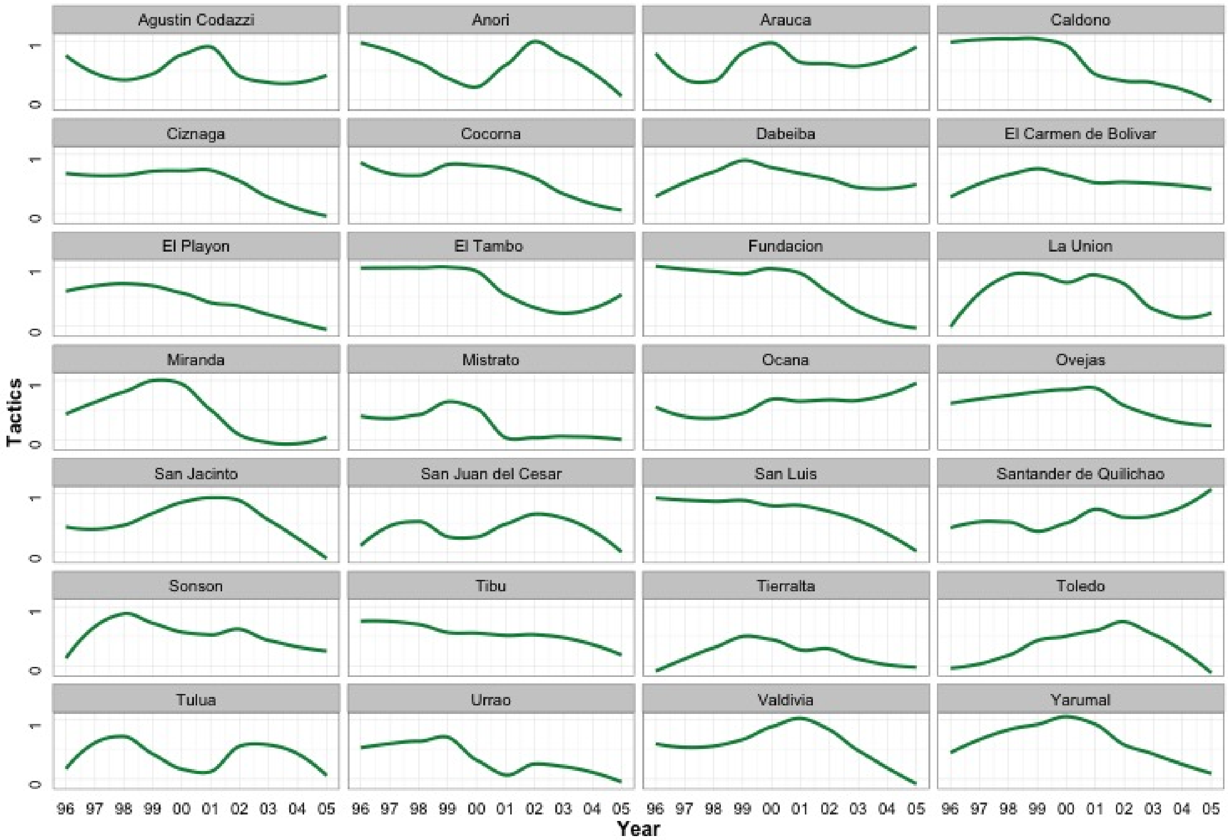


Figure 1: Shifts in tactical choice *within* an ongoing insurgency: rebel violence in Colombia, 1996-2005. Higher values (Tactics $\rightarrow$ 1) indicates relatively more irregular violence.

Once rebels are capable enough to pursue, establish and defend territorial control of a region, irregular fighting, especially attacks on civilians, diminishes (Kalyvas, 2006). Resource gains may also lead to public goods provision, increasing non-combatant sympathy for the insurgency, and further consolidation of rebel control (Wood, 2003). The allocation of public goods reduces the likelihood of defection and increases the attractiveness of rebel recruitment. The provision of private benefits such as familial trust funds—financial support allocated to family members in the event of combatant capture and detention or death—also provide a potent tool of recruitment and retention.[14] "Groups with access to economic resources are able to translate those endowments into selective incentives", Weinstein writes, "in order to motivate individuals to join the rebellion" (2007, 9). These distributional commitments are only credible when rebel groups acquire the resources and capacity to manage them. Insurgent organizations that have the means to recruit, mobilize and support a capable fighting force, provide credible public and private goods to

[14] Although uncommon, formal trust funds and pensions have been administered by rebel groups. The Revolutionary Armed Forces of Colombia, for example, spent roughly 2.5 million on a trust fund for captured rebels in 2003. They also provide continuing financial assistance to relatives of detained members (Saskiewicz, 1999).

supporters and establish territorial control have the classical markings of primitive states and often fight like them, engaging in direct assaults on government forces and strongholds when strategic conditions favor such tactics.

While resource gains may hasten a transition from irregular to conventional tactics, unanticipated losses force rebels to allocate scarce resources to the fighting effort in a manner that matches their reduced capacity. This means that weakened insurgents are likely to return to mobile, indirect engagements as well as violence against civilians (Wood, 2010, 2014). Surprise attacks, sabotage, and ambushes become more common. To stymie human and capital losses, rebels may roll back allocation of public goods or turn to violence against civilians as a means to compel compliance with requests of support (Weinstein, 2007).

- *Use of conventional tactics increases with rebel capacity.* Windfalls to rebel income and capacity lead to a relative increase in the use of conventional tactics. Alternatively, negative shocks to insurgent capacity lead to a shift from conventional to irregular tactics.

Government capacity

Government capacity figures prominently in rebel strategy. Capable governments deter rebels from direct combat by investing in counterinsurgent efforts, while weak governments are susceptible to frontal assaults. Windfalls to state dominated resources can lead to increased investment in security infrastructure. Capital-intensive sectors, like petroleum production, are immobile and often easy to tax. Positive shocks to industries that generate government revenue increase state capacity to engage in counterinsurgency campaigns. As Carter argues, "under relatively weak conditions states able to allocate resources to deter the group launching a [conventional] campaign always will do so" (2015, 12). External intervention—whether through arms transfers, foreign aid, or logistical support—can also increase a beleaguered military's capacity to neutralize internal threats.

Alternatively, where extractive industries become attractive targets of rebel capture, multinational firms may create repressive capacity through side payments to military leaders and institutions. In 1995, for example, British Petroleum formally contracted the Colombian air force, military and national police to protect their top producing oil wells and transport pipelines, including earmarked funds for healthcare services, troop housing and weapons (1996; 1998; N.d.; 1995). Similarly, in 1997, Occidental Petroleum agreed to make substantial cash transfers to several Colombian military and police units in exchange for protection of their oil extraction and refinement machinery, as well as untapped oil fields (1997; 1996/1997). Occidental's military support contract explicitly set aside cash to fund a network of informants, used by the military to dismantle rebel fronts operating in areas where Occidental's financial interests were most substantial. By the late 1990s, a quarter of all Colombian army units were deployed to oil producing municipalities, with a formal mandate to repress guerrilla activity (Soltani, 2002).

A realized shift in the balance of military power towards the state makes the continued use of conventional tactics by rebels unwise (Butler and Gates, 2009). Insurgents almost always enjoy greater force mobility than their government rivals and use of irregular tactics exploits this asymmetry to a greater degree than pitched engagements. Unlike conventional engagements, irregular tactics can be easily managed by a small number of fighters and are less susceptible to state intervention. Indeed, as Fearon observes, "in contrast to ordinary crime and conventional military confrontations, mafias and insurgencies face the problem that adding more fighters raises the risk of detection and thus capture for all existing fighters" (2007, 4). The risk of government infiltration covaries positively with state capacity (Besley and Persson, 2010). Consequently, observing a positive shock in government revenue and counterinsurgent capacity, rebels are likely to recognize conventional tactics are no longer tenable and turn to irregular warfare.

The strategic advantages gained through external support and exogenous resource booms are mirrored by the devastating consequences of aid withdrawal or loss of territorial and operational control over key economic resources (Nielsen et al., 2011; Dube and Naidu, 2015). A crumbling security infrastructure, in addition to weakening strategic capabilities, can have a demoralizing effect on military forces. Sensing the inability of military units to project or maintain control over contested areas, insurgents may allocate resources to cutting off and dismantling bases through conventional means. In areas where state forces remain intact, guerrillas rely on covert operations that target resupply convoys and other vulnerable targets.

- *Rebels resort to irregular violence as government capacity increases.* Positive shocks to government income and counterinsurgent capacity make conventional engagements unprofitable for insurgents. Relatedly, negative shocks to government capacity lead to an increased production of conventional violence on state forces.

Outside options and mobilization

The economic opportunities of civilians outside of mobilization also influence tactical choice. When non-combatants provide essential formal and informal support for rebels, insurgents are less likely to predate civilian communities and more capable of engaging state forces militarily (Weinstein, 2007). Poor economic conditions may turn the tide of the war toward rebel forces. How? Economic depression weakens outside options. The elimination of outside options to engage in profitable and productive economic activity makes mobilizing new fighters and retaining seasoned combatants easier.[15] "In opportunity cost models", argue Bazzi and Blattman, "a

[15]Income from labor-intensive commodities, like coffee, are primarily distributed to plantation owners, farmers and transitory workers. Bergquist (1986) and Dube and Vargas (2013) note that contemporary coffee cultivation

civilian's incentive to rebel rises as household income and economic opportunities decline" (2014, 4). Mobilization is, by consequence, decreasing in economic opportunity (Grossman, 1991).[16] Besley and Persson (2008, 23-24) study a related model of insurgent mobilization. As rebel ranks swell and mature, leaders can more effectively (and cheaply) employ conventional tactics in direct engagements with government forces.[17]

As economic conditions improve, the reservation wage of potential insurgents increases, making recruitment more costly. This effect is likely most prominent when participation in insurgency is a full-time commitment.[18] When the opportunity costs of mobilizing or supporting rebellion are substantial, it is unlikely that insurgents will be able to field enough voluntary fighters to continue the use of conventional fighting, which is both more capital and labor intensive than irregular violence.

- *Rebels turn to irregular violence as local economic conditions improve.* Attractive outside options make mobilization of non-combatants difficult. When outside options decline, insurgents produce increased conventional violence.

3 Research Design

Collecting reliable data on rebel capacity—force levels, armaments, financial prosperity—is challenging. The difficulty of collecting fine-grained measures of capacity is why existing research analyzes relative capacity between rebel groups and their state rivals. But rebel income is rarely equally distributed within the organization, and insurgent capacity is almost always unevenly applied across contested geography. Subunits that control access points to scarce resources are wealthier and more capable than fronts in the same organization that rely primarily low-level extortion. Local capacity of rebels is a consequence of locally acquired income, especially in the Colombian context.[19] If my argument is correct, local shocks to group revenue should induce

in Colombia is not mechanized due to environmental conditions (rugged terrain in growing areas) and relies primarily on manual labor during harvest months.

[16] See, also, Becker (1968) and Jayachandaran (2006).

[17] Alternatively, a dearth of outside options can also make intelligence gathering by state forces easier, since information on insurgent activity becomes less expensive to acquire from collaborators that cannot consistently profit from another occupation (Berman et al., 2011). Coordinating conventional violence exposes rebels to heightened risk of detection as well. Conventional fighting requires more fighters, support staff and armaments than irregular warfare. Each additional element required to engage state forces directly is another linkage that counterinsurgents can exploit. When economic conditions worsen, rebel units, weapon trafficking rings and communal support networks become cheaper to infiltrate. The opportunity costs of mobilization, thus, covary negatively with the risks of infiltration and detection.

[18] The distinction between full-time and part-time rebel mobilization is discussed by Mikulaschek and Shapiro (2015).

[19] Some rebel groups—al-Qa'ida in Iraq and the Islamic State of Iraq and Syria—maintain substantial central control over financing. In these groups, locally derived income may only partially shape capacity. For more details, see Johnston et al. (2015).

microlevel variation in how rebels fight. This is not to say that macrolevel exogenous shocks do not influence rebel grand strategy, as Kalyvas and Balcells (2010) show. Instead, my claim, and the core empirical contribution of this article, is that the study of insurgent micropolitics requires data on local dynamics.

I study rebel capacity in Colombia, where rebels have relied heavily on coca cultivation, refinement and trafficking to fund their operations since the mid-1990s. Following the collapse of the cartel system, guerrilla groups, including the Revolutionary Armed Forces of Colombia (FARC) and the National Liberation Army (ELN), seized the opportunity to tax small-scale rural cultivation of coca bushes and coca paste traffickers (Lee and Thoumi, 1999; Thoumi, 2002). The FARC *Estado Mayor Central* introduced the National Financial Commission and *ayudantías* (auditors) were assigned to monitor and manage the finances of individual fronts (local subunits). The ELN instituted a similar system (2015). Although limited revenue was shared across the organization, individual fronts—which govern a handful of municipalities each— retained control over how local income was spent. The termination of the air bridge between Bolivia, Peru and Colombia, coupled with widespread eradication efforts abroad, lead to a severe reduction in regional coca exports (Angrist and Kugler, 2008). Rebels capitalized on this coca shortage by expanding domestic production networks and increasing their in-house capacity to refine leaves into coca paste and, finally, cocaine (Rangel, 2000). Using coca production to study rebel capacity requires granular data on drug cultivation. As I detail later, I study coca cultivation in two ways. First, I gather administrative data on coca eradication.[20] While reliable, these data contain known and unknown measurement error. Second, to account for these reporting errors, I develop and implement a new method for retrospective estimation of coca cultivation using high resolution satellite imagery. These data allow me to unpack the blackbox of rebel capacity in new ways.

The Colombian case is also ideal for studying local shocks to state strength and civilian opportunities outside rebellion. In Colombia, Dube and Vargas (2013) investigate plausibly random shocks to municipal-level income from coffee and oil production, induced by changes in world market prices and supply.[21] Their study presents evidence linking income growth in coffee with increased wages and hours worked, and rising oil productivity and prices with municipal-level capital revenue gains.[22] Variation in local income derived from coffee, thus, strongly correlates with economic opportunities outside of rebel mobilization.[23] Previous scholarship correlates oil

[20]For details, see Mejía and Restrepo (2014).

[21]Dube and Vargas (2013) also investigate an admittedly poor measure of rebel income, an indicator variable for coca production in 1994, and find a positive relationship between this dummy variable and armed engagements but no relationship with one-sided guerrilla attacks. The coca cultivation data I study is a substantial advancement over this approach, and yields a more coherent explanation for this result.

[22]More broadly, price slumps labor-intensive sectors decrease demand for unskilled labor and reduce wages among employed laborers (Fjelde, 2015).

[23]Coffee production in Colombia is labor-intensive and absorbs a large number of low-skill, migratory workers during harvest months.

windfalls with state weakness and failure (Auty, 1993; Ross, 2001; Ramsay, 2011). In Colombia, however, well-managed royalty institutions exist to redistribute income gains back to oil-producing municipalities and these gains substantially influence municipal wealth.[24] Local and federal agencies, in conjunction with multinational firms, have a demonstrated commitment to protecting this revenue stream from rebel capture (1998; N.d.; 1995; 1997; 1996/1997).

Coca, coffee and oil production, thus, map closely onto the theoretical argument. But income shocks to these commodities may be driven by conflict dynamics in Colombia. Following Dube and Vargas (2013), I address this concern by studying how world market prices and supply impact local income. Because Colombia is not a major producer of oil, international petroleum prices are plausibly uncorrelated with changes in domestic production, which may be associated with rebel violence. On the other hand, Colombia is a major global exporter of coffee and coca. I instrument local income growth from coffee with variation in rainfall, temperature and production intensity of the three other major coffee exporters (Brazil, Indonesia, and Vietnam). My approach to rebel income shocks is similar, but leverages novel climatic data. I instrument coca income shocks in a number of ways, including panel-varying rainfall and temperature measures, soil suitability metrics, out-of-country farmgate prices, atmospheric windspeed, distance to counternarcotics airports, and production levels of other key coca exporters (Bolivia and Peru). These varied instruments are strong, valid, and yield highly consistent results.

In the rest of this section, I detail data collected for this study and the identification strategy used to investigate how income shocks shape rebel violence.

Data

Conflict

To investigate how rebel tactics vary, I study geocoded event data collected by the Conflict Analysis Resource Center (CERAC), introduced by Restrepo, Spagat and Vargas (2006). The dataset covers the Colombian conflict, from 1988 to 2005, and records more than 21,000 war-related events drawn from media reports and supplemented with data gathered from a network of Catholic priests. Importantly, these reports distinguish between irregular violence—ambushes, hit-and-run attacks and other indirect engagements—and conventional attacks, where rebels intentionally confront government soldiers and police officers in direct, armed combat.[25] The data also track irregular attacks that escalate, where government forces return fire and pursue rebels. Since these complex events represent strategic miscalculations by the rebels and do not

[24] Smith (2004), Morrison (2009), Thies (2010) present cross-national evidence that natural resources and nontax revenue may increase state capacity.

[25] To clarify how irregular and conventional attacks differ, I gathered a random sample of CERAC events and traced their corresponding source text. In roughly 85% of cases, rebels initiated conventional attacks, with a limited number of formal military operations occuring during the sampled period. Acts of irregular violence typically involved ambushes on counterinsurgents travelling along jungle trails and use of cylinder bombs.

reflect meaningful variation in tactical choice (rebels did not intend to engage in conventional violence), I exclude them from the present analysis.[26] Beyond violence between combatants, CERAC also records guerrilla violence against civilians.

Coffee, oil and coca

To study the impact of coffee and oil income shocks, I draw on data collected by Dube and Vargas (2013). Information on coffee cultivation is recorded by a 1997 census of coffee growers (figure 3a). Daily production of petroleum in barrels at the municipal level is available for 1988 (figure 3b). Internal coffee prices and international market prices for oil are drawn from their data archive.

I supplement these measures with data from the Colombian National Police on the extent and intensity of coca eradication (figure 3c). Publicly available data on coca cultivation in hectares is produced using both aerial photography and satellite imagery of agricultural activity from 1999-2005. An estimate of coca production at the municipal level also exists for 1994. Due to the four year gap between estimates, I primarily proxy coca leaf cultivation with the total eradicated hectares per year in each municipality.Mejía and Restrepo (2014) employ a similar technique and present evidence that the level of eradication corresponds to the intensity of cultivation. Reyes (2014) leverages exogenous variation in the patterns of eradication and confirms that anti-narcotic efforts in Colombia closely match variation in production.[27] Eradication flights were primarily limited by the operating radius of their police escorts (helicopters) as well as cloud cover, precipitation and windspeed. I review the environmental measures below. Importantly, if eradication intensity is correlated with state capacity, estimates of coca income that rely on this measure may underestimate the true causal effect of coca income on rebel tactics. Empirical support for the theoretical argument (that positive rebel revenue shocks will lead to conventional tactics) is likely the lower bound on the actual relationship.

I also gather market prices for coca and derivative products. Domestic farm-gate cocaine prices are collected from reports produced by the United Nations Office on Drugs and Crime (UNODC). These reports also detail the estimated coca leaf and cocaine exports of Bolivia and Peru, the region's other coca price-makers. I also incorporate information from a National Directorate of Coca Leaf Commercialization and Industrialization report which, with the support of UNODC, tracks monthly trends in farm-gate coca leaf prices in the Chapare region of Bolivia from 1991 to 2007 (UNODC, 2008).

[26] Future research could leverage these complex events to study the conditions under which rebels misjudge their targets willingness and/or capability to escalate small-scale engagements.

[27] Extending Reyes, I exploit several key features that influence eradication flights. I combine data on the locations of private and state-operated airports used by the Colombian Counternarcotics Police to fly eradication missions (see figure 7a) with factors that influence the feasibility of small aircraft and helicopter flight. The airports used for eradication have remained constant since the late 1980s.

Climate and environment

To identify exogenous variation in coca production, I assemble novel microdata on historical precipitation and temperature variation in Colombia. The baseline climate reanalysis was prepared by The National Centers for Environmental Prediction and Department of Energy using state-of-the-art assimilation techniques (Saha et al., 2010).[28] Monthly surface precipitation and temperature values are extracted from a 2.5-degree latitude by 2.5-degree longitude grid of earth from 1979 to 2010. These values are then converted to municipal-year measures of total rainfall, average monthly rainfall and within-year rainfall variation. All measures are area-weighted, a method Dell, Jones and Olken (2014) recommend for studying agricultural production. Similar measures of temperature fluctuations are also calculated. These covariates supplement earlier work that relied on cross-sectional variation in climatic variables (Dube and Vargas, 2013; Mejía and Restrepo, 2014). From the same source, I also collect both components of wind velocity, u and v, and calculate average monthly windspeed. Windspeed and vertical wind sheer are environmental factors that influence when small aircraft and helicopter operation are safe and feasible. Windspeed also affects the dispersion of chemical neutralizers used to deleaf coca bushes. Variation in wind velocities are studied at an atmospheric height layer relevant to both aircraft navigation and chemical dispersion (eradication).

I also address concerns regarding soil quality with geographic information from Centro de Estudios Economicos (CEDE) panel data. This source provides indices of soil erosion, soil aptitude (mineral deposits) and water accessibility. Given the agronomy of coca production, these measures of suitable growing conditions make it possible to identify, with a high level of precision, municipalities that are fertile ground for coca cultivation. Indeed, as Mejía and Restrepo (2014) assert, these indices are reliable predictors of the cross sectional location of coca crops and cultivation expansion during the period of this study.

Identification

In the main analysis, the outcome of interest, $Y_{m,t}$, identifies the proportion of attacks in municipality m in year t that are irregular. The violence data identify the number of guerrilla **attacks**, and direct armed **clashes** between rebels, state forces and/or paramilitary groups in a given year. $Y_{m,t} = \frac{attacks}{attacks+clashes}$ during conflict years and zero otherwise. I restrict the main analysis to violence between armed combatants. As a robustness check, I include attacks on civilians as irregular violence and, separately, omit engagements between guerrilla and paramilitary units.

[28] These data are derived from reanalysis (climate modeling) of underlying meteorological data. While recent research suggests that reanalysis produces extremely accurate and precise measures of temperature variation independent of proximity to weather stations, the evidence regarding precipitation is less convincing (although it remains highly consistent with other surface level collection approaches) (Auffhammer et al., 2013). In Colombia, the number of reporting stations is relatively low but consistent over time. Consistency over time is important because station placement is not endogenous to the conflict.

The measure of tactical substitution, $Y_{m,t}$, takes the value zero under two conditions: either no events have occurred in a given municipal-year or all engagements were conventional in nature. To address this inferential problem, $X_{m,t}$ includes an indicator variable that takes the value one when a municipality experiences positive levels of conflict in a given year and zero otherwise ($py_{m,t}$). This empirical strategy also implies that the coefficients of interest are calculated using only variation in tactical choice. In other words, the results presented do not address the choice between mobilizing against government forces and withdrawing from the conflict. Instead, the main analysis focuses precisely on the tactical choice of rebels to substitute conventional warfare for irregular tactics or vice versa.

The spatial fixed effects, α_m, absorb constant municipal characteristics, whether observed or unobserved, disentangling the unit-level shock from varied sources of omitted variable bias. Time fixed effects, f_t, further neutralize any common trends across municipalities in a given year. One such common shock was the presidential election of anti-FARC candidate Alavaro Uribe in 2002. Incorporating within and between constants ensures the quantity of interest is identified via localized economic shocks. I include a region-specific time trend, $\mu_r t$. This addresses concerns regarding trends (like territorial control) that vary across time by region.

As a baseline, I present OLS estimates of the relationship between economic sector values and rebel tactics in the first column of table 1. I estimate the following linear probability model:

$$\begin{aligned} Y_{m,t} = \alpha_m + f_t + \mu_r t &+ (Oil_{m,t=1988} \times O.Price_t)\beta_1 + (Coffee_{m,t=1997} \times Co.Price_t)\beta_2 \\ &+ (Coca_{m,t} \times Ca.Price_t)\beta_3 + X_{m,t}\beta_4 + \epsilon_{m,t}. \end{aligned} \tag{3.1}$$

Unless otherwise stated, all models are scaled using population weights. I use weighted estimation for two related reasons. First, the precision of the dependent variable may vary with population size. If the intensive margin of violence varies with population size (and it does), then $\epsilon_{m,t}$ is likely heteroskedastic (Solon, Haider and Wooldridge, 2015). While I correct for clustered error structures at the departmental level (a conservative approach), heteroskedasticity may continue to harm the precision of regression coefficients. Second, given the construction of the dependent variable, low and high intensity conflict zones where rebels allocate all effort to conventional or irregular violence obtain the same value (0 and 1 respectively) even though causal effects may be heterogeneous. Weighted estimation identifies heterogenous effects which vary by municipal population size (although not the population average effect). I return to this subject later. Yet, as Deaton (1997) and Solon, Haider and Wooldridge (2015) caution, weighted regressions may produce less precise model estimates than OLS. In table 9, panel A, I present evidence that increased precision is achieved via population scales. Although I primarily study time-varying population estimates, a highly consistent but less precise estimates are achieved using averaged population values (table 9, panel B).

In table 1, models 1-5, I present the two stage least squares estimates of the effect of economic shocks on rebel tactics.[29] I estimate the following model for the second stage:

$$\begin{aligned} Y_{m,t} = \alpha_m + f_t + \mu_r t + (Oil_{m,t=1988} \times O.Price_t)\beta_1 + (\widehat{Coffee_{m,t=1997} \times} Co.Price_t)\beta_2 \\ + (\widehat{Coca_{m,t} \times Ca}.Price_t)\beta_3 + X_{m,t}\beta_4 + \epsilon_{m,t}. \end{aligned} \tag{3.2}$$

This second stage analysis is primarily focused on $(Oil_{m,t=1988} \times O.Price_t)$, $(\widehat{Coffee_{m,t=1997} \times} Co.Price_t)$, and $(\widehat{Coca_{m,t} \times Ca}.Price_t)$. The coffee and coca sector values are the two endogenous regressors instrumented with $IV_{m,t}$ in the first stages. I describe these instruments in detail below and in table 2.

$$\begin{aligned} &(Coffee_{m,t=1997} \times Co.Price_t), (Coca_{m,t} \times Ca.Price_t) \\ &= \alpha_m + f_t + \mu_r t + (Oil_{m,t=1988} \times O.Price_t)\beta_1 + IV_{m,t}\beta_2 + X_{m,t}\beta_3 + \epsilon_{m,t}, \end{aligned} \tag{3.3}$$

4 Results

In the main analysis, local income shocks are evaluated as level changes, so the interpretation of the point estimates is straightforward. Positive coefficients indicate that positive shocks are associated with irregular tactics (since irregular tactics dominate rebel strategies as the outcome variable approximates 1). Negative coefficients, however, indicate that positive shocks are associated with an increased use of conventional tactics. If the results follow the empirical expectations of the theoretical argument, coffee and oil sector growth should have **positive** coefficients (mobilization is more difficult when outside options are substantial and government capacity is high), while the coca shock variable should be **negative** (stronger rebels produce relatively more conventional violence).

In the first column of table 1, I present OLS estimates of the relationship between local income and rebel tactics. The results show that increases in local income from oil extraction deter conventional violence while increases in rebel income significantly increase the use of conventional tactics. Although slumps in coffee income are associated with increased direct assaults on government forces, this coefficient is insignificant. The estimates on coca and coffee could be downward biased, however. Intensification of clashes between rebels and government forces in agricultural areas might reduce supply, increasing international prices. For coffee, this supply effect would bias against the theorized relationship between opportunity costs and tactical choice. For coca, coefficients would trend towards zero (since supply and price effects offset as

[29] Since the outcome variable I study is a proportion (fractional response), least squares may yield biased results. Although methods exist for estimating a two stage model using fractional probit and logistic models, none perform well in a difference-in-differences framework. As an alternative, I study a two stage residual inclusion model that leverages several desirable qualities of the two-limit Tobit estimator. Although particularly well-suited for the present study, this approach is applicable to a wide-range of empirical models of bargaining dynamics. I then replicate the main analysis using this model and find additional support for the benchmark results. I detail the method, data and results in the appendix A.

violence increases). To account for potential bias, I instrument coffee and coca income. I review the instrumental variables approach next.

Using an instrumental variables approach, presented in models 1 through 5, I find that income shocks robustly shape rebel tactics, even at a local level. In line with my argument, the coffee sector shock coefficient is positive, evidence that increased income from local coffee production causes rebels to shift to irregular tactics. When local income rises, incentives for civilians to mobilize or support rebels decline. Analogously, when coffee productivity and export prices diminish and the opportunity costs of mobilization decline, rebels produce more conventional violence. A similar relationship holds for shocks to oil income. As exports and international prices increase, rebels favor irregular violence. In oil-producing municipalities, these positive shocks lead to increased counterinsurgent capacity, through increased police activity, deployment of federal troops, and private contracts between oil-exporting firms and military units. The negative coefficient on the coca variable indicates that stronger rebels produce relatively more conventional violence. Negative shocks to rebel income, thus, have the anticipated effect of increasing the relative use of irregular, hit-and-run tactics. The magnitudes of these effects are substantial. A single deviation increase in local income from coffee is associated with an 8% shift in the portfolio of rebel violence, increasing the relative use of irregular violence. Similar increases in the value of oil and coca are associated with 6% and 4% shifts in tactical choice, respectively. These results also confirm that the OLS estimates are downward biased. For coffee, the coefficient is more than 10 times greater after instrumentation, while the substantive effect of coca income shocks is nearly three times larger with the IV approach. These differences are large and statistically significant.

In table 1 model 1, I instrument coca production using panel estimates of rainfall and temperature variation.[30] These data provide precise monthly estimates of municipal precipitation and surface climate conditions, which I aggregate to the municipal-year level. To study exogenous variation in coffee sector growth, I rely on the base instruments used by Dube and Vargas (2013). In models 2, 3 and 5, I interact my panel estimates of precipitation and temperature with a set of soil indices (water accessibility, soil erosion and soil aptitude; model 2), out-of-country farm-gate prices (model 3), and minimum linear distance to the closest counternarcotics airport (model 5).[31] Soil suitability indices provide another means of leveraging the varying agronomic conditions that favor coca but not coffee cultivation. The out-of-country coca leaf prices studied in model 3 are compiled from surveys of coca traders in Chapare region of Bolivia. Fluctuations in these farm-gate prices is driven primarily by rapid depreciation of local soil productivity during the sampled period, as well as substantial variation in the intensity of manual and aerial

[30]For an overview of the instruments, see table 2.

[31]In table 10, I interact these climate measures with cocaine exports from Bolivia and Peru. I exclude this specification due to potential concerns regarding violations of the exclusion restriction, but the results obtained are highly consistent.

eradication in Cochabamba (none of which are plausibly related to municipal-level production in Colombia). The airports used for launching counternarcotics sorties, considered in model 5, remained fixed over the sample. This allows me to combine plausible exogenity in climatic conditions with discontinuities in the fuel capacity of escort aircraft. Each collection of instruments provides different yet plausibly random instrumentation of coca production. Although the first stages differ significantly in how they identify shocks to coca productivity and value, the second stage results are remarkably stable and consistently indicate that OLS estimates undervalue the impact of rebel endowment shocks on tactical choice.

Reduced form estimates, presented in appendix table 13, yield evidence that these high resolution climatic measures and interactions are not consistently correlated with the outcome of interest, tactical substitution. Rainfall and temperature variation, for example, are unlikely to violate the exclusion restriction. Yet there is historical evidence that insurgent groups vary tactics according to regularized climatic seasons. Such concerns are particularly problematic with respect to instrumenting coca production, for which rebels may have developed an informal (and undocumented) production schedule.[32] To address these concerns, I incorporate several measures of atmospheric windspeed in model 4. I estimate monthly wind velocity averages at an atmospheric threshold that only plausibly influences tactical substitution through impacting the feasibility of small aircraft eradication flights.[33] While cautious, this instrumentation approach produces estimates that differ from the other instrument baskets only at the margin.

Each collection of instruments is jointly strong, and not overidentified. Given that my identification strategy employs as many as nine instruments to identify exogenous variation in two endogenous regressors, the standard F test would be an inappropriate benchmark for checking weak identification of the instruments. As Stock and Yogo (2005) confirm, the F statistic is appropriate for models with a single endogenous regressor and a limited number of instruments (at most 3). As an alternative, I report the Cragg-Donald F statistic. The bias-minimizing critical value of this statistic for the model specifications studied in table 1 is 18.3 ($k_2 = 2$, n = 9, bias = 5%, $\alpha = .95$). The lowest observed value of this statistic is 39.43, which means the instruments are jointly strong and bias approximates zero. Using multiple instruments for each endogenous regressor can lead to invalid inferences due to overidentification. To test if my instruments are strong but invalid, I calculate the Hansen statistic for all models, which confirms that none suffer from bias due to overidentification.

[insert table 1 about here]

One of the central contributions of this paper is how I use coca income shocks to study rebel capacity. In table 1, I identify these income shocks at the municipal-year level using data on the

[32] Recall, unlike opium in Afghanistan, coca has no optimal growing season in Colombia.
[33] It is worth noting that these crop dusting aircraft were not equipped for offensive engagements.

intensity of aerial eradication. Recent research validates the claim that changes in eradication are closely associated with variation in the productivity of coca bushes (Mejía and Restrepo, 2014; Reyes, 2014). But these administrative records contain known and unknown measurement error. At the height of coca production in Colombia (2000-2002), for example, eradication figures substantially exceeded total production. Eradication was also reported in municipalities where coca production remains undocumented in archival records. Eradication figures are based on the estimated size of treated fields, as well as aircraft flight patterns, which both introduce additional noisiness to the measure.

To address observed and potential measurement error in records of eradication activity, I develop and implement a new method for retrospective estimation of coca production. Aerial photos of coca fields were not collected between 1994-1999, which prohibits a reconstruction of production estimates using standard means.[34] I sidestep this limitation by leveraging very high resolution estimates of coca production from 1999 through 2001 to validate pixel-by-pixel estimates of illicit activity.[35] The coca production estimates this method yields are novel, and the approach is generalizable to a broad class of related agricultural studies with incomplete data.

I start by supplementing UNODC data on local coca production and administrative eradication estimates with greenest pixel mosaics of Colombia, from 1996 to 2005 (see figure 6). Since coca leaves have no regularized growing season, these mosaics identify the maximum vegetation productivity of each 30 meter pixel of Colombia.[36] These mosaics are drawn from the normalized difference vegetation index (NDVI) spectrum collected by the LANDSAT 5 satellite. Images are also corrected for atmospheric anomalies. I study NDVI values from 0 to 1, with higher values indicating greater wetness concentration. Pixels are evaluated across ten equal unit bins ($\in [0, 1]$ by .1) for each municipality on an annual basis.[37] I then analyze variation in the count of interval pixels in municipalities known to have produced coca in 1999, 2000 and 2001 to impute production levels between 1996 and 2005. This approach is a generalization of the stepwise multiple linear regression described in Dorigo et al. (2007, 171-2), with municipal estimates regressed on the entire spectral band. For municipalities m that produced coca during the study sample, I

[34]The standard remote sensing approach to estimating narcotics production combines very high resolution satellite imagery with near ground-level aerial photos of coca fields. These aerial photos represent the ground truths used to calibrate assessments of spectrum images (Verger et al., 2009, 2688-9). The process of comparing these ground truths and satellite images is labor intensive and subject to inconsistencies between coding teams. The collection of aerial photos is also capital-intensive and represents a prohibitive obstacle for retrospective studies of drug production.

[35]Rulinda et al. (2012, 174) implement a similar technique for benchmarking vegetative drought indices in Kenya and Tanzania.

[36]Coca fields are typically larger than 30 meter squares, so granularity of the pixel size should be sufficient. At this resolution, the most important validation properties tested in Verger et al. (2009, 2700-1) still hold.

[37]Computations of this nature involve petabytes (millions of gigabytes) of base data. This analysis would not have been possible without support from the Google Earth Engine program, which provided access to their cloud-based supercomputer resources.

estimate the following model where t equals 1999, 2000, and 2001 sequentially.

$$\begin{aligned}\text{UNODC}-EST_{m,t} = \alpha + (NDVI_{m,t})\beta_{1,t} + ... + (NDVI_{m,t})\beta_{10,t} + (NDVI^2_{m,t})\beta_{11,t} \\ + ... + (NDVI^2_{m,t})\beta_{20,t} + (Erad_{m,t})\beta_{21,t} + (Erad^2_{m,t})\beta_{22,t} + \epsilon_{m,t}.\end{aligned} \tag{4.1}$$

Using $\beta_{i,t}$, where $i \in [1, 22]$ and $t \in [1999, 2001]$, I produce within and out-of-sample predictions of coca production, $\widehat{Coca - NDVI}_{m,t}$. In areas where coca bushes were never cultivated, $\widehat{Coca - NDVI}_{m,t}$ takes the value zero. These three out-of-sample predictions vary in their consistency with observed cultivation patterns, with estimates derived from the year 2000 mosaic yielding the most precision. I retain estimated production figures from the year 1999 and 2001 mosaics as robustness checks.

In table 3, models 1 through 5, I replicate the main analysis using production values derived from the year 2000 mosaic.[38] The findings are consistent with the main analysis in table 1 and provide further evidence of the relationship between coca windfalls and conventional fighting by rebels. When coca productivity and drug prices rise, rebels produce relatively more conventional violence against state forces. In the final two columns, I instrument variation in the predicted values of coca production using the 1999 and 2001 mosaics. Although these production estimates are marginally less precise than those derived from the year 2000 mosaic, the results again indicate that income shocks robustly shape the character of political violence in Colombia.

Robustness

The core findings are consistent across various instrumentation approaches, including a novel method for estimating coca production. Before considering extensions to the main argument, however, I review several robustness checks.

The outcome variable is measured as the proportion of rebel violence classified as irregular warfare. By construction, this measure is more sensitive to variation in low-intensity areas than municipalities with a high level of violence. Because this sensitivity could bias the main results, I subject the benchmark models to a number of tests using various measures of conflict intensity as control variables. These results are presented in table 4. Models 1 through 5 yield evidence that the impact of economic shocks on tactical substitution is not driven by areas with very high or low conflict intensity. In model 6, I introduce an analytic weight that exploits variation in the intensive margin of violence. These weighted regression estimates attribute greater weight

[38] To clarify,

$$\begin{aligned}Y_{m,t} = \alpha_m + f_t + \mu_r t + (Oil_{m,t=1988} \times O.Price_t)\beta_1 + (\widehat{Coffee_{m,t=1997}} \times Co.Price_t)\beta_2 \\ + (\widehat{Coca - NDVI}_{m,t} \times Ca.Price_t)\beta_3 + X_{m,t}\beta_4 + \epsilon_{m,t}.\end{aligned} \tag{4.2}$$

to municipalities that produce more violence. Notice that increases in the substantive impact of coca and coffee shocks correspond to improved precision in the coefficient estimates.

In models 7 and 8 of table 4, I demonstrate that recoding the outcome variable by including attacks on civilians as a form of irregular warfare as well as excluding violence against paramilitary units do not change the main findings. The precision of agricultural coefficients in model 8 declines, however. This seems reasonable since paramilitary groups often acted as informal and unregulated government units during this period. I conclude sensitivity tests of the outcome measure by investigating only the sample of municipalities that experienced some positive level of rebel violence conflict during the studied period. Perhaps this is the more appropriate set of cases to study. Although the relevant counterfactual changes, the model yields results highly consistent with the full sample.

Finally, trafficking of coca through otherwise unrelated municipalities may cause conflict spillovers.[39] These spillovers may be severe enough to bias the findings in areas that experience the highest levels of drug traffic, where engagements between counterinsurgents and rebels might complicate identification of local income shocks. Although actual trafficking activity is largely unobserved, I study complex trafficking equilibria to identify municipalities that *should* experience drug traffic. I start by building a road network dataset of Colombia and gather data on rebel unit locations and drug transit points from the Colombian Ministry of Defense. I then solve a classic route optimization problem detailed by Dell (2015) and produce estimates of drug traffic intensity at the municipal level. I detail the method, data and results in the appendix B.

The optimal paths (red) are presented in figure 2. Note that some paths are darker than others, indicating the same edges are used by multiple routes. To study traffic intensity, I calculate the total length of roadways used by all paths crossing a given municipality. This value is then interacted with variation in (1) aggregate production of coca and (2) within-front production of coca.[40] I incorporate these measures as exogenous covariates in the main analysis. These results are presented in table 5. Although plausible, I find no relationship between potential trafficking routes and tactical substitution, and the main results are unchanged after conditioning on this measure.

[39] Conflict spillovers might also occur in municipalities through which oil passes via transit pipelines. While it is difficult to estimate flow dynamics, I consider whether conditioning on within-municipality transit pipeline length $\times$ price variation alters the main results. It does not. I thank Oleg Polivin for this point and for sharing data on pipeline fixtures.

[40] Within-front estimates are generated using a Voronoi map of rebel strongholds (figure 7b) (Marbate and Gupta, 2013).

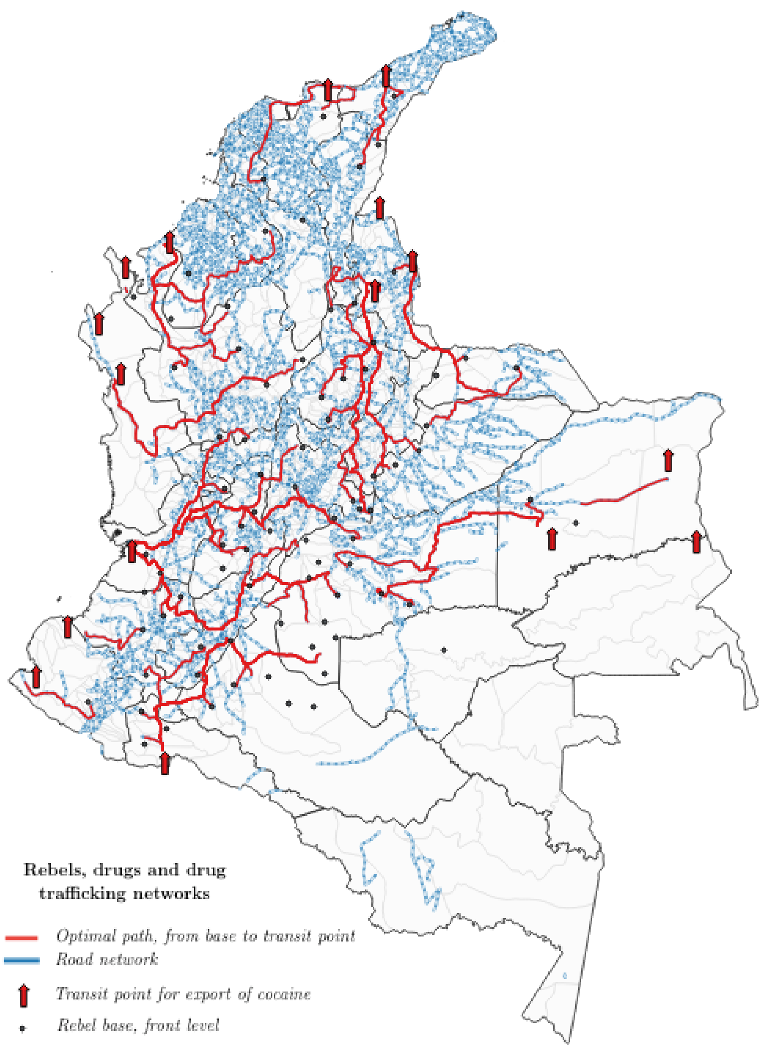


Figure 2: Road network with optimized drug trafficking routes between rebel fronts and drug transit points

Theoretical & empirical extensions

Colombia is an ideal setting to study three empirical extensions of the theoretical argument: how do military aid shocks influence rebel tactics? how do shifts in insurgent endowments influence violence? which commodities are prone to rebel capture?

First, external interference can shift the balance of military capacity in favor of or against rebels. Although FARC and ELN may have received support from Ecuador and Venezuela during the late 2000s, no compelling evidence exists that such support influenced tactical choices outside of border regions. US tactical and financial support of the Colombian military and police, however, has been well-documented, and remains substantial. If foreign military support has been allocated effectively, positive shocks to capacity should deter conventional violence. To study this conjecture, I analyze military aid and base location data assembled by Dube and Naidu (2015). I include this measure of external aid as an exogenous shock to state capacity in areas where Colombia's military presence is well-established, as well as bordering regions, where increased aid and training may compel rebels to avoid direct combat and employ irregular violence with increased frequency. Results are presented in table 5, columns 3-5.[41] In line with results presented in Dube and Naidu (2015), tactical choice is neither significantly influenced by these external shocks, nor are the core findings altered by including this measure of foreign support.[42] Over the past decade, the US has contributed over 9.3 billion dollars of military support to the Colombian government (Otis, 2014). Policy makers might be justly concerned that this failure to deter conventional violence is a indication of aid mismanagement.

Second, economic endowments shape insurgent tactics, even at a microlevel. Previous research has relied on the assumption that these endowments are fixed (Weinstein, 2007). Weinstein (2007, 287-292) admits this assumption is untenable in Colombia and a natural experiment, studied by Angrist and Kugler (2008), gives us an opportunity to test how shifting economic endowments shape violence. Incidentally, this shift in the rent structure of Colombia's most prominent rebel groups also serves as a placebo test of the main analysis. Following major eradication and interdiction efforts in Peru and Bolivia, Colombian production of coca increased roughly 750% from 1994—the first year of the major efforts in Peru and Bolivia—and 1999, when domestic production peaked and Peruvian and Bolivian production reached historical lows. Before the collapse of the air bridge, we might expect (1) shocks to the coca sector to have an insignificant effect on guerrilla tactics and violence, and, (2) rebels would fight the state over other rent sources (like oil production, transport and exports). In panel A of table 6, I demonstrate that the relationship between coca sector shocks and rebel tactics only holds after domestic drug

[41] In sequence, I include base municipalities × military aid; bordering municipalities × military aid; bases and bordering municipalities.

[42] Two recent studies, Strandow, Findley and Young (2015) and Sexton (2015), present similar findings on subnational allocation of foreign developmental and military aid and insurgent violence.

production becomes a major source of rebel financing. Yet panel A reveals relatively weak support for the second expectation, that rebels directly engaged state forces to capture, by various means, revenue from oil exports. In panel B of table 6, I exclude coca shocks from the model due to limited coverage early in the sample, and find support for the claim that conventional fighting increased precisely when the prize for directly engaging state forces was greatest.

This additional model specification, however, also presents evidence that the theorized relationship between labor-intensive income shocks (coffee) and rebel tactics does not hold before the period of endowment adjustment. This result is not troubling. Prior to the expansion of the coca industry, the FARC maintained a limited corps of fighters and support staff, largely drawn from villages with a long history of logistical and ideological support for peasant leagues and guerrilla organizations (Saskiewicz, 1999; Thoumi, 2002). These individuals were least likely to join FARC for purely economic reasons. Following the adjustment in their rent model, however, the FARC expanded rapidly and new recruits were drawn away from transitory labor markets, including in the coffee industry. Consequently, while table 1 presents evidence of a robust relationship between negative income shocks and conventional warfare after this period of adjustment, mobilization prior to the coca boom was not as sensitive to variation in outside options.

Third, we know relatively little at the microlevel about why some commodities are more prone to contestation than others.[43] When do rebels risk conventional tactics to seize natural resources? The argument I propose links variation in state capacity to taxation of capital-intensive commodities. To study how rebel strategy over natural resources varies, I leverage microlevel variation in the value of gold, nickel and emerald production. I gather data from Minercol, Ingeominas and Servicio Geológico Colombiano archives. Because Colombian production of gold and nickel do not drive international markets, I treat export prices of these commodities as plausibly exogenous. For gold, I consider level changes in sector values derived from municipal production averages interacted with international prices. In the case of nickel, I collect actual royalty payments from the federal government to municipalities for the sample period. If the theoretical argument is correct, government revenue windfalls derived from gold and nickel production should deter conventional fighting in municipalities that produce these commodities as export prices increase. Results are presented in table 7. Consistent with oil income, I find that positive shocks to these commodities force rebels to scale down conventional fighting.

Previous research suggests contestation may increase with value-density (Lujala, Gleditsch and Gilmore, 2005; Lujala, 2009). To test this argument, I combine municipal-year emerald production with US demand shocks for precious gemstones drawn from International Monetary Fund records. Although the federal and relevant municipal governments receive rents from the extraction and export of emeralds, the mines that produce these gemstones are geographically

[43]Two pioneering works, Le Billon (2001) and Ross (2003), introduce important typologies of natural resources that have been mobilized in the course of modern insurgencies. While 'lootability' and 'obstruction' may underpin rebel strategy, as I discuss below, contestation over resources varies with institutional control as well.

concentrated and many were controlled by an 'emerald tsar', Vctor Carranza (2013). These mines were protected by cartel-led paramilitary units. Unlike price shocks to gold and nickel, column 3 of table 7 indicates increased foreign demand for emeralds leads to more conventional violence by rebels. This result indicates that rebels increasingly carried out direct attacks on government forces even as tax revenue, and state capacity, increased with foreign demand for emeralds. This finding highlights an important nuance of the argument and potential avenue for future research. Windfalls to capital-intensive commodities may increase state capacity enough to deter conventional fighting, but in areas where value-dense commodity production is concentrated and controlled by quasi-state institutions, rebel rent capture through conventional fighting may be a viable insurgent strategy.

5 Conclusion

What explains variation in rebel tactics? My argument is simple. Three constraints shape the incentives and opportunities for armed rebel groups to shift from irregular to conventional tactics and vice versa: economic opportunities of non-combatants, state strength, and rebel capacity. These constraints are difficult to observe directly, so I study plausibly exogenous shocks to three commodities at the core of each constraint: coffee, oil and coca. Colombia is an ideal setting for studying how local income shocks to these goods influence tactical choice. The observable implications of the argument are straightforward. When governments benefit from local windfalls and economic conditions improve for civilians, insurgents turn to irregular tactics. When rebels are strengthened by revenue growth, they favor conventional tactics.

The main results confirm that tactical choices are substantially affected by these constraints, and in ways that challenge prominent theories of rebel violence. The core findings are robust to accounting for numerous potential sources of bias, including atmospheric dispersion of illicit crop herbicides, violence spillovers from drug trafficking, and foreign military aid shocks. Understanding the ways economic shocks impact how rebels fight has implications for scholarship and policy-making. Scholars must take seriously the variety of violence rebel groups produce and how they allocate scarce resources across a portfolio of tactics. To use Tarrow's (2007) words, rather than hiving away the traditional modes of civil war violence, future research must study the variety of brutality employed by rebels in the course of insurgency. This paper also advances the micropolitical turn in the study of political violence—linking local income shocks to granular shifts in tactics—and brings rebel capacity back into the study of rebellion, theoretically and empirically.

Policy makers, particularly in the United States, must think harder about how development and military aid are allocated. This paper follows a number of recent studies contesting the effectiveness of aid in reducing political violence (Dube and Naidu, 2015; Strandow, Findley and Young, 2015; Sexton, 2015). As evidence of aid ineffectiveness accumulates, it will become difficult to defend current foreign assistance programs. Practitioners should also consider how private control over value-dense, geographically concentrated natural resources influences the nature and intensity of conflict, especially where state institutions are weak or overburdened.

Overall, this paper stresses the need to study how and why rebels vary their tactics. A deeper understanding of the economic factors that alter rebel warmaking challenges and enriches current scholarship and opens up new avenues for future research.

References

Adano, Wario, Ton Dietz, Karen Witsenburg and Fred Zaal. 2012. "Climate change, violent conflict and local institutions in Keyna's drylands." *Journal of Peace Research* 49(1):65–80.

Angrist, Joshua and Adriana Kugler. 2008. "Rural windfall or a new resource curse? Coca, income, and civil conflict in Colombia." *Review of Economics and Statistics* 90(2):195–215.

Auffhammer, Maximilian, Solomon Hsiang, Wolfram Schlenker and Adam Sobel. 2013. "Using weather data and climate model output in economic analyses of climate change." *Review of Environmental Economics and Policy* 7(2):181–198.

Auty, Richard M. 1993. *Sustaining Development in Mineral Economics: The Resource Curse Thesis*. Routledge.

Bazzi, Samuel and Christopher Blattman. 2014. "Economic shocks and conflict: evidence from commodity prices." *American Economic Journal: Macroeconomics* 6(4):1–38.

Becker, Gary. 1968. "Crime and punishment: an economic approach." *Journal of Political Economy* 78(2):169–217.

Bergquist, Charles. 1986. *Coffee and conflict in Colombia, 1886-1910*. Duke University Press.

Berman, Eli, Michael Callen, Joseph H. Felter and Jacob N. Shapiro. 2011. "Do Working Men Rebel? Insurgency and Unemployment in Afghanistan, Iraq, and the Philippines." *Journal of Conflict Resolution* 55:496–528.

Besley, Timothy and Torsten Persson. 2008. "The incidence of civil war: theory and evidence." Working Paper 14585.

Besley, Timothy and Torsten Persson. 2010. "State capacity, conflict and development." *Econometrica* 78:1–34.

Blakeslee, David and Ram Fishman. 2014. "Weather shocks, crime and agriculture: evidence from India." Working paper.

Blattman, Christopher and Edward Miguel. 2010. "Civil war." *Journal of Economic Literature* 48(1):3–57.

Brückner, Markus and Antonio Ciccone. 2011. "Rain and the democratic window of opportunity." *Econometrica* 79(3):923–947.

Bueno de Mesquita, Ethan. 2013. "Rebel tactics." *Journal of Political Economy* 121(2):323–357.

Buhaug, Hegre. 2010. "Climate not to blame for African civil wars." *Proceedings of the National Academy of Sciences* 107(38):16477–16482.

Burke, Marshall, Edward Miguel, Shanker Satyanath, John Dykema and David Lobell. 2009. "Warming increases the risk of civil war in Africa." *Proceedings of the National Academy of Sciences* 106(49):20670–20674.

Burke, Marshall, John Dykema, David Lobell, Edward Miguel and Shanker Satyanath. 2010. "Climate robustly linked to African civil war." *Proceedings of the National Academy of Sciences* 107(51):E185.

Butler, Christopher and Scott Gates. 2009. "Asymmetry, Parity, and (Civil) War: Can International Theories of Power Help Us Understand Civil War?" *International Interactions* 33(3):330–340.

Carter, David. 2015. "When terrorism is evidence of state success: securing the state against territorial groups." *Oxford Economic Papers* 2014 (advance access):1–17.

Collaborative agreement between BP Exploration (Colombia) and Colombian Ministry of Defense-National Army. 1995.

Collaborative agreement between Occidental de Colombia, Inc. and Colombian Ministry of Defense-NationalArmy. 1996/1997.

Collier, Paul and Anke Hoeffler. 2004. "Greed and grievance in civil war." *Oxford Economic Papers* 56(563-595).

Collier, Paul, Anke Hoeffler and Mans Soderbom. 2004. "On the duration of civil war." *Journal of Peace Research* 41:253–227.

Colombia: Human Rights Concerns Raised By The Security Arrangements of Transnational Oil Companies. 1998.

Crime, InSight. 2015. "ELN.".
URL: *http://www.insightcrime.org/colombia-organized-crime-news/eln-profile*

Cunningham, David E., Kristian Skrede Gleditsch and Idean Salehyan. 2013. "Non-state actors in civil wars: A new dataset." *Conflict Management and Peace Science* 30(5):515–531.

de la Calle, Luis and Ignacio Sanchez-Cuenca. 2015. "How Armed Groups Fight: Territorial Control and Violent Tactics." *Studies in Conflict and Terrorism* 0:1–19.

Death of a tsar. 2013. The Economist.

Deaton, Angus. 1997. *The analysis of Household Surveys: A Microeconomic Approach to Development Policy*. World Bank.

Dell, Melissa. 2015. "Trafficking Networks and the Meixcan Drug War." *The American Economic Review* 105(6):1738–79.

Dell, Melissa, Benjamin Jones and Benjamin Olken. 2014. "What do we learn from the weather? The new climate-economy literature." *Journal of Economic Literature* 52(3):740–798.

Dorigo, W. A., R. Zurita-Milla, A. J. W. de Wit, J. Brazile, R. Singh and M. E. Schaepman. 2007. "A review on reflective remote sensing and data assimilation techniques for enhanced agroecosystem modeling." *International Journal of Applied Earth Observation and Geoinformation* 9:165–193.

Dube, Oeindrila and Suresh Naidu. 2015. "Bases, Bullets, and Ballots: The Effect of US Military Aid on Political Conflict in Colombia." *The Journal of Politics* 77(1):249–267.

Dube, Oeindrilla and Juan Vargas. 2013. "Commodity price shocks and civil conflict: evidence from Colombia." *Review of Economic Studies* 80:1384–1421.

Fearon, James. 1995. "Rationalist explanations for war." *International Organization* 49(3):379–414.

Fearon, James. 2007. *Institutions and economic performance*. Harvard University Press chapter Economic development, insurgency and civil war.

Fearon, James and David Laitin. 2003. "Ethnicity, insurgency and civil war." *American Political Science Review* 97(1):75–90.

Fellman, Michael. 1989. *Inside War: The Guerrilla Conflict in Missouri during the American Civil War*. Oxford University Press.

Findley, Michael G. and Joseph K. Young. 2012. "Terrorism and Civil War: A Spatial and Temporal Approach to a Conceptual Problem." *Perspectives on Politics* 10(2):285.

Fjelde, Hanne. 2015. "Farming or Fighting? Agricultural Price Shocks and Civil War in Africa." *World Development* 67:525–534.

Fjelde, Hanne and Nina von Uexkull. 2012. "Climate triggers: rainfall anomalies, vulnerability and communal conflict in sub-Saharan Africa." *Political Geography* 31(7):444–453.

Grossman, Herschel. 1991. "A general equilibrium model of insurrection." *American Economic Review* 81(912-921).

Hegre, Havard and Nicholas Sambanis. 2006. "Sensitivity analysis of the empirical literature on civil war onset." *Journal of Conflict Resolution* 50(4):508–535.

Hidalgo, Daniel, Suresh Naidu, Simeon Nichter and Neal Richardson. 2010. "Economic determinants of land invasions." *Review of Economics and Statistics* 92(3):505–523.

Holtermann, Helge. 2015. "Relative Capacity and the Spread of Rebellion: Insights from Nepal." *Journal of Conflict Resolution* pp. 1–29.

Hsiang, Solomon. 2010. "Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America." *Proceedings of the National Academy of Sciences* 107(35):15367–15372.

Hsiang, Solomon, Kyle Meng and Mark Cane. 2011. "Civil conflicts are associated with the global climate." *Nature* 476:438–441.

Hultman, Lisa. 2012. "Attacks on Civilians in Civil War: Targeting the Achilles Heel of Democratic Governments." *International Interactions* 38(2):164–181.

Human Rights Watch interview with Stephen T. Newton, president of Occidental de Colombia, Inc. 1997.

Humphreys, Macartan. 2005. "Natural resources, conflict and conflict resolution: uncovering the mechanisms." *Journal of Conflict Resolution* 49(4):508–537.

Jayachandaran, Seema. 2006. "Selling labor low: wage responses to productivity shocks in developing countries." *Journal of Political Economy* 114(3):538–575.

Jia, Ruixue. 2014. "Weather shocks, sweet potatoes and peasant revolts in historical China." *The Economic Journal* pp. 92–118.

Johnston, Patrick, Howard Shatz, Danielle Jung and Jacob N. Shapiro. 2015. "Foundations of the Islamic State: Management, Money, and Terror in Iraq.".

Kalyvas, Stathis. 2006. *The logic of violence in civil war.* Cambridge University Press.

Kalyvas, Stathis and Laia Balcells. 2010. "International System and Technologies of Rebellion: How the End of the Cold War Shaped Internal Conflict." *American Political Science Review* 104(3):415–429.

Laitin, David and Jacob N. Shapiro. 2008. *Terrorism, Economic Development, and Political Openness*. Cambridge University Press chapter The Sources of Terrorism: An Ecological and Organizational Perspective.

Le Billon, Philippe. 2001. "The Political Ecology of War: Natural Resources and Armed Conflict." *Political Geography* 20:561–584.

Lee, Rensselaer W. and Francisco E. Thoumi. 1999. "The criminal-political nexus in Colombia." *Trends in Organized Crime* 5(2).

Lockyer, Adam. 2010. "The Dynamics of Warfare in Civil War." *Civil Wars* 12(1-2):91–116.

Lujala, Paivi. 2009. "Deadly Combat over Natural Resources: Gems, Petroleum, Drugs, and the Severeity of Armed Civil Conflict." *Journal of Conflict Resolution* 53(1):50–71.

Lujala, Paivi, Niles Petter Gleditsch and Elisabeth Gilmore. 2005. "A Diamond Curse? Civil War and a Lootable Resource." *Journal of Conflict Resolution* 49(4):538–562.

Marbate, Punam and Reetu Gupta. 2013. "Fortune's Method: An Efficient Method for Voronoi Diagram Construction." *International Journal of Advanced Research in Computer and Communication Engineering* 2(12):4808–4814.

Mares, Dennis. 90. "Climate chance and levels of violence in socially disadvantaged neighborhood groups." *Journal of Urban Health* 4(768-783).

Mejía, Daniel and Pascual Restrepo. 2014. "Bushes and bullets: illegal cocaine markets and violence in Colombia." Working paper.

Miguel, Edward and Shanker Satyanath. 2011. "Re-examining economic shocks and civil conflict." *American Economic Journal: Applied Economics* 3(4):228–232.

Miguel, Edward, Shanker Satyanath and Ernest Sergenti. 2004. "Economic shocks and civil conflict: an instrumental variables approach." *Journal of Political Economy* 112(4):725–753.

Mikulaschek, Christoph and Jacob N. Shapiro. 2015. "Lessons from America's post-9/11 Wars.".

Morrison, Kevin M. 2009. "Oil, Nontax Revenue, and the Redistributional Foundations of Regime Stability." *International Organization* 63(1):107–138.

Nielsen, Richard A., Michael G. Findley, Zachary S. Davis, Tara Candland and Daniel L. Nielson. 2011. "Foreign aid shocks as a cause of violent armed conflict." *American Journal of Political Science* 55(2):219–232.

Nunn, Nathan and Nancy Qian. 2014. "U.S. food aid and civil conflict." *American Economic Review* 104(6):1630–1666.

Oil Companies Buying an Army To Ward Off Rebels in Colombia. 1996.

Otis, John. 2014. The FARC and Colombia's Illegal Drug Trade. Technical report Wilson Center: Latin American Program.

Petroleum, British. N.d. "BP in Colombia:a refutation of recent allegations (company document).".

Ramsay, Kristopher. 2011. "Revisiting the Resource Curse: Natural Disasters, the Price of Oil, and Democracy." *International Organization* 65(3):507–529.

Rana, Shan Aman. 2014. "The economic causes of terror: evidence from rainfall variation and terrorist attacks in Pakistan." Working paper.

Rangel, Alfredo. 2000. "Paraistes and predators: guerrillas and the insurection economy of Colombia." *Journal of International Affairs* (577-601).

Reporter, Staff. 1997. BP's secret soldiers. Mail and Guardian.

Restrepo, Jorge, Michael Spagat and Juan Vargas. 2006. "The Severeity of the Colombian Conflict: Cross-Country Datasets Versus New Micro-Data." *Journal of Peace Research* 43:99–115.

Reyes, Luis. 2014. "Estimating the causal effect of forced eradication on coca cultivation in Colombian municipalities." *World Development* 61:70–84.

Ross, Michael. 2004. "What do we know about natural resources and civil war?" *Journal of Peace Research* 41:337–356.

Ross, Michael L. 2001. "Does Oil Hinder Democracy?" *World Politics* 53(3):325–361.

Ross, Michael L. 2003. *Oil, Drugs, and Diamonds: How Do Natural Resources Vary in Their Impact on Civil War?* Lynne Rienner pp. 47–70.

Rulinda, C. M., A. Dilo, W. Bijker and A. Stein. 2012. "Characterising and quantifying vegetative drought in East Africa using fuzzy modelling and NDVI data." *Journal of Arid Environments* 78(169-178).

Saha, Suranjana, Shrinivas Moorthi, Hua-Lu Pan, Xingren Wu, Jiande Wang, Sudhir Nadiga, Patrick Tripp, Robert Kistler, John Woollen, David Behringer, Haixia Liu, Diane Stokes, Robert Grumbine, George Gayno, Jun Wang, Yu-Tai Hou, Hui-Ya Chuang, Hann-Ming H. Juang, Joe Sela, Mark Iredell, Russ Treadon, Daryl Kleist, Paul Van Delst, Dennis Keyser, John Derber, Michael Ek, Jesse Meng, Helin Wei, Rongqian Yang, Stephen Lord, Huug Van Den Dool, Arun Kumar, Wanqiu Wang, Craig Long, Muthuvel Chelliah, Yan Xue, Boyin Huang, Jae-Kyung Schemm, Wesley Ebisuzaki, Roger Lin, Pingping Xie, Mingyue Chen, Shuntai Zhou, Wayne Higgins, Cheng-Zhi Zou, Quanhua Liu, Yong Chen, Yong Han, Lidia Cucurull, Richard W. Reynolds, Glenn Rutledge and Mitch Goldberg. 2010. "The NCEP climate forecast system reanalysis." *Bulletin of the American Meteorological Society* 91(8):1015–1057.

Sarsons, Heather. Forthcoming. "Rainfall and conflict: a cautionary tale." *Journal of Development Economics* .

Saskiewicz, Paul E. 1999. *The Revolutionary Armed Forces of Colombia - People's Army (FARC-EP): Marxist-Leninist insurgency or criminal enterprise?* Naval Postgraduate School.

Sexton, Renard. 2015. "Aid, insurgency and the pivotal role of control: Evidence from Afghanistan.".

Smith, Benjamin. 2004. "Oil Wealth and Regime Survival in the Developing World." *American Journal of Political Science* 48(2):232–246.

Solon, Gary, Steven J. Haider and Jeffrey M. Wooldridge. 2015. "What are we weighting for?" *The Journal of Human Resources* 50(2):301–316.

Soltani, Atossa, ed. 2002. *Bush Reveals the Crude Nature of US Colombia Policy by Proposing Military Protection for OXY Plan Will Only Fuel Civil Strife in Colombia.* Amazon Watch.

Staniland, Paul. 2012. "States, Insurgents, and Wartime Political Orders." *Perspectives on Politics* 10(2):242–264.

Stock, James and Motohiro Yogo. 2005. *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg.* Cambridge University Press chapter Testing for Weak Instruments in Linear IV Regression.

Strandow, Daniel, Michael Findley and Joseph Young. 2015. Foreign Aid and the Intensity of Violent Armed Conflict. American Political Science Association.

Tarrow, Sidney T. 2007. "Inside insurgencies: Politics and violence in an age of civil war." *Perspectives on Politics* 5(3):587–600.

Terza, Joseph V., Anirban Basu and Paul J. Rathouz. 2008. "Two-Stage Residual Inclusion Estimation: Addressing Endogeneity in Health Econometric Modeling." *Journal of Health Economics* 27(3):531–543.

Thies, Cameron. 2010. "Of Rulers, Rebels and Revenue: State Capacity, Civil War Onset and Primary Commodities." *Journal of Peace Research* 47(3):321–332.

Thoumi, Francisco E. 2002. "Illegal drugs in Colombia: from illegal economic boom to social crisis." *Annals of the American Academy of Political and Social Science* 582:102–116.

UNODC. 2008. *Coca cultivation in the Andean region: a survey of Bolivia, Colombia and Peru*. United Nations Office on Drugs and Crime.

Vanden Eynde, Oliver. 2015. Targets of violence: evidence from India's Naxalite conflict. Technical report Paris School of Economics.

Verger, A., B. Martínez, F. Camacho-De Coca and F. J. García-Haro. 2009. "Accuracy assessment of fraction of vegetation cover and leaf area index estimates from pragmatic methods in a cropland area." *International Journal of Remote Sensing* 30(10):2685–2704.

Walter, Barbara F. 2009. "Bargaining Failures and Civil War." *Annual Review of Political Science* 12:243–261.

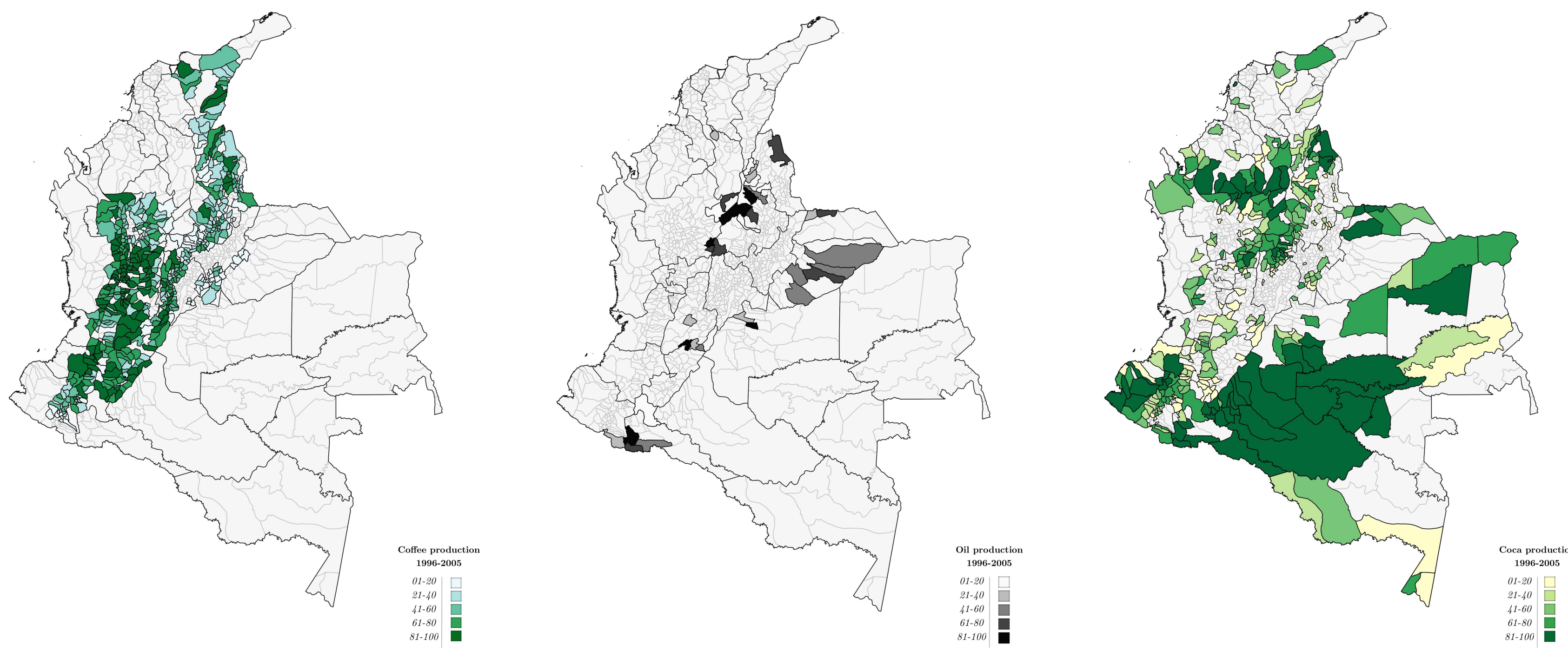
Weinstein, Jeremy. 2007. *Inside rebellion: the politics of insurgent violence*. Cambridge University Press.

Wood, Elisabeth J. 2003. *Insurgent Collective Action and Civil War in Elsalvador*. Cambridge University Press.

Wood, Reed M. 2010. "Rebel Capability and Strategic Violence against Civilians." *Journal of Peace Research* 47(5):601–614.

Wood, Reed M. 2014. "From Loss to Looting? Battlefield Costs and Rebel Incentives for Violence." *International Organization* 68(4):979–999.

Wooldridge, Jeffrey M. 2013. *Econometric analysis of cros section and panel data*. The MIT Press.



(a) Coffee production (b) Oil production (c) Coca production (eradication intensity)

Figure 3: Variation in oil, coffee and coca production, 1996-2005 averages

Table 1: OLS and instrumental variables estimation of the effect of economic shocks on rebel tactics

	OLS estimates	(1) base + climate	(2) base + rainfall × soil indices	(3) base + rainfall × Chapare prices	(4) base + climate + windspeed	(5) base + climate + dist. to airport
Coffee sector shock	0.00828	0.103^{*}	0.105^{*}	0.0653^{*}	0.0822^{γ}	0.103^{*}
	(0.0175)	(0.0517)	(0.0522)	(0.0314)	(0.0450)	(0.0475)
Coca sector shock	-0.00116^{*}	-0.00335^{*}	-0.00376^{*}	-0.00384^{*}	-0.00318^{*}	-0.00334^{*}
	(0.000457)	(0.00161)	(0.00173)	(0.00174)	(0.00159)	(0.00158)
Oil sector shock	0.249^{***}	0.248^{***}	0.248^{***}	0.252^{***}	0.249^{***}	0.248^{***}
	(0.0509)	(0.0404)	(0.0388)	(0.0354)	(0.0396)	(0.0409)
Diagnostics						
C-D F statistic		58.63	57.19	56.26	39.43	42.49
Hansen statistic		4.272	3.324	3.536	7.135	6.271
Hansen p-value		0.370	0.505	0.618	0.415	0.508
Coffee sector (first stage)	-					
AP F statistic		4.528	5.152	5.454	7.393	3.683
AP p-value		0.00325	0.00158	0.000602	0.0000211	0.00399
Coca sector (first stage)	-					
AP F statistic		2.957	2.658	2.555	2.657	5.710
AP p-value		0.0270	0.0419	0.0397	0.0247	0.000171
N	9680	9680	9530	9680	9660	9680

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted. The coffee sector value is instrumented using the product of cumulative coffee export volume of three major producers (Brazil, Vietnam, and Indonesia) and rainfall variation, price-maker exports interacted with temperature trends and the product of cubic rainfall volume, temperature and major exporter production. The coca sector value is identified using municipality estimates of coca bush eradication, interacted with internal prices. The sequence of first stage instruments is introduced in table 2.

- Clustered standard errors in parentheses, department.

$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Overview of first stage inclusion of various instruments in table 1

Instrumental variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Rainfall × price-maker coffee production	✓	✓	✓	✓	✓
Temp. × price-maker coffee production	✓	✓	✓	✓	✓
Rainfall × temp. × price-maker coffee production	✓	✓	✓	✓	✓
Rainfall	✓			✓	✓
Temp.	✓			✓	✓
Rainfall × temp.	✓				✓
Rainfall × soil erosion index		✓			
Rainfall × water accessibility index		✓			
Rainfall × soil suitability index		✓			
Rainfall × Chapare market coca prices			✓		
Rainfall^2 × Chapare market coca prices			✓		
Temp. × Chapare market coca prices			✓		
Temp.^{2} × Chapare market coca prices			✓		
Rainfall^2				✓	
Temp.^{2}				✓	
Atmospheric wind speed				✓	
Atmospheric wind speed^2				✓	
Rainfall × distance to airport					✓
Temp. × distance to airport					✓
Rainfall × temp. × distance to airport					✓

— The first three rows introduce the instruments employed by Dube and Vargas (2013). Coffee sector income is instrumented using the product of cumulative coffee export volume of three major producers (Brazil, Vietnam, and Indonesia) and rainfall variation, price-maker exports interacted with temperature trends and the product of cubic rainfall volume, temperature and major exporter production.

— Rows 4 through 20 introduce novel climatic instruments gathered for this project. I study how rainfall and temperature variation influence the production of coca. In sequential models, I incorporate soil aptitude indices, out-of-country market prices for coca leaves, atmospheric wind speed, and distance to the nearest counternarcotics airport. In the main text, I review potential violations of the exclusion restriction.

Table 3: Retrospective estimation of coca production using year 2000 mosaic, with supplemental year 1999 and 2001 measures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Coffee sector shock	0.0807*	0.0762*	0.0508	0.0736*	0.0857*	0.0800*	0.0736*
	(0.0367)	(0.0350)	(0.0313)	(0.0339)	(0.0392)	(0.0357)	(0.0324)
Coca sector shock (remote sensing; 2000 base)	-0.0331**	-0.0329**	-0.0317**	-0.0335**	-0.0330**		
	(0.0105)	(0.0103)	(0.0108)	(0.0106)	(0.0102)		
Coca sector shock (1999 base)						-0.0489$^{\gamma}$	
						(0.0292)	
Coca sector shock (2001 base)							-0.0387**
							(0.0123)
Oil sector shock	0.257***	0.258***	0.260***	0.258***	0.257***	0.294***	0.257***
	(0.0633)	(0.0629)	(0.0607)	(0.0623)	(0.0640)	(0.0611)	(0.0748)
Diagnostics							
C-D F statistic	90.94	87.03	135.8	68.35	67.98	31.18	31.44
Hansen statistic	5.270	2.373	2.929	8.107	8.944	3.881	4.021
Hansen p-value	0.384	0.795	0.818	0.423	0.347	0.693	0.674
N	8768	8768	8768	8768	8768	8768	8768

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted.

- Clustered standard errors in parentheses, department.

$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Impact of economic shocks on tactics adjusting for various measures/weights of conflict intensity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coffee sector shock	0.0571$^{\gamma}$	0.0607*	0.0637*	0.0656*	0.0647*	0.122**	0.0581*	0.0602$^{\gamma}$	0.0735*
	(0.0303)	(0.0297)	(0.0308)	(0.0306)	(0.0302)	(0.0385)	(0.0283)	(0.0321)	(0.0337)
Coca sector shock	-0.00420*	-0.00388*	-0.00384*	-0.00385*	-0.00383*	-0.00728**	-0.00334$^{\gamma}$	-0.00301$^{\gamma}$	-0.00439*
	(0.00177)	(0.00177)	(0.00173)	(0.00176)	(0.00176)	(0.00266)	(0.00201)	(0.00180)	(0.00223)
Oil sector shock	0.253***	0.259***	0.259***	0.252***	0.254***	0.248**	0.276***	0.273***	0.254***
	(0.0458)	(0.0441)	(0.0408)	(0.0374)	(0.0396)	(0.0823)	(0.0304)	(0.0269)	(0.0356)
Intensity measures	✓	✓	✓	✓	✓	-	-	-	-
Intensity weighted estimation	-	-	-	-	-	✓	-	-	-
Alternative outcome measure	-	-	-	-	-	-	include	exclude	-
	-	-	-	-	-	-	non-combatants	paramilitaries	-
Alternative subset	-	-	-	-	-	-	-	-	only units
	-	-	-	-	-	-	-	-	w/ + violence
Number of conflict events	-0.00628$^{\gamma}$								
	(0.00363)								
ln(Number of conflict events)		-0.0247							
		(0.0252)							
One event			0.0228						
			(0.0323)						
Two or fewer				-0.00200					
				(0.0187)					
Three or fewer					0.00431				
					(0.0248)				
Diagnostics									
C-D F statistic	57.47	56.71	56.31	56.04	56.14	31.67	56.30	56.24	42.09
Hansen statistic	3.517	3.546	3.522	3.549	3.549	4.116	5.471	3.200	7.104
Hansen p-value	0.621	0.616	0.620	0.616	0.616	0.533	0.361	0.669	0.213
N	9680	9680	9680	9680	9680	9680	9680	9680	6955

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted.
- Clustered standard errors in parentheses, department.
$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Coca trafficking network analysis, US military aid × mil. bases, colonial origins of resistance

	(1)	(2)	(3)	(4)	(5)	(6)
Coffee sector shock	0.0655*	0.0655*	0.0614$^{\gamma}$	0.0654*	0.0613$^{\gamma}$	0.113*
	(0.0314)	(0.0315)	(0.0318)	(0.0313)	(0.0318)	(0.0531)
Coca sector shock	-0.00386*	-0.00380*	-0.00369*	-0.00384*	-0.00369*	-0.00428*
	(0.00174)	(0.00182)	(0.00169)	(0.00174)	(0.00169)	(0.00180)
Oil sector shock	0.252***	0.253***	0.215***	0.252***	0.215***	0.250***
	(0.0353)	(0.0352)	(0.0295)	(0.0355)	(0.0296)	(0.0367)
Trafficking network × nat'l prod.	1.17e-13					
	(5.33e-13)					
Trafficking network × reg'l prod.		1.55e-09				
		(2.91e-09)				
Diagnostics						
C-D F statistic	56.28	52.64	55.37	56.28	55.39	55.13
Hansen statistic	3.548	3.604	3.662	3.550	3.655	5.374
Hansen p-value	0.616	0.608	0.599	0.616	0.600	0.372
N	9680	9680	9680	9680	9680	9680

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted.
- Clustered standard errors in parentheses, department.
$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Adjustment in economic endowments and resource mobilization following collapse of coca air bridge

Panel A: estimation of coca shocks using project production capacity

	Before adjustment	After adjustment
Coffee sector shock	0.0235	0.0890^{*}
	(0.0493)	(0.0399)
Coca sector shock	-0.386	-0.0554^{γ}
	(0.298)	(0.0334)
Oil sector shock	-0.443^{γ}	0.237^{***}
	(0.226)	(0.0644)
Diagnostics		
C-D F statistic	14.72	7.859
Hansen statistic	2.428	3.452
Hansen p-value	0.787	0.631
N	3872	9680

Panel B: addressing potential misspecification, estimation without coca shocks

	Before adjustment	After adjustment
Coffee sector shock	0.0717	0.100^{*}
	(0.140)	(0.0509)
Oil sector shock	-0.793^{***}	0.238^{***}
	(0.0894)	(0.0674)
Diagnostics		
C-D F statistic	7.134	228.4
Hansen statistic	0.305	1.632
Hansen p-value	0.858	0.442
N	6846	9680

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted.
- Clustered standard errors in parentheses, department.
$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Shocks to mining sectors: gold, nickel and emerald

	(1)	(2)	(3)
Coffee sector shock	0.0649*	0.0654*	0.0653*
	(0.0309)	(0.0314)	(0.0314)
Coca sector shock	-0.00473**	-0.00385*	-0.00383*
	(0.00181)	(0.00174)	(0.00176)
Oil sector shock	0.257***	0.252***	0.252***
	(0.0324)	(0.0353)	(0.0353)
Gold sector shock	0.000149**		
	(0.0000576)		
Nickel sector shock		0.00316$^{\gamma}$	
		(0.00187)	
Emeralds sector shock			-0.0487*
			(0.0222)
Diagnostics			
C-D F statistic	43.00	56.24	56.54
Hansen statistic	3.284	3.517	3.537
Hansen p-value	0.656	0.621	0.618
N	9680	9680	9680

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted. Instruments are noted in the overview of table 1.

- Clustered standard errors in parentheses, department.

$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Summary statistics

Variable	Mean	Std. Dev.	N
Panel variables			
Guerrilla attacks on government forces (irregular)	0.383	1.204	9680
Guerrilla clashes with government forces (conventional)	0.427	1.417	9680
Tactical substitution	0.136	0.316	9680
Log eradication coca, hectares	0.353	1.405	9680
Rainfall (reanalysis monthly average), MM	0.329	0.291	9680
Temperature (reanalysis monthly average), K	288.232	14.234	9680
Windspeed (reanalysis monthly average), KM/hour	1.409	0.608	9660
Log population, millions	-4.342	0.972	9680
Municipal variables			
Oil production, hundred thousand barrels per day (1988)	0.003	0.054	968
Coffee production, thousands of hectares (1997)	0.830	1.535	968
Rainfall volume annual total, cm^3 (precise estimate)	1856.373	974.628	968
Temperature, celsius (precise estimate)	21.325	4.99	968
Water accessibility index	$3303.66e3$	$537.03e3$	953
Soil erosion index	1.95	1.058	953
Soil suitability index	2.664	1.201	953
Minimum distance to counter-narcotics airport, linear KM	124.409	78.305	968
Annual variables			
Log internal market coffee price, thousands of 2006 pesos per pound	0.524	0.224	10
Log global oil price, thousands of 2006 pesos per barrel	4.245	0.454	10
Log internal market cocaine price, pesos per KG	8.037	0.386	10
Log Chapare market (farm-gate) coca price, US dollars per KG	9.907	5.187	10
Log coffee price-maker production, millions of 60 KG bags	3.61	0.215	10

Appendices

Table of Contents

Figures

Tables

A An alternative two stage approach

Since I study mixing between two strategies, the outcome of interest — tactical substitution — is bounded by zero and one. It is known that ordinary least squares may produce estimates of the dependent variable outside the unit interval. To address this concern, I develop a fractional response two stage model. To do this, I estimate a set of linear first stage models that replicate the single step method employed in the main analysis and extract residuals. I then include these residuals in a second stage, along with the endogenous regressors. In the linear case, this two stage residual inclusion (2SRI) method is equivalent to 2SLS. When the outcome variable is non-linear (e.g., binary or fractional response), 2SRI is more consistent than two stage non-linear least squares (Terza, Basu and Rathouz, 2008, 536-537).

Although fractional specifications of two stage probit and logistic models exist, neither perform well in a panel difference-in-differences framework. If, however, the distribution of the outcome variable piles up at each corner of the unit interval, a latent variable analysis is consistent and unbiased. This approach is analogous to truncation of the dependent variable, where variation is only observed above and below thresholds determined by an underlying data generating process. In the present study, the data generating process at each corner of the distribution is straightforward. Rebels can allocate up to their maximum capacity in any given period. Although capacity may vary from unit to unit or within units over time, allocation of *all* fighting effort to irregular or conventional engagements obtains the same value along the outcome variable independent of rebel capacity (either zero in the case of conventional fighting or one, when insurgents focus solely on irregular violence). The impact of resource shocks on tactical substitution, therefore, is truncated. The main analysis addresses this concern indirectly through population weights, which covary with the degree of unobserved censoring on the dependent variable. This approach likely produces underestimates of the quantities of interest, however.

Even if we indirectly adjust for truncation of the outcome, the potential bias of OLS estimates remains. I address this concern by exploiting several desirable properties of a two-limit Tobit model in the second stage. Most importantly, a two-limit Tobit adjusts estimates with respect to the probability of being within the limits of the latent variable (the likelihood of observing a value strictly between zero and one). Following Wooldridge (2013), let L_1 and L_2 define the two limits of y, the outcome variable. Define the latent variable y' as $\mathbf{x}\beta + u$, such that u, conditional on $\mathbf{x}$, follows a normal distribution. Where y' is less than or equal to L_1, let the outcome variable equal the lower threshold. If y' is greater than or equal to the upper limit, let y equal L_2. Extending the one-limit Tobit, let values between the limits coincide with the latent quantity, so $y = y'$ when y' is greater than to L_1 and less than L_2. Consequently, the two-limit estimate is only appropriate when the probability of observing values at both limits is non-zero. The measure of tactical substitution studied in the main analysis (figure 4a), as well as alternative measures including non-combatant attacks (figure 4b) and excluding paramilitary violence (figure 4c), follows this bimodal pile-up at each tail with a (roughly) continuous distribution within the limits. What's more, the log likelihood of this approach is well-behaved and standard asymptotic theory follows maximum likelihood estimation, even within a difference-in-differences framework leveraging analytic weights and clustered error structures. Although this model is particularly appropriate for the present analysis, related work on the empirical implications of theoretical bargaining models may profit from it's application.

To clarify, I implement separate models in the first stage,

$$\begin{aligned}(Coffee_{m,t=1997} \times Co.Price_t) \\ &= \alpha_m + f_t + \mu_r t + (Oil_{m,t=1988} \times O.Price_t)\beta_1 \\ &\quad + IV_{m,t}\beta_2 + X_{m,t}\beta_3 + \epsilon_{m,t},\end{aligned} \tag{A.1}$$

$$\begin{aligned}(Coca_{m,t} \times Ca.Price_t) \\ &= \alpha_m + f_t + \mu_r t + (Oil_{m,t=1988} \times O.Price_t)\beta_1 + IV_{m,t}\beta_2 + X_{m,t}\beta_3 + \epsilon_{m,t},\end{aligned} \tag{A.2}$$

where $IV_{m,t}$ is a vector of exogenous instruments that varies according to each model and described in the overview of instrumental variables above.[44] I then identify the unexplained variation in $(Coffee_{m,t=1997} \times Co.Price_t)$ and $(Coca_{m,t} \times Ca.Price_t)$, labelling the residuals as r_{co} and r_{ca} respectively. I then incorporate these residuals in a second stage model (of tactical substitution), with lower and upper lower limits following the discussion above,

$$\begin{aligned}Y_{m,t} \\ &= \alpha_m + f_t + \mu_r t + (Oil_{m,t=1988} \times O.Price_t)\beta_1 + (Coffee_{m,t=1997} \times Co.Price_t)\beta_2 + r_{co} \\ &\quad + (Coca_{m,t} \times Ca.Price_t)\beta_3 + r_{ca} + X_{m,t}\beta_4 + \epsilon_{m,t}, \text{ such that } 0 < Y_{m,t} < 1.\end{aligned} \tag{A.3}$$

This second stage analysis is primarily focused on $(Oil_{m,t=1988} \times O.Price_t)$, $(Coffee_{m,t=1997} \times Co.Price_t)$, and $(Coca_{m,t} \times Ca.Price_t)$. Recall $(Coffee_{m,t=1997} \times Co.Price_t)$ and $(Coca_{m,t} \times Ca.Price_t)$ in the presence of r_{co} and r_{ca} are equivalent to $(\widehat{Coffee_{m,t=1997} \times Co.Price_t})\beta_2$ and $(\widehat{Coca_{m,t} \times Ca.Price_t})\beta_3$ in equation (3.2).

The estimates derived from this model are presented in table A. These results reveal that the linear probability models studied in the main analysis present underestimates of the causal impact of resource shocks on tactical substitution. This result obtains because population weighted regressions exploit scales to account for some but not all of the latent data generating process at the limits of the distribution. Instrument strength and estimate precision are also improved in this approach. The most important result to observe, however, is the stability of main results

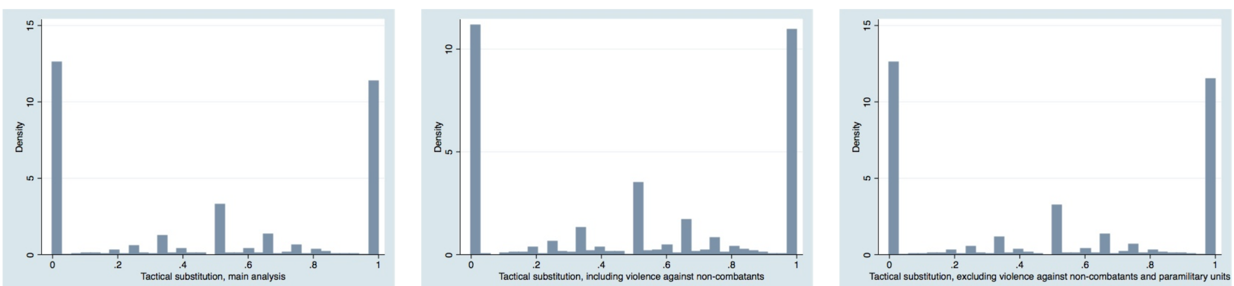
[44] To avoid first and second stage inconsistencies, I invert the classification of $py_{m,t}$ in $X_{m,t}$ such that it takes the value b, where $b \in [0, 1]$ during municipal peace-years. This change is trivial in the linear case and is used to ease estimation of the two-limit Tobit second stage.

in estimates produced by a potentially biased weighted OLS model and the two-limit Tobit 2SRI approach introduced above. To maintain consistency with previous research and to ease interpretation, I favor the OLS approach for the main analysis.

Table 8: Second stage estimation of two-limit Tobit model

	(1)	(2)	(3)	(4)	(5)
Coca sector shock	-0.0149***	-0.0181***	-0.0147***	-0.0129***	-0.0118***
	(0.000276)	(0.000277)	(0.000267)	(0.000276)	(0.000277)
Coffee sector shock	0.565***	0.576***	0.218***	0.495***	0.580***
	(0.00514)	(0.00519)	(0.00523)	(0.00518)	(0.00518)
Oil sector shock	0.646***	0.654***	0.673***	0.647***	0.642***
	(0.00464)	(0.00467)	(0.00464)	(0.00464)	(0.00464)
N	9680	9530	9680	9660	9680

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted. Instruments are noted in the overview of table 1.
- Clustered standard errors in parentheses, department.
$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$



(a) Outcome variable, main (b) Including non-combatants (c) Excluding paramilitarys

Figure 4: Histograms of main and supplementary measures of tactical substitution, indicating pile-ups at lower and upper limits

B Optimal route equilbria estimation

I solve a classical route optimization problem detailed by Dell (2015) and produce estimates of drug traffic intensity at the municipal level.

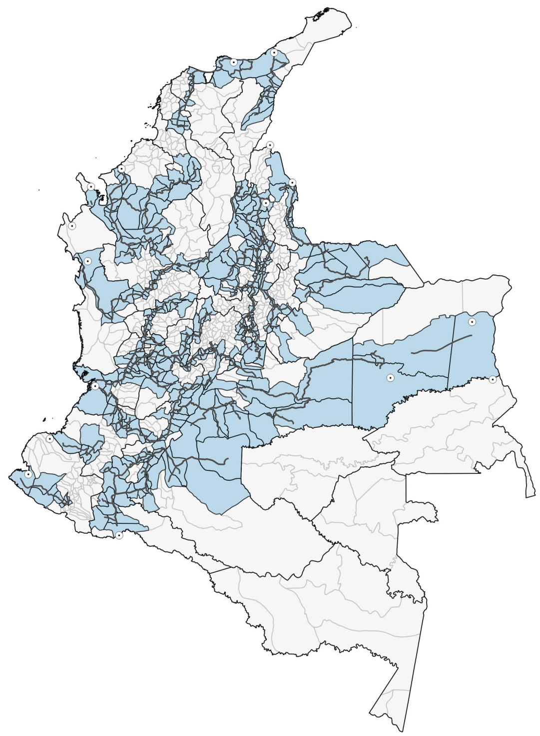
I start with an undirected graph of all major roads in Colombia R composed of intersections N and roadways E (so, $R = (N, E)$). Rebels attempt to move coca paste and cocaine from their strongholds — front bases — to transit points, where drugs exit the country by boat or aircraft. Bases and transit points are drawn from archival data provided by the Colombian Ministry of Defense. Each unit attempts to minimize the cost of shipment. For simplicity, let each roadway $e \in E$ have a cost function determined by the length (l_e) of the road, so the expense of traveling along a given road is equal to $c_e(l_e)$.

Since the purpose of this optimization exercise is study the potential impact of spillovers due to increased drug transit activity, I leave the analysis of congestion dynamics to future research. Drawing on the main findings, one could imagine that such congestion costs might force rebels to reroute traffic following positive shocks to oil production and export (or any other dynamic that increases government capacity), as in figure 5b. In appendix B, I present a map of municipalities that should experience drug traffic *if and only if* increases in government capacity force traffickers to exploit an alternative path around oil producing municipalities (since changes in capacity effectively remove some e from E) (see figure 5c). This might serve as an fruitful extension of the present study.

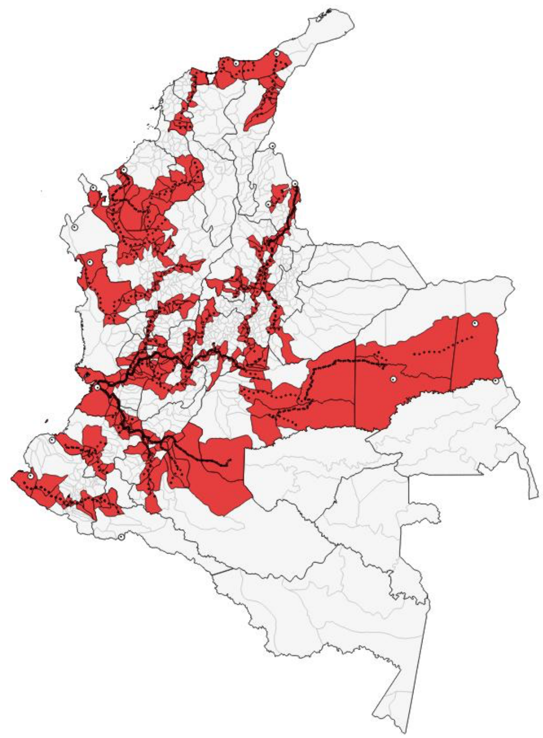
If traversing $n \in N$ is costless, then the total cost of a potential trafficking route p is $V(p)$ $= \sum_{e \in p} c_e(l_e)$. I assume movement through intersections is costless to avoid imposing additional assumptions on this optimization exercise. Yet counterinsurgents might focus efforts at key junctures in the network. I leave this dynamic to future research.

Let $P_{s,t}$ denote the set of all possible routes between rebel strongholds s and transit points t. Rebels optimize routes such that:

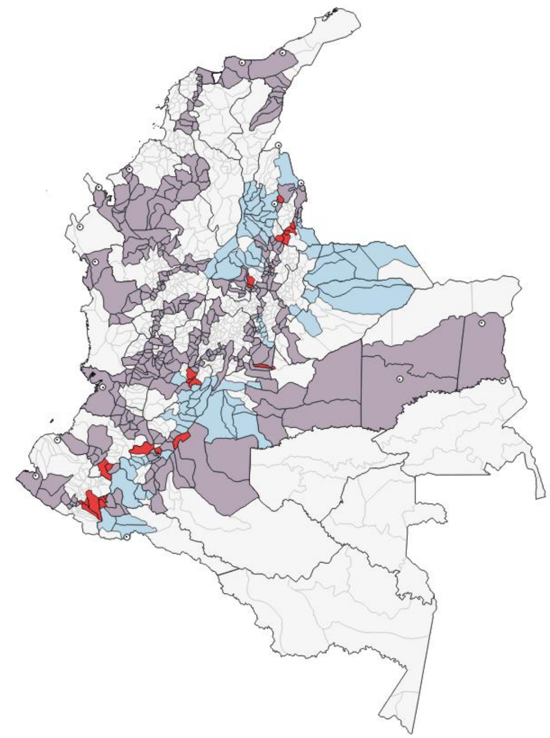
$$\min_{p \in P_{s,t}} V(p). \tag{B.1}$$



(a) optimal routes without consider potential congestion due to capacity shocks



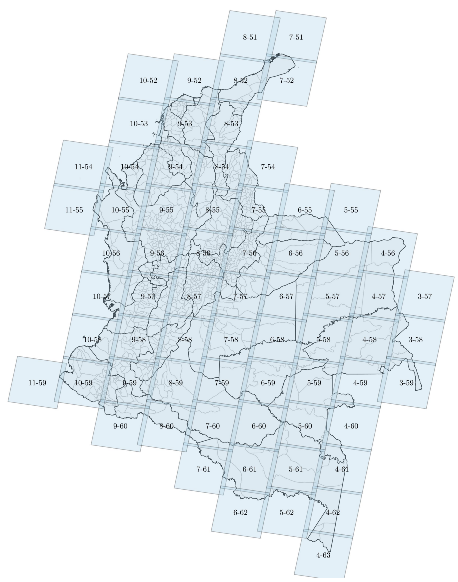
(b) With congestion due capacity increases via]] positive oil income shocks



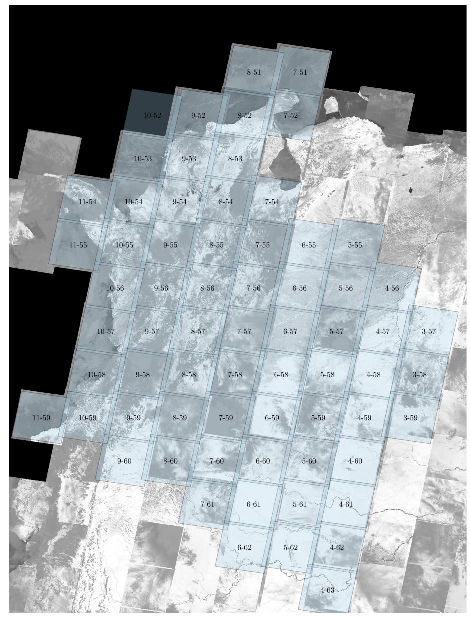
(c) Municipalities that experience trafficking related violence if and only if positive oil income shocks increase congestion costs

Figure 5: Coca trafficking routes, without and with oil shock capacity barriers

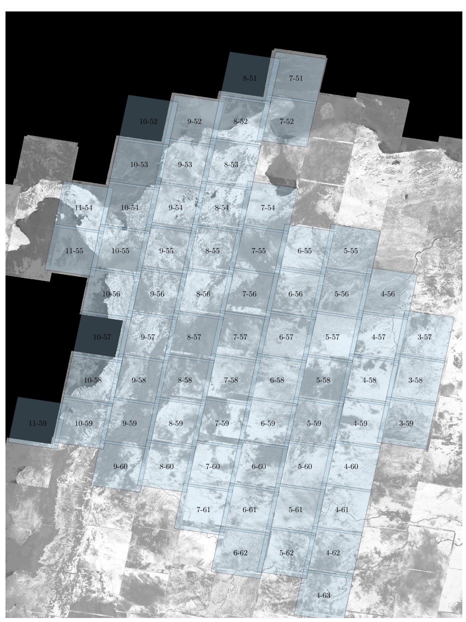
C Geographic figures



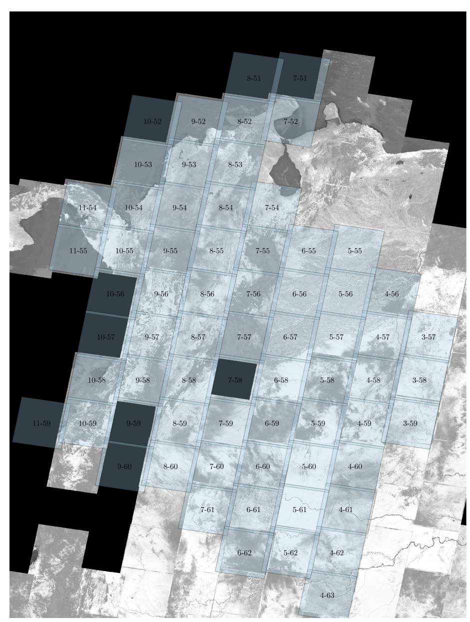
(a) Landsat 5 row/path



(b) 1999 mosaic



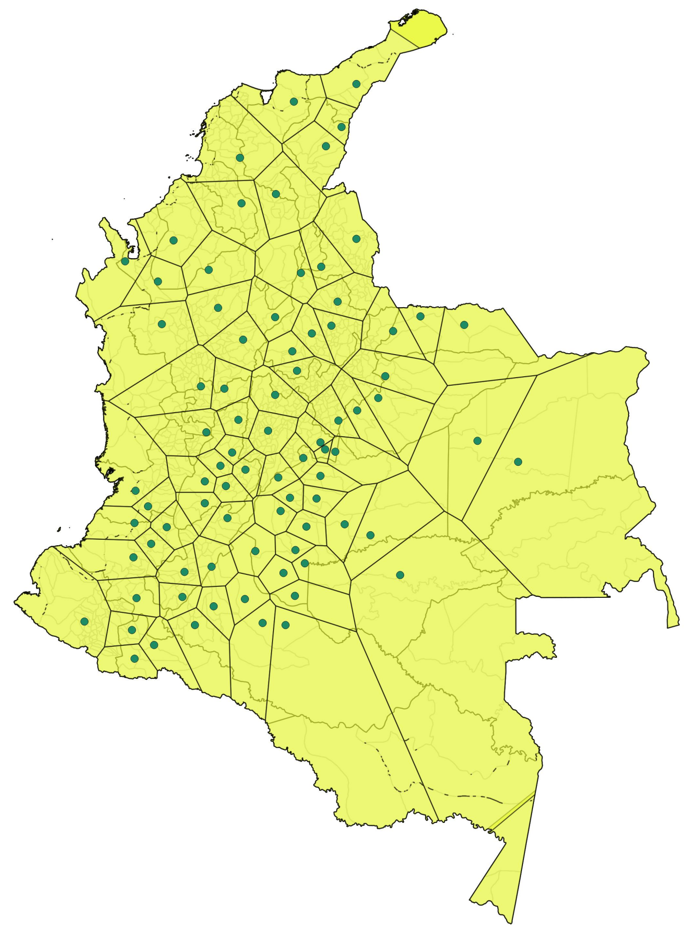
(c) 2000 mosaic



(d) 2001 mosaic

Figure 6: Landsat 5 row/path classification for Colombia and greenest pixel mosaics used for retrospective coca production estimation (1999, 2000, 2001)

(a) Location of counternarcotics airports



(b) Voronoi map of rebel fronts based on confidential historical military data

Figure 7: Counternarcotics airports and rebel base locations

D Online only

Table 9: Weighted regression diagnostics

Panel A: benchmark models with without population weight

	(1)	(2)	(3)	(4)	(5)
Coffee sector shock	0.110**	0.110**	0.0808**	0.0996**	0.113**
	(0.0358)	(0.0351)	(0.0267)	(0.0333)	(0.0370)
Coca sector shock	-0.00260	-0.00238	-0.00309$^{\gamma}$	-0.00303*	-0.00261
	(0.00161)	(0.00162)	(0.00160)	(0.00153)	(0.00162)
Oil sector shock	0.295***	0.293***	0.301***	0.299***	0.295***
	(0.0333)	(0.0353)	(0.0280)	(0.0302)	(0.0326)
Diagnostics					
C-D F statistic	38.90	39.74	35.52	26.51	28.56
Hansen statistic	3.633	1.950	7.012	5.851	5.384
Hansen p-value	0.458	0.745	0.220	0.557	0.613
N	9680	9530	9680	9660	9680

Panel B: benchmark models with average population weight

	(1)	(2)	(3)	(4)	(5)
Coffee sector shock	0.103*	0.105*	0.0674*	0.0835$^{\gamma}$	0.104*
	(0.0504)	(0.0509)	(0.0311)	(0.0441)	(0.0463)
Coca sector shock	-0.00336$^{\gamma}$	-0.00380*	-0.00398*	-0.00327*	-0.00343*
	(0.00172)	(0.00186)	(0.00177)	(0.00167)	(0.00167)
Oil sector shock	0.254***	0.255***	0.260***	0.255***	0.254***
	(0.0418)	(0.0397)	(0.0353)	(0.0406)	(0.0421)
Diagnostics					
C-D F statistic	55.13	54.11	53.14	37.03	39.89
Hansen statistic	4.334	3.247	3.409	7.610	6.823
Hansen p-value	0.363	0.517	0.637	0.368	0.448
N	9680	9530	9680	9660	9680

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted. Instruments are noted in the overview of table 1.

- Clustered standard errors in parentheses, department.

$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: Additional instrumentation: rainfall and temperature $\times$ external production

	(1)	(2)	(3)	(4)	(5)
Coffee sector shock	0.0924*	0.102**	0.0641*	0.0777*	0.0938*
	(0.0426)	(0.0382)	(0.0298)	(0.0338)	(0.0406)
Coca sector shock	-0.00331$^{\gamma}$	-0.00371*	-0.00395*	-0.00298$^{\gamma}$	-0.00333*
	(0.00170)	(0.00166)	(0.00176)	(0.00170)	(0.00163)
Oil sector shock	0.249***	0.248***	0.253***	0.249***	0.248***
	(0.0398)	(0.0388)	(0.0349)	(0.0404)	(0.0403)
Diagnostics					
C-D F statistic	41.28	40.13	39.54	30.73	33.64
Hansen statistic	4.843	4.189	11.61	7.267	8.865
Hansen p-value	0.679	0.758	0.170	0.700	0.545
N	9680	9530	9680	9660	9680

Dependent variable is $\frac{attacks}{attacks+clashes}$. Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted. Instruments are noted in the overview of table 1.

- Clustered standard errors in parentheses, department.

$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: First stage results of table 1, coffee sector value (coffee sector value regressed on instruments and exogenous regressors)

	(1)	(2)	(3)	(4)	(5)
Oil sector shock	0.0282	0.0369	0.0237	0.0699	0.0196
	(0.0659)	(0.0664)	(0.0622)	(0.0630)	(0.0681)
Rainfall × price-maker coffee production	-0.00353***	-0.00360***	-0.00360***	-0.00353***	-0.00355***
	(0.000933)	(0.000937)	(0.000908)	(0.000905)	(0.000964)
Temp. × price-maker coffee production	-0.215***	-0.221***	-0.287***	-0.216***	-0.216***
	(0.0455)	(0.0453)	(0.0593)	(0.0433)	(0.0461)
Rainfall × temp. × price-maker coffee production	0.000144***	0.000146***	0.000146***	0.000143***	0.000144***
	(0.0000349)	(0.0000350)	(0.0000342)	(0.0000339)	(0.0000360)
Rainfall	-2.491			-0.0721	-4.786
	(1.815)			(0.131)	(7.638)
Temp.	0.00828			0.905	0.100*
	(0.0338)			(1.185)	(0.0421)
Rainfall × temp.	0.00885				0.0162
	(0.00619)				(0.0257)
Rainfall × soil erosion index		0.0331			
		(0.0234)			
Rainfall × water accessibility index		-1.18e-08			
		(3.69e-08)			
Rainfall × soil suitability index		0.0217			
		(0.0367)			
Rainfall × Chapare market coca prices			-0.0351*		
			(0.0148)		
Rainfall^2 × Chapare market coca prices			0.0124*		
			(0.00539)		
Temp. × Chapare market coca prices			-0.00496**		
			(0.00150)		
Temp.^2 × Chapare market coca prices			0.0000167**		
			(0.00000506)		
Rainfall^2				0.0999	
				(0.128)	
Temp.^2				-0.00155	
				(0.00202)	
Atmospheric wind speed				-0.317*	
				(0.145)	
Atmospheric wind speed^2				0.0443*	
				(0.0187)	
Rainfall × distance to airport					0.0241
					(0.0651)
Temp. × distance to airport					-0.000759*
					(0.000283)
Rainfall × temp. × distance to airport					-0.0000791
					(0.000219)
Diagnostics					
AP F statistic	4.528	5.152	5.454	7.393	3.683
AP p-value	0.00325	0.00158	0.000602	0.0000211	0.00399
N	9680	9530	9680	9660	9680

Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted.
- Clustered standard errors in parentheses, department.
$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12: First stage results of table 1, coca sector value (coca sector value regressed on instruments and exogenous regressors)

	(1)	(2)	(3)	(4)	(5)
Oil sector shock	2.596	2.683	2.565	2.683	2.287
	(9.021)	(9.037)	(9.090)	(9.135)	(8.765)
Rainfall × price-maker coffee production	-0.00638	-0.00731	-0.00826	-0.00660	-0.00577
	(0.0105)	(0.0107)	(0.0108)	(0.0106)	(0.0104)
Temp. × price-maker coffee production	-0.188	-0.260	-0.552	-0.223	-0.183
	(0.814)	(0.827)	(0.846)	(0.827)	(0.800)
Rainfall × temp. × price-maker coffee production	0.000582	0.000625	0.000638	0.000595	0.000553
	(0.000560)	(0.000568)	(0.000572)	(0.000565)	(0.000552)
Rainfall	-36.41			2.841	-259.7$^{\gamma}$
	(43.59)			(2.520)	(139.9)
Temp.	-0.112			8.262	0.262
	(0.478)			(19.26)	(0.653)
Rainfall × temp.	0.134				0.914$^{\gamma}$
	(0.152)				(0.486)
Rainfall × soil erosion index		0.0570			
		(0.647)			
Rainfall × water accessibility index		3.03e-08			
		(0.000000613)			
Rainfall × soil suitability index		0.791			
		(0.895)			
Rainfall × Chapare market coca prices			0.0335		
			(0.221)		
Rainfall^2 × Chapare market coca prices			0.209		
			(0.150)		
Temp. × Chapare market coca prices			-0.0195		
			(0.0189)		
Temp.^{2} × Chapare market coca prices			0.0000700		
			(0.0000635)		
Rainfall^2				-0.250	
				(1.505)	
Temp.^{2}				-0.0145	
				(0.0337)	
Atmospheric wind speed				-0.942	
				(1.436)	
Atmospheric wind speed^2				0.252	
				(0.185)	
Rainfall × distance to airport					1.504$^{\gamma}$
					(0.794)
Temp. × distance to airport					-0.00336
					(0.00436)
Rainfall × temp. × distance to airport					-0.00525$^{\gamma}$
					(0.00274)
Diagnostics					
AP F statistic	2.957	2.658	2.555	2.657	5.710
AP p-value	0.0270	0.0419	0.0397	0.0247	0.000171
N	9680	9530	9680	9660	9680

Municipality fixed effects, year fixed effects, log of population and linear trends by region are omitted.
- Clustered standard errors in parentheses, department.
$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13: Reduced form of table 1 (tactical substitution regressed on instruments and exogenous regressors)

	(1)	(2)	(3)	(4)	(5)
Rainfall × price-maker coffee production	-0.000372*	-0.000375**	-0.000349*	-0.000373**	-0.000375**
	(0.000145)	(0.000145)	(0.000140)	(0.000142)	(0.000143)
Temp. × price-maker coffee production	-0.0234***	-0.0257***	-0.0219**	-0.0232**	-0.0235***
	(0.00657)	(0.00653)	(0.00735)	(0.00714)	(0.00652)
Rainfall × temp. × price-maker coffee production	0.0000145*	0.0000148*	0.0000139*	0.0000147*	0.0000146*
	(0.00000588)	(0.00000590)	(0.00000560)	(0.00000572)	(0.00000583)
Rainfall	-1.178			-0.0444	-0.322
	(1.235)			(0.0661)	(3.445)
Temp.	-0.0162$^{\gamma}$			0.312	-0.00695
	(0.00860)			(0.352)	(0.0154)
Rainfall × temp.	0.00391				0.000892
	(0.00427)				(0.0118)
Rainfall × soil erosion index		0.0176			
		(0.0143)			
Rainfall × water accessibility index		2.82e-09			
		(2.13e-08)			
Rainfall × soil suitability index		-0.0321			
		(0.0229)			
Rainfall × Chapare market coca prices			-0.00213		
			(0.00439)		
Rainfall^2 × Chapare market coca prices			-0.00187		
			(0.00390)		
Temp. × Chapare market coca prices			0.000154		
			(0.000266)		
Temp.^{2} × Chapare market coca prices			-0.000000522		
			(0.000000899)		
Rainfall^2				0.00652	
				(0.0565)	
Temp.^{2}				-0.000566	
				(0.000611)	
Atmospheric wind speed				0.0669*	
				(0.0302)	
Atmospheric wind speed^2				-0.00144	
				(0.00408)	
Rainfall × distance to airport					-0.00541
					(0.0272)
Temp. × distance to airport					-0.0000767
					(0.000105)
Rainfall × temp. × distance to airport					0.0000191
					(0.0000918)
N	9680	9530	9680	9660	9680

Dependent variable for all models is $\frac{attacks}{attacks+clashes}$. Omitted exogenous regressors include a population measure and oil sector shocks. Municipality fixed effects, year fixed effects, log of population and linear trends by region are also omitted.
- Clustered standard errors in parentheses, department.
$^{\gamma}$ $p < .1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$