Territorial Control in Civil Conflicts[1]

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Introduction

Since the so-called Great War of Africa, the eastern provinces of the Democratic Republic of the Congo (DRC) were controlled by the foreign-backed insurgents. The zones of control were, however, not uniform in the eastern DRC. The Kivu provinces, which had a plenty of precious or *lootable* mineral resources such as gold and cobalt, were controlled and even contested by the rebels. In fact, a study identifies 132 active non-state armed actors in Kivu as of September 2017 (Congo Research Group and Watch, Human Rights, 2020). By contrast, the province of Katanga, which is a part of the Copperbelt—one of the largest deposits of copper in the world, were controlled by the government in spite of the long history of the struggle for independence.

The case of the DRC is consistent with the well-known but not yet tested thesis about resource lootability and rebels' strategic incentives; rebels seeks for territorial control over lootable resources (e.g., gold) but not the one over non-lootable resources (e.g., copper). Conceptually, lootable resources are those with a high value-to-weight ratio and that can be extracted with little capital or technology. Lootable resources are therefore attractive funding sources for rebels because they can be transported to markets easily or because the rebels have the capability to prevent producers from avoiding extortion. By contrast, *non-lootable* resources may be more valuable than lootable resources but are also more difficult for rebel forces to transport or to extort. Thus, we expect that the existence of lootable resources increases the likelihood of rebel's establishment of territorial control, while non-lootable resources do not have an equivalent effect.

We empirically test this proposition with new data that measures both the dependent variable of territorial control and the independent variable of natural resource wealth at the local level for countries in sub-Saharan Africa experiencing civil war between 1989 and 2013. The data for territorial control is based on coding of conflict events involving rebel and government forces and an algorithm that incorporates road networks and topographical features to measure the extent to control extends to areas nearby where conflict events occur. The data for natural resources includes almost 200 different types of resources as well as information about the output and value of these resources. Assessing the relationship between these variables is difficult because the value of natural resources may be influenced by conflict events, including events that result from combatants attempts to control a location. Furthermore, while the data we introduce allows us to identify when rebels control a location, it does not directly measure a rebel movements desire to control this location, which is likely to be influenced by factors such as the authorities' counterinsurgency efforts. To address these concerns, our analysis employs a two-stage selection model. In the first stage, we seek to determine the factors that influence rebel presence in a location, and use the results to inform a second stage in which we estimate how natural resources and other factors influence the extent of rebel control. Consistent with our expectations, we find that locations with more valuable resources experience more rebel control, but only when these resources are lootable.

The paper makes a number of contributions to the literature on resources and conflict. There has been considerable debate on the role of lootable natural resources in driving conflict dynamics, with some research identifying lootability as an important influence but other research suggesting that lootability has little effect on conflict (Ross M. , 2004; Conrad, Greene, Walsh, & Whitaker, 2019). One issue with this literature is, however, that it has not directly investigated how lootable resources influence control of territory, despite the fact that these two concepts would seem to be tightly linked. This paper seeks to develop new theory that outlines more precisely how lootable resources influence territorial control. The new data that is used in the paper is both subnational and cross-national. This allows us to assess how the characteristics of locations influence territorial control, while also investigating whether these relationships hold across different conflicts. The data on territorial control is, to our knowledge, the first to measure this concept in a way that is consistent with Kalyvas' (2006) conceptualization across different conflicts. The data on natural resources includes many more resources than do existing data sources, and also include information about the output and value of these resources. This allows a more systematic comparison of how these types of resources influence territorial control. Furthermore, we suggest that it is the value, not simply the presence, of natural resources that creates incentives for rebels to control locations with lootable resources. Most existing subnational data sources on natural resources record the presence but not the value of such resources, and the data we utilize in the paper addresses this issue as well.

Literature Review

Control of territory is a central goal of combatants in civil wars. Governments seek to exercise sovereignty over their territory. Rebel combatants challenge this sovereignty, seeking to overthrow the incumbent entirely or drive it from some of its territory. While control of territory is the ultimate objective of combatants, it also provides resources that permit a combatant to prevail during a civil war. Changing the distribution of territory influences the balance of power. Territory allows combatants to establish military bases and sanctuaries where forces can be marshalled, trained, and begin to attack the enemy (Salehyan, 2008). Combatants can extract human, natural, and financial resources through coercion (Kalyvas, 2006) or the provision of services (Stewart, 2018), and to deny these resources to their opponent. Civilians can provide support in the form of recruits, donations, and information (Rubin M. , 2020; Berman, Shapiro, & Felter, 2011). Territory provides a focal point to which supporters from more distant areas can migrate for protection. With less of a need to hide from government forces, territorial control enables rebels to be more open in establishing bases, organizing forces, effectively training recruits in those bases and in the field. Territorial control also influences the strategies of violence that combatants adopt; for example, rebels rely more heavily on terrorism than conventional and guerilla attacks when the government exercises strong control (Kalyvas, 2006; de la Calle & Sánchez-Cuenca, 2015). Control of territory, then, can provide important benefits to combatants that allow them to marshal their forces and political support, shift the balance of power in their favor, and to prevail in civil conflicts. But control also involves opportunity costs, requiring the allocation of a limited amount of military power to a location. These military forces must be sustained and cannot be allocated to other tasks without placing the combatant's control at risk. Given these opportunity costs, what characteristics of a location make it desirable to control?

Surprisingly few studies have addressed this question directly, but we can infer some potential from research that examines the location and duration of conflict events. The loss of strength gradient means that the effectiveness of military force declines with distance (Boulding, 1962). While Boulding himself argued that the loss of strength gradient was becoming less relevant because of the deployment of technologies that allow the projection of power over long distances, it retains particularly relevant in many civil conflicts where such weapons are not employed widely. Combatants that have fewer capabilities to project power than their opponent should seek territory that is far from the opponent's centers of military and political gravity. In most civil conflicts, rebel combatants have fewer military capabilities than the government they fight. They can counter greater government power by seeking to control territory that is distant from government territory or that is difficult for government forces to penetrate, such as forested or mountainous areas (Fearon & Laitin, 2003). Controlling territory near international borders provides rebels with easier access to neighboring countries through which they can receive external support or export goods they have obtained illicitly to fund their activities (Buhaug & Gates, 2002). Buhaug, Gates, and Lujala (2009) analyze the location of conflict events and find that events located farther from the national capital are associated with longer civil wars. This suggests that rebels choose to fight far from the government's center of gravity and hence to ensure their survival. Other work finds that terrain ruggedness increases the onset and incidence of civil war violence (Carter, Shaver, & Wright, 2019). None of these studies, however, directly analyze the causes of territorial control.

Recent studies more directly analyze the incentives for territorial control. Both governments and rebels seek to establish control over locations from which they can extract human, physical, and financial resources. Given that governments are typically more powerful, rebel movements seek locations whose characteristics allow them to exercise control at lower cost. Rebels seek to control territory in areas where their current and potential supporters are concentrated, at least at the outset of a conflict (Kalyvas, 2006, p. 113). This allows them to more easily recruit fighters and supporters and tap potential supporters for intelligence about enemy activities (Rustad, Buhaug, Falch, & Gates, 2011; Carter, Shaver, & Wright, 2019). Combatants seek to control key nodes of transportation networks in order to move soldiers and equipment between locations and deny mobility to their opponent (Hammond, 2018; Zhukov, 2012; Detges, 2016). Rebels might seek territory in locations where the local population experiences relative deprivation and would be more receptive to the movement's demands for political change. However, government forces might also seek to exert control in these locations to forestall rebellion. Furthermore, there is some evidence that conflict events occur in locations with lower levels of relative deprivation, which rebels and governments might seek to control because these locations can provide more resources (Hegre, Ostby, & Raleigh, 2009).

Among different types of resources, a substantial number of studies focus on natural resources. In fact, much of the literature on civil war has focused on how natural resource wealth influences onset, duration, and conflict dynamics. Both governments and rebel movements can tax producers of such resources and use the income to finance their war efforts. Many governments in the developing world fund large shares of their budgets with such taxes (Ross M. , 2012). Rebel movements also tax producers of natural resources (Fearon, 2004; Walsh, Conrad, Whitaker, & Hudak, 2018). The presence of natural resource increases the likelihood of civil war onset (Ross M. , 2012) and the duration of such conflicts (Fearon, 2004; Conrad, Greene, Walsh, & Whitaker, 2019; Lujala, 2010; Lujala, Rod, & Thieme, 2007). Recent research has shifted the focus of analysis of the effects of natural resource from the country level to the sub-national level. This research finds that locations with natural resource wealth are more likely to experience conflict events (Berman, Couttenier, Rohner, & Thoenig, 2017; Christensen, 2019; Harari & La Ferrrara, 2018). Both governments and rebels would have powerful incentives to control such locations. Control permits combatants to more effectively coerce or persuade producers of natural resources to pay government or rebel taxes. Control also prevents the opposing combatant from securing such sources of income.

Despite the plethora of studies, however, a number of questions about how natural resources influence control remain unanswered. Fearon (2004) suggests that resources that are "lootable" are especially attractive to rebels, who lack the access to legal markets and transportation and logistical infrastructure needed to extract and transport nonlootable resources. Other research does not find much support for this proposition and instead concludes that rebel movements are able to tax producers of nonlootable resources quite effectively (Ross M. , 2004; Conrad, Greene, Walsh, & Whitaker, 2019). Existing studies also focus on a single resource, such as oil or gemstones (Lujala, Rod, & Thieme, 2007; Lujala, Gleditsch, & Gilmore, 2005), or a handful of resources, such as widely-extracted minerals (Berman, Couttenier, Rohner, & Thoenig, 2017). Yet we know that governments and also rebels can tax and earn income from a wide range of resources (Walsh, Conrad, Whitaker, & Hudak, 2018). We also know little about how changes in the prices of natural resources influence conflict dynamics, as most studies that investigate the effects of resource wealth at the sub-national level analyze the effect of the presence, but not the value, of such wealth. We might expect that locations with more valuable resources, or resources that increase in value, would create stronger incentives for combatants to control.

Theory

Rebels seek to control locations that produce natural resource wealth. They can use income generated by the production of natural resources to fund their war effort. But rebel movements specialize in the use and threat of violence, not resource extraction. For this reason, they rarely seek to control resource-rich locations so that they can extract wealth themselves. Instead, they tax or extort producers. Rebels threaten violence unless producers give them a share of their income from natural resources (Walsh, Conrad, Whitaker, & Hudak, 2018). By refraining from extracting resources by themselves, rebels create a principal-agent problem. They worry that producers will shirk on their extortion payments, seeking to avoid these entirely or understating the amount or value of resources they produce, or will shirk on output, reducing the amount of resources they extract. Rebels need to have forces nearby to monitor producers and punish those who pay none or little of the taxes they impose. This creates an incentive for rebels to seek to control territory near where natural resources are produced. The proximity of rebel forces gives them the means to track producers' output and punish those who underpay.

But controlling territory is costly for rebels. They must divert personnel from military operations to the extortion of producers. These military forces must also be of sufficient strength to defend the location from government attacks. Since the government is likely to know if and where the rebels are engaging in extortion, the rebels lose the element of surprise and freedom of movement. Rebel extorters must ensure that producers can get their goods to domestic or international markets, or be able to transport extorted resources themselves to such markets. This means that they need the logistical capacity to move resources over long distances, and to protect these movements from attacks by government forces or other armed actors.

Furthermore, the government also has incentives to control locations that contain valuable natural resources, both to funds its own activities through taxation and to prevent the rebels from profiting from these resources. This should influence where rebels chose to deploy their military assets, as they may need to fight against government forces to secure control of such locations. This is problematic for the rebels for three reasons. First, in most civil wars, the government has more military capability than the rebels. This means that the rebels will be outnumbered or will have to divert forces from other locations to uproot government forces. Second, the rebels lose the element of surprise. The government can expect the rebels to seek to control locations with valuable natural resources and position its forces in anticipation of attack. Third, the government is likely to have a first mover advantage. In most cases, the government existed before the development of the rebel group. This means that the government had time to anticipate rebellions in the future and build the transportation infrastructure, fighting positions, and so on that they would need to protect valuable locations, such as the national capital, major cities, key transportation nodes, and areas containing valuable natural resources. Based on this reasoning, we expect that the most economically important locations that produce natural resource wealth will be well-defended by the government, and that the rebels will refrain from engaging in battle near these locations.:

> *Hypothesis 1*: Rebels will be less likely to have a presence in locations that contain more valuable natural resources.

We now turn to analyzing how natural resource wealth influences rebels' attempts to control locations in the areas where their forces are present. We focus on how a characteristic of a natural resource—its lootability—influences rebel and government incentives to control a location (Lujala, Gleditsch, & Gilmore, 2005; Ross M. L., 2003). A resource is more lootable to the extent that it has one of two characteristics. The first is the value-to-weight ratio; resources with a higher value-to-weight ratio are more lootable. Examples of high value-to-weight resources include most gemstones and many minerals, such as gold; resources with lower value-to-weight resources include pumice or sand. Locations with more high value-to-weight ratio natural resources are more attractive for rebels to control. The reason is that rebels, or the producers they extort, can more easily transport resources with high ratios to distant markets for sale. Such resources can be transported by an individual smuggler, a single vehicle, or a small aircraft. This allows the rebels or producers to earn income from the resource while more easily avoiding government interception.

Rebels can still earn income from less lootable resources. They can do this by extorting producers. For example, rebels in Colombia frequently bomb, or threaten to bomb, oil pipelines. Oil producers pay rebels to refrain from such attacks. Other rebels threaten to kidnap workers or managers at natural resource extraction or production facilities in exchange for payments. This sort of extortion does not require that rebels control territory nearby. Instead, they only require the capacity to hide small forces that can engage in hit-and-run attacks. We expect, then, that the presence of less lootable resources will still be attractive targets for rebels, but do not expect this to create an incentive for them to establish territorial control nearby. As discussed above, such locations are likely to be well-defended by government forces or security contractors employed by the producer, making it more difficult for rebels to maintain a territorial base in the area.

A second and distinct characteristic of more lootable resources is that they are labor intensive (Dube & Vargas, 2013; Snyder & Bhavnani, 2005). This type of lootable natural resource requires less human or economic capital to extract. Production of such lootable resources do not need complicated equipment or a large skilled workforce. The classic example is artisanal production of minerals such as alluvial gemstones or minerals. Large-scale oil production is far less lootable on this score, requiring substantial investments in drilling, extraction, refining, and transportation equipment and skilled workers to operate and maintain this equipment. These types of less lootable resources are less attractive for rebels to control. They typically lack the funds to purchase or maintain equipment, and the knowledge needed to supervise and monitor production to avoid shirking. A more attractive option, as discussed above, is for rebels to extort producers of such resources in ways that are more clandestine than controlling territory. More labor-intensive resource extraction, in contrast, is easier for rebels to oversee. They can use violence or rewards to attract a less skilled workforce to a location they control that contains the resource and more easily extract profits directly by managing production themselves or indirectly by supervising and taxing the producers. Thus, the degree to which a natural resource is lootable should influence their incentives to control a location.

Lootability by definition implies high value. But values can still range based on quantity, with lower quantities of a lootable resource being less valuable than higher quantities of a lootable resource. As such, quantity and price determine the overall value and the higher the value, the more incentive to control that area. Greater quantities could come from a single location, but more often they come from multiple locations in a general area producing the resources. This implies that rebels will seek to control a sizeable area. But even if there is only a single (or a few) high producing mines, rebels may still want to control a larger area to give them a sufficient buffer to hold the mines against future attacks. As such, we hypothesize here about the size of the area that rebels seek to control:

> *Hypothesis 2*: The greater the value of a lootable resource, the larger the *area* of territorial control that rebels will seek to establish

Empirical Approach

To test the hypotheses, we draw on recently available spatial and time-varying data on the location of state and rebel control (Tao, Strandow, Findley, Thill, & Walsh, 2016)[2] in internal armed conflicts as identified by the UCDP Dyadic Dataset (Pettersson & Öberg, 2020). This data is combined with recently available spatial and time-varying data on the value of lootable and non-lootable resources (Denly, Findley, Hall, Stravers, & Walsh, 2019).[3] The consequent dataset records rebel control, the value of natural resources, and other important covariates for all grid-cells in 91 state-rebel dyads (43 of which had some degree of control present in the conflict) across 18 African countries between 1989 and 2013. In total, our dataset has 1,061,483 observations.

Our analysis seeks to uncover the causal impacts of natural resource value on rebels' presence and control. This goal is aided by the fact that territorial control, and the occurrence of conflict that underlies our measure of control, does not affect where natural resources are present. This limits straightforward problems with reverse causality. Natural resources, however, are not

[2] See Appendix A for a broader discussion of the territorial control data.
[3] See Appendix B for a broader discussion of the natural resource data.

as-if randomly assigned with respect to control and as a result we cannot simply regress rebel control on natural resource values. We identify three main problems that inhibit our efforts to uncover causal effects and that we seek to address.

First, the *value* of a natural resource may be endogenous to conflict. While conflict does not impact the location of a resource, it does impact the ability of producers to extract and sell a resource, which affects the resource's value. In addition, confounders may influence both the type of resource present (i.e., value) and where rebels fight or establish control. Valuable minerals, for instance, may occur more frequently in mountainous terrain that is also easier for rebels to control. The endogeneity between conflict and the "value" and location of a resource may introduce bias into our ability to estimate the impact of resource's value in a location on the extent of subsequent rebel territorial control.

Second, not every location in a country has the "potential" to be controlled by a rebel. Our sample, however, includes observations where a rebel can never establish control, where rebels have the potential to control a location but where control does not occur, and locations where control is observed. In locations where control is not possible, the value of natural resources cannot have a causal impact. This leads to bias if natural resources are not randomly distributed with respect to factors that might influence control between locations where control can and cannot be observed.

Third, our theory builds a case for why the presence of valuable lootable resources incentivizes rebels to devote more effort and resources to establishing control (again, in locations where they could theoretically establish control). Rebels' *desire* for control, however, is a latent variable. While we would like our dependent variable to capture "more rebel effort devoted to control," our data instead measures "observed control." Observed control is a function of rebel effort but it is also a function of other factors such as state efforts to establish control or to eliminate rebel activity (i.e., state counterinsurgency). If we fail to adjust for these other factors, the dependent variable will not match our theory, and our statistical tests will not be an appropriate test for our hypothesis.

We take steps to address each of these issues to improve our ability to draw appropriate causal inference from our empirical analysis. First, to address the problem of omitted variables, we identify plausible confounding variables and include them as control variables in our statistical analysis. These variables, as well as our main independent variables recording the value of natural resources, are also lagged by one month to avoid simultaneity. This step, however, does not address the possibility that an underlying conflict process correlates with both the *value* of a resource in a location and observed rebel control over time. To address this additional concern, we follow Denly, Findley, Hall, Stravers, and Walsh (2020) and provide robustness tests by using the lagged value of the resource on the world market as an instrumental variable. While conflict may influence local values, it is unlikely to have a significant impact on global values—especially when resources are extracted in many locations other than the current conflict country. Moreover, the exclusion restriction—global resource values should affect the territorial control only through its effect on local resource values—seems plausible if not perfect. This analysis is not currently incorporated in our paper but will be available in a future iteration.

Second, to address the problem that control is not a potential outcome in all cases and that the presence and value of natural resources may not be random with respect to the possibility of control, we employ a Heckman selection model (Heckman, 1979). In other words, we explicitly assume that an omitted—and potentially unobservable—variable determines selection into locations where rebel control is a possibility, the value of natural resources present in these areas, and the extent of rebel control observed. We first determine the probability of observing rebel presence in a dyad-grid-month before including the resulting correction in our outcome model that includes just observations where the rebel had the potential to establish control. We use the first instance of conflict of any type involving a rebel group as a proxy for the possibility of control, which we term “rebel presence.” All variables included in the selection equation are also included in the outcome equation except for the portion of water in a grid as this variable theoretically impact where rebels choose to operate but not their desire to establish control (except through its impact on rebel presence). While we view a selection model as the appropriate test for our hypothesis, we also show that our results hold when run on the full sample.

Third, our dependent variable measures observable control but our theory focuses on rebel desire for (or effort directed toward) control. To get a less-biased estimate of rebel effort, we need to remove the effect of variables that prevent rebel desire for control from translating into control. Following existing work on territorial control (Kalyvas, 2006), we view observed control as determined by a combination of rebel desire for control, rebel power projection, state interest, and state power projection. Rebels may establish control despite low desire when they have high relative ability to project power. Similarly, high desire may not lead to observed control when relative ability to project power is low. To account for this, we include in our statistical analysis variables that represent state and rebel ability to project power in a location. The remaining variables in the equation—specifically our main variables capturing the value of natural resources—are then left to explain remaining variation in observed rebel control. This remaining variation is rebel desire for control. By including these additional variables, we can align our statistical tests with our theory and hypotheses. Below, we discuss how our data is assembled, the statistical models we use, and the variables that we include in our equations.

Data

The unit of analysis is the dyad-grid-month. This means that each observation records information about a month in a PRIO-GRID in an ongoing UCDP internal armed conflict. Because we use UCDP dyads, we are only looking at control by rebel groups fighting the state although we do include variables capturing control by all other actors (non-rebel groups and states) in the dyad. The dataset covers 91 state-rebel dyads in 18 countries between 1989 and 2013. The countries in our dataset are Angola, Burundi, Central African Republic, Chad, Comoros, Congo, Djibouti, Eritrea, Ethiopia, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Rwanda, Sierra Leone, Somalia, Sudan, and Uganda. As we note, this results in a full panel dataset of 1,061,483 observations used for statistical analysis.

Dependent Variable: Rebel Control

The information on territorial control is based on point data recording the time, location, and description of an armed conflict event (Sundberg & Melander, 2013). Although point data has the advantage of being very fine-grained, measurement error in the underlying point data can propagate and the hexagonal grids used to identify control are large in number. This makes statistical computation a challenge. To address this, we aggregate control and resource locations to PRIO grid-cells (Tollefsen, Strand, & Buhaug, 2012), which we hereafter refer to as a "grid" or a "grid-cell." Each grid, 259,200 of which cover the entire globe, is a 0.5 x 0.5 decimal degree square that encompasses approximately 3,000 square kilometers. This spatial unit is still sufficiently small to capture the substantial variation in control and resources locations in a conflict but sufficiently large to minimize problems of measurement error and computational load.

For each hex in the initial control data we identify the single actor who has control and carry this value forward until another actor in the hex establishes control or the current actor loses control. This is done by first transforming the hex control data into a continuous time series before filling in missing control values. A value if "full" is set if only one actor has control in a hex at a time, "partial" if more than one actor has control at a time, and "none" if no control was ever established, control was lost, or if another actor established full control.

Control hexes were than aggregated to the dyad-grid-month. Three variables were created during aggregation: the portion (or "extent") of a grid-cell controlled by the rebel, the portion controlled by the state, and the portion controlled by other non-state actors that are not part of the current dyad. In our analysis, we combine control by the state and control by other rebel groups into a single "other control" variable. Each type of control ranges from 0% indicating no portion of the grid is controlled to 100% indicating complete control of a grid by the rebel, state, or other actors. When multiple actors had partial control in a grid this was normalized so that the sum of all control values in a grid did not exceed 100%. For example, if the same two actors had partial control in all hexes in a grid, the control value for both actors would be 50%.

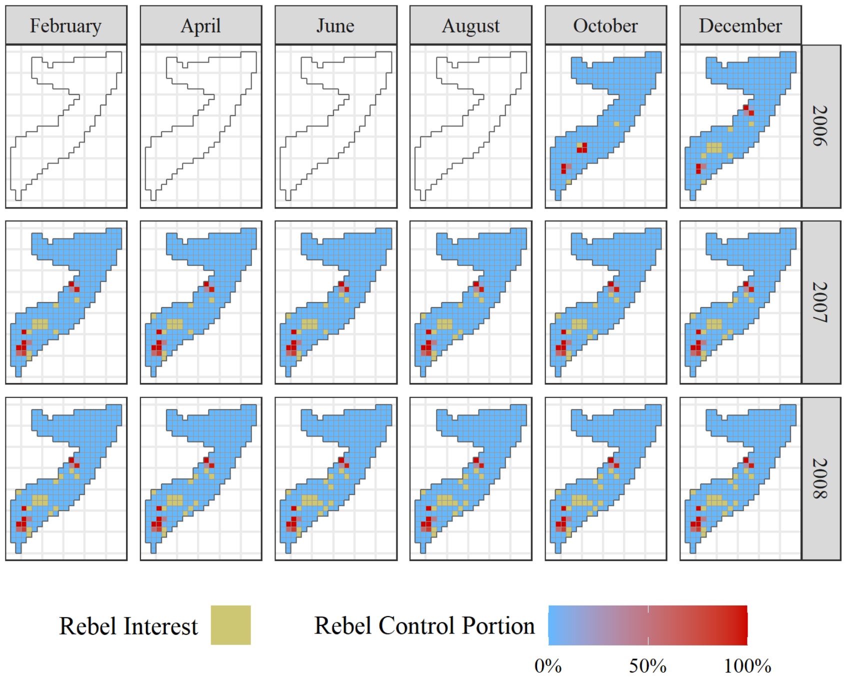
Selection Variable: Rebel Presence

To identify grid-cells where it was possible to observe rebel control, we rely on the occurrence of conflict of any type. Conflict includes state-rebel violence, rebel one-sided violence, and rebel-non-state fighting—essentially any type of observable indicator that a rebel was present in a location. The occurrence of conflict, of course, is not a perfect proxy. It is possible, for example, for rebels to be present in a location without violence being observed. This may occur in two situations. First, when rebel presence is light, insurgents may avoid detection by the state and leave a location before fighting occurs. Second, rebels can operate in locations contained behind a de factor front line. In both cases, identifying presence based on polygonal as opposed to point data may help as locations between areas of rebel operation (e.g., supply lines or bases) are also recorded as having presence. A future iteration of this paper will include additional methods for measuring rebel presence based on conflict polygons to determine if our results are sensitive to the proxy used (Kikuta, 2020).

The 2020 version of the UCDP GED dataset was used to record the location of violence (Pettersson & Öberg, 2020). All observations in a grid in a dyad during and after the first month that violence occurred involving the rebel are given a value of "1" while all other observations are given a value of "0." This means that a grid that never experienced any type of violence is given a value of "0" for all dyad-months. A grid that did experience violence is given a value of "0" for all months prior to the first occurrence of violence and a "1" for all months during and after the first occurrence of violence. In total, rebels are present in 94,754 dyad-grid-months (9%). By comparison, rebels have some level of control in 35,049 dyad-grid-months (3.3%), which is about 1/3rd of the observations for which control is possible.

To get a sense of what presence and control look like in a conflict, we present a map of one dyad in our dataset: Somalia vs. the Islamic Courts Union from October 2006 to December 2008 (see figure 1). Light blue grid-cells indicate no rebel control (these areas may be controlled by the state or by another rebel group). Dark yellow grid-cells indicate observations where control could be observed based on the occurrence of violence. Red cells indicate grids with some degree of rebel control. The darker the red, the more of the grid that is under the control of the Islamic Courts Union. As we see, throughout the conflict there is substantial variation in both presence and control.

Figure 1. Islamic Courts Union Presence and Control in Conflict with Somalia



Independent Variable: Natural Resource Value

The main independent variable is the value of lootable and non-lootable natural resources in a grid-month (Denly, Findley, Hall, Stravers, & Walsh, 2019). To create this variable, we separately identified the maximum value of lootable and non-lootable resources in a grid-cell.[4] The value of a resource is based on the total production of that resource in a location multiplied by the local market value. The data pool the different resource types and use relevant multipliers to compute comparable values, such that we can understand better the overall value of resources in a given location.

[4] Grid cells are small enough that they tend to only have one resource of value. We also created a variable that sums the total value of all lootable and non-lootable resources in a grid cell. The two variables were highly collinear (correlation > 0.99), which means that the choice between these two operationalizations of resource value does not matter.

Control Variables

Additional control variables are brought in from the most recent version of the PRIO-GRID dataset (Tollefsen, Strand, & Buhaug, 2012) and are joined by grid-year. Since the PRIO-GRID dataset measures variables at the yearly level this means that observations at the grid-month level actually reflect values for that year. We additionally include variables recording ethnic recruitment (the provision of manpower) and ethnic support (whether more than 50% of an ethnic group backed a combatant) for the state and for the rebel. Our cases include no situations where the state received ethnic recruitment or support. This data was drawn from the Geo-EPR and the ACD2EPR datasets, which record the location and characteristics of ethnic groups and their relation to combatants in internal conflicts (Vogt, et al., 2015). As with other data, this variable is joined to our main dataset by grid-month.

Statistical Models

To test our hypotheses, we run a Heckman selectin model (Heckman, 1979). This process is composed of two steps. The first, selection, step is used to identify the causes of selection into grids where rebel control is possible (i.e., grids with rebel presence). A probit model is used, which allows generation of the inverse-mills ratio, which is included as a variable to correct for selection bias in the second, outcome, step. The outcome model identifies the correlates of rebel control in a subsample of our full data where non-zero rebel control in a grid is a potential outcome.

We specify the second outcome model as a mixed effects linear regression. The simplified equation for this model is as follows:

$$
\begin{aligned}
Y_{i,t} = \beta_0 + \beta_1\left(Lootable_{i,t-1} + Nonlootable_{i,t-1}\right) \\
+ \beta_2\left(Ethnic\ Recruits_{i,t-1} + Ethnic\ Support_{i,t-1}\right) + \beta_3 IMR_{i,t-1} + u_i \\
+ \delta_i\left(Lootable_{i,t-1} + Nonlootable_{i,t-1}\right) + \beta Z_{i,t} + e_{i,t}
\end{aligned}
$$

Here, $Y_{i,t}$ is rebel control in dyad-cell i and month t. The outcome variable is a continuous value between zero and one. The model also includes an intercept by dyad-cell β_0 and a random intercept by dyad-cell u_i. The coefficients β_1 identifies the effect of lootable and non-lootable resource value. The coefficients β_2 identifies the effect of co-ethnic support, which is an alternative explanation for control that may also function as a confounding variable. The coefficient β_4 identifies the presence of selection effects. A significant non-zero value indicates that selection effects are present. The vector $Z_{i,t}$ and β are a set of control variables and a corresponding set of coefficients. Specifically, we include variables capturing state and rebel power projection (a combination of grid accessibility, proximity to state forces, and state interest) in a dyad-cell. Random slopes for lootable and non-lootable resources by dyad-cell, u_t, are also included. Finally, the error term is captured by $e_{i,t}$. All independent variables are lagged by one month and those with skewed distributions are logged to increase normality.

As noted above, β, captures the effect of variables affecting state and rebel power projection as well as state interest. To measure state and rebel power projection we include variables recording the extent of urban area in a grid, the extent of harsh terrain in a cell (a combination of forest and mountain cover), the distance from a cell to the nearest urban center, the distance from a grid to the nearest border, and neighboring control by the rebel and actors other than the rebel. Each of these variables affect the ability of state and rebel forces to operate and fight effectively in a grid-cell. To measure state interest, we include variables recording the prior number of state-initiated attacks and prior control by actors other than the rebel.[5]

[5] We do *not* include prior rebel control as there is significant serial correlation which limits the ability of the statistical models to identify the effect of other variables. The impact of lootable resources, however, is still positive and significant when we include a dummy for prior rebel control (coefficient = 0.015, P-value < 0.001).

While these included variables also address the effect of observed confounding—i.e., variables that correlate with both the value of natural resources and the extent of rebel control in a cell—they do not address the problem of unobserved confounding. We account for unobserved confounding through use of random intercepts by dyad-cell u_i and random slopes for lootable/non-lootable resources also by dyad-cell δ_i. These random effects address unobserved between-subjects (dyad-cells) variance. For example, rebels may differ in their ability to establish control or profit from natural resources in unobserved ways.

The dyad-cell was chosen as the unit on which to introduce a random intercept and slope (as well as the unit on for which clustered standard errors were produced) because our research design randomly samples dyad-cells. We include random intercepts and slopes because we think of our set of dyad-cells as being randomly sampled from a larger population. We are not interested in the effect of resources for our set of dyad-cells per se, but rather the "fixed" effect of other variables (specifically the value of natural resources) across any potential case. Use of random effects, in other words, allows us to make general claims about the impact of natural resources (see Yarkoni 2019). Random effects are also more efficient than fixed effects by dyad-cell but are not necessarily unbiased. To address this concern, we re-estimate our main models in a robustness check by using dyad-cell fixed effects with standard errors clustered by dyad-cell.[6] Our results are unchanged. For this reason, we rely on the model with random effects as it demonstrates no increase in bias, is more efficient, and theoretically aligns more closely to our research goal.

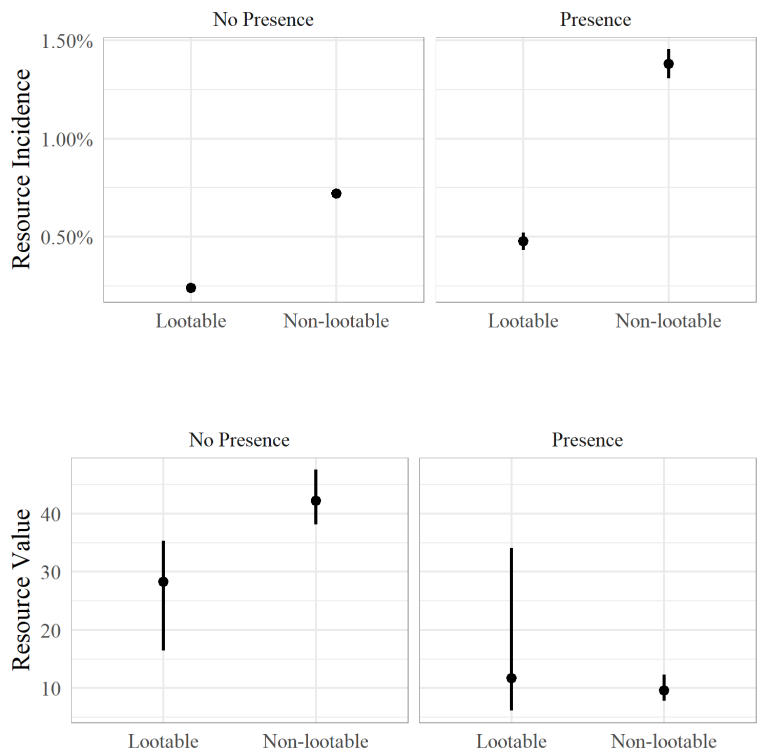
[6] Our results are also robust to standard errors clustered by grid-cell with fixed effects by dyad. The standard errors are smaller than when we cluster by dyad suggesting that our estimate is more appropriately conservative.

Results: Natural Resources and Rebel Presence

We begin our analysis by examining Hypothesis 1: the comparison of natural resources across areas where control is possible and areas where control is not possible (again, as measured by the first presence of violence involving the rebel). The main concern is that the occurrence and value of natural resources in areas where rebels can contest for control are systematically different than in areas where a rebel cannot contest. If this is true, then our sample of natural resources in areas of potential rebel control is non-random. As we show below, we find reason to believe that this is the case; lootable and non-lootable resources in areas of rebel presence are more common but also of much less value. This motivates our use of a selection model.

Across areas with and without potential rebel control, as measured by the first occurrence of violence involving the rebel, both the incidence and value of natural resources vary substantially. Figure 2 shows the incidence of lootable and non-lootable resources across rebel presence (top row) and the value of lootable and non-lootable resources across rebel presence (bottom row).

Figure 2. The Incidence and Value of Natural Resources Across Rebel Presence

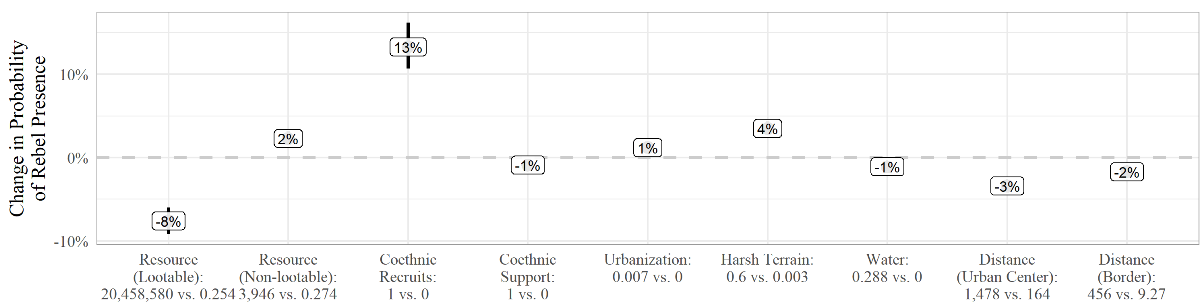


We see that natural resources have a higher incidence in areas of rebel "presence" (the top right panel). This higher incidence occurs for both lootable and non-lootable resources. In areas with no presence, for example, lootable resources occur in about 0.25% of observations. By comparison, lootable resources occur in about 0.5% of observations in areas where rebels have presence and the possibility of exercising control—an incidence twice as large. However, when we examine the value of the lootable resources we see the opposite trend. In areas where rebels may be present, we see that median values of natural resource are, on average, much smaller (bottom right panel compared to bottom left panel). Median value drops from a value of 30 (indicating a value of $30 million for the lootable resource in the grid) to a value of 12. In sum, while lootable resources are about twice as frequent in areas where rebels can be present their median value drops by more than half. The pattern is similar for non-lootable resources.

Rebels, in other words, select into areas with more plentiful but less valuable resources. This might reflect strategic activity on the part of both the state and the rebel. Knowing the value of resources, states use their capability to deter rebel operations in areas that hold particularly valuable mineral deposits or gem mines. As a result, rebels do not try contest these locations and we observe no violence. Amongst available remaining areas, however, rebels are more likely to operate in grid-cells where resources—both lootable and non-lootable—are present. Another possibility is that more valuable resources are also more difficult to profit from—industrial diamond mines or oil fields, for example, may contain a lot of wealth but they are also hard to secure and the resources contained within are hard to extract, transport, and sell. Consequently, rebels choose to move into areas with resources, while less valuable, are possible to profit from.

Due to this initial investigation and our theoretical concern about the possibility of selection effects, we analyze the causes of rebel presence (the selection equation in our two-stage Heckman correction). This analysis allows us to produce the inverse mills ratio (IMR) used for the second outcome stage of the Heckman correction. We discuss the result of the outcome equation, which is a direct test of our main hypotheses, in the next section. Figure 3 below shows the results of our statistical model regressing rebel "presence" on our independent variables, including the value of natural resources. The effect of lagged and neighboring territorial control is not shown as they are treated as nuisance terms. The X-axis lists each variable and the change in the variable for which an effect is estimated while the Y-axis shows the impact of moving from the 5th to the 95th percentile of variable values on the probability of observing rebel presence in a grid. All other variables are held at their means.[7] A positive number means that the chance of rebel presence in a grid goes up when the variable increases in value while a negative number means the reverse. These results represent a change in absolute probabilities. So, in the case of co-ethnic recruits this represents a move from a 3.6% chance of rebel presence to a 17% chance of rebel presence, which gets rounded to a 13 percentage-point increase.

Figure 3. Predictors of the Occurrence of Rebel Presence



Because we assess a change in quantile values, the effects are comparable across variables, i.e., we are comparing a move from a low to a high value of variable based on the observed data distribution of that variable. Across the board, most factors have an impact, but individual effect sizes are modest. Altogether, the model has a pseudo-R2 (McFadden's) of 0.33, which suggests that the model does a reasonable job of explaining variation in rebel presence. Of the variables that have an effect, the presence of co-ethnic recruits has the largest impact followed by harsh terrain and lootable resources (in this last case the effect is negative). The significant negative impact of lootable resources provides evidence in support of H1. We will see that once our statistical model

[7] Although an observed values approach is ideal for generating predictions (Hanmer & Kalkan 2013), the size of the dataset prevented use of an observed values approach.

accounts for selection into locations with the potential for non-zero rebel control, a number of these variables have an impact on opposite to their effect on rebel presence.

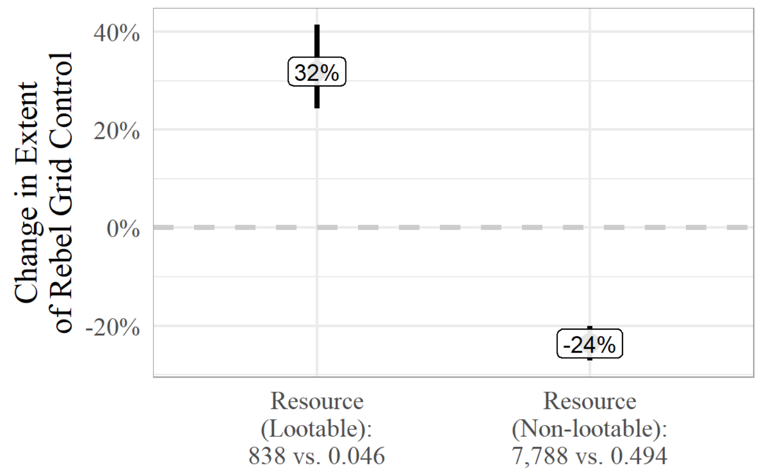
Results: Natural Resources and Territorial Control

Below, we present the results of our outcome equation, which corresponds to Hypothesis 2. As a refresher, we use a mixed effects linear model subset to only observations with rebel presence (as measured by violence involving the rebel) and an extra variable—the inverse mills ratio—that corrects for bias due to observing our variables only for areas with rebel presence. We start by presenting these results and discussing their implications for our theory. We next turn to presenting a set of robustness tests demonstrating that our main results still hold.

Resource Value and the Extent of Rebel Territorial Control

The graph below (figure 4) shows the impact of the value of lootable and non-lootable resources on the extent of rebel control in a grid-month using the observed values approach to produce predictions. As with the results for selection into rebel presence, this graph shows the effect of moving from a low- to a high-value of a lootable or non-lootable resource. Specifically, the effect of moving from the 5^{th} percentile to the 95^{th} percentile. The Y-axis shows the change in the portion of a grid-cell controlled. The point-label shows the median value while the error bar shows the 95% confidence interval.

Figure 4. Predictors of the Extent of Rebel Control



The increase of 32 percentage-points associated with moving from low- to high-value lootable resources means that a rebel controls about 1/3rd more of a grid-cell (from 23.6% to 55.5% control when all other variables are held at their observed values). The confidence interval is far from zero indicating that the effect is statistically significant at conventional levels (p-value < 0.001). This impact is also substantively large since the mean value of rebel control in areas where rebels can establish control is 27% of a grid-cell. By comparison, a rebel is expected to control 24 percentage-points less of a grid-cell when valuable non-lootable resources are present (in this case, from 24% to 0% when all other variables are held at their observed values).

This result provides strong support for Hypothesis 2. Grid-cells with more valuable lootable (but not non-lootable) resources lead to more extensive rebel control. Our model has a marginal R-squared of 0.417 (Nakagawa, Johnson, & Schielzeth, 2017), which means that the fixed effects portion of our model explains a large portion of the variation in observed control in areas with rebel presence. This finding suggests that the presence of lootable resource and the absence of non-lootable resources is one of the main drivers of where rebels seek to establish control through violence (attacking or defending).

Because we acknowledge that our selection equation is imperfect, we also run our main model using the full sample. Table 1 below shows the coefficients for our main model that accounts for selection into areas of rebel presence (1), the main model in areas of rebel presence but without the correction for selection effects (2), and our main model run on the full sample. As before, these results are based on using a linear mixed effect model with a random intercept and a random slope for lootable/non-lootable resources by dyad.

Table 1. Main Model Coefficients

	Main Model (1)	Main Model (No correction) (2)	Main Model (Full Sample) (3)
Lootable Resources	0.041*** (0.022, 0.061)	-0.018 (-0.054, 0.019)	0.005** (0.000, 0.009)
Non-lootable Resources	-0.024*** (-0.041, -0.008)	-0.020*** (-0.034, -0.006)	-0.002*** (-0.003, -0.001)
(Inverse Mills Ratio)	-0.553*** (-0.952, -0.155)		

Note: Significance Level (95% CI in parentheses): * p < .1, ** p < .05, *** p < .01. The model also includes control variables: other parties' control, state-initiated attacks, urbanization, harsh terrain, distance to an urban center, distance to a border, neighboring lootable resources, neighboring non-lootable resources, neighboring rebels' control, and neighboring other parties' control.

Predictions produced from model (1) are shown in the previous figure. Briefly, lootable resources increase the extent of control while non-lootable resources reduce it. Both effects are conventionally significant. In addition, the inverse mills ratio is significant suggesting that selection effects are present. Compared to our main model (1), the effect of lootable resources is not significant when we fail to correct for the possibility that natural resources (and other factors) differ systematically in areas with and without rebel presence (2). The effect of non-lootable resources remains significant and negative. As we believe the evidence suggests that this model is misspecified this finding is not unexpected and does not provide evidence counter to H2.

Finally, model (3) shows the results of our analysis run on the full sample of all grid-cells in the dyads for which we have data. The direction and significance of the resource variables, however, but not their magnitude matches that of model (1). More valuable lootable resources increase observed rebel control while more valuable non-lootable resources decrease it. Both effects are significant at conventional levels (p-value < 0.05). The smaller coefficient value makes sense given that many observations never have the possibility of control, average control is much lower, and the average value of lootable resources much higher. For example, average control in the full sample is just 2% compared to 27% in the subsample. We take these results as demonstrating that our results are robust to use and non-use of the two-stage Heckman sample correction and as additional evidence in favor of Hypothesis 2. Using the full sample biases our effect estimates downward but does not undermine their statistical significance.

Robustness Tests

We also present coefficient estimates for a small selection of robustness tests in Table 2. Model (1) shows our main model run with fixed effects by dyad instead of random intercepts and slopes. Model (2) reruns the fixed effect model but uses logit instead of ordinary least squares. Finally, model (3) reruns the fixed effects specification on the entire sample. Our main expectation is that model (1) will generate coefficients very similar in size and significance to our main model presented in the previous table. We also expect that valuable lootable resources predict control of any level (2), although our theory is about the extent of control and not just its presence so this model is not a direct test of our hypothesis.

Table 2: Coefficient Tables for Different Model Specifications

	Fixed Effects (Selection) (1)	Logit + FE (Selection) (2)	Fixed Effects (Full Sample) (3)
Lootable Resources	0.041*** (0.018, 0.063)	0.516* (-0.061, 1.093)	0.001 (0.000, 0.003)
Non-lootable Resources	-0.020** (-0.035, -0.005)	-0.103 (-0.395, 0.190)	-0.001 (-0.004, 0.001)
(Inverse Mills Ratio)	-0.624*** (-1.027, -0.222)		

Note: Significance Level (95% CI in parentheses): * p < .1, ** p < .05, *** p < .01. The model also includes control variables: other parties' control, state-initiated attacks, urbanization, harsh terrain, distance to an urban center, distance to a border, neighboring lootable resources, neighboring non-lootable resources, neighboring rebels' control, and neighboring other parties' control.

Per our expectation, the fixed effects model (1) is nearly identical to our main model. The estimated impact and confidence interval for lootable and non-lootable resources is identical as is the level of statistical significance. This provides evidence that use of random effects is unbiased and thus appropriate. In addition, the logit model with fixed effects (2) shows that lootable but not non-lootable resources have an impact on the occurrence of rebel control. The effect of lootable resources, however, is only modestly significant (p-value < 0.1). This finding provides evidence that the extent of control matters—when valuable natural resources are present, rebels seek to establish a large control area that enables these resources to be efficiently extracted, transported, and sold. Such a production chain is not possible when territorial control is small in area as there is no buffer from state interference provided.

Finally, the coefficient for the value of natural resources—both lootable and non-lootable—is not significant in the full sample run using fixed effects. Although the direction of the coefficient for lootable resource value is positive and the lower bound dips just slightly below zero (the confidence interval ranges from -0.0004 to 0.003), the effect is not quite significant at conventional levels (p-value = 0.116). This is not unexpected given that fixed effects are less efficient than random effects and we have theoretic reason to believe that using the full sample biases our coefficient estimate downward. We take this as neither confirming nor disconfirming Hypothesis 2.

Overall, these additional robustness tests do not undermine our core finding: the presence of more valuable lootable natural resources in grid-cells where rebels can establish control leads to a greater extent of rebel territorial control. On the whole, then, our statistical analysis provides strong evidence in favor of Hypothesis 2 as well as the idea that natural resources play an important role in determining where rebels seek to establish territorial control.

Conclusion

In this paper, we considered determinants of territorial control during civil war with an emphasis on rebel need to access natural resources, because of the benefits they confer. Although the topic of territorial control has become central in the violent armed conflict literature (and well beyond for that matter), control has been treated primarily as an independent variable. In this study, we reversed this and showed that natural resource wealth in fact motivates groups to control territory. Specifically, rebel groups seek to control larger shares of territory when *lootable* natural resources are present, and rebel group presence is possible.

Our point of departure was the conventional wisdom that rebels seek to control territory in order to benefit from natural resource wealth, but we developed additional theoretical insights, especially as relates to differential incentives of governments and rebels. The larger contribution of the study comes from our investigation of the theoretical claims through two new data sets – on territorial control and natural resources – that are far more extensive than any of their kind. The territorial control data use a sophisticated hybrid transportation network approach based on newly coded data of armed conflicts across Sub-Saharan Africa. The natural resource data are based on extensive USGS reports and in have an order of magnitude more observations than any other data set, and they include not only world price information but also local price. The results of our analyses support our claims about rebel control of lootable resources.

The paper has implications for the broader literature in a number of ways. Perhaps the greatest contribution is that we offer both an argument and analysis for why territorial control patterns emerge and evolve as they do. Existing studies that treat territorial control as an independent variable largely take the control zones as given and then explore the resulting patterns of violence. Here, we have moved the analysis back a critical step to explain emergence and evolution, which in turn has implications for violence. A next key step will be for future research to complete the explanation by bringing together both directions into a coherent story.

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Appendix

A. Measuring Territorial Control

A.1 Existing Approaches

While territorial control is central to theories of civil conflict, we lack an approach to measuring control that is transparent, can be applied across conflicts and time, and identifies locations where both government and rebel forces are capable of exerting control. The Non-State Actor dataset (Cunningham, Gleditsch, & Salehyan, 2009) includes a binary variable measuring whether a rebel group controls territory or not during a conflict, but does not identify the location or degree of control or vary over time. Other approaches address these issues by using conflict events to identify locations controlled by government and rebel forces. This has the advantage of allowing spatial and temporal variation. The Carter Centers Syria Conflict Mapping Project, for example, uses open sources of information to map over 70,000 conflict events in the country from 2012 onwards to identify areas controlled by government and rebel forces.[8] However, it does not seek to identify different degrees of control by these actors, and does not appear to have published explicit guidelines that explain how different types of conflict events translate into control or its absence. Anders (2019) addresses the first of these difficulties. Building on the theory presented in (Kalyvas, 2006), she assumes that rebels employ more terrorist attacks in areas where they exert less control, and more conventional attacks where they exercise greater control. She treats control as a latent variable, and uses Kalyvas' (2006) theoretical insights to inform the measurement of control. This approach is promising, as it allows the creation of time-varying measures of control

[8] See "Support for Peace in Syria," Carter Center, available at https://www.cartercenter.org/peace/conflict_resolution/syria-conflict-resolution.html

with high levels of spatial resolution. However, it rests on theory that has not been systematically evaluated across multiple conflicts. The approach we take below differs in that we seek to measure directly which armed actor initiates violent events and controls the location where such events occur. Our approach requires the collection of these two variables, which is more costly and time-consuming. In future research, we plan to compare our data to the estimates produced in Anders (2019). Measures of control based on event data identify the location of conflict events. It seems plausible that if an actor controls a particular location, its ability to mount attacks and to defend territory extends beyond this point, and is influenced by transportation networks and terrain features that facilitate or hinder the movement of military forces. This possibility is not considered in approaches that use conflict events as their underlying data source.

Other measures of territorial control, such as those published by the Institute for the Study of War for a number of contemporary conflicts, rely on subject-matter experts to identify larger areas under the control of armed actors.[9] This approach is promising because experts can include a wide range of information in their measurement of control. It is often not clear, however, exactly what information and rules experts use rely on, or the degree to which this information and rules are applied in the same manner across conflicts or within conflicts over time. A related approach, employed for example in Kocher, Pepinsky, & Kalyvas (2011) and Rubin (2020) is to rely on intelligence reports generated by government military and police agencies concerning the extent of rebel presence and control across locations. This type of data can be assumed to be quite reliable, since government forces have strong incentives to carefully identify where and how the rebel forces they are fighting are located and how they operate. But by its nature, such data is available

[9] Available at http://www.understandingwar.org/map-room

only for specific conflicts, and access to the data depends on it being declassified or the willingness of the authorities to provide it to researchers.

A.2 Our Approach

To address these issues, we introduce an approach to measuring the degree and location of territorial control by combatants that is generalizable across conflicts, uses theory and new data to identify degrees of control and how conflict events create different degrees of control, identifies the degree to which control of a location extends into the surrounding area, and is reproducible and not reliant on subject matter expertise. Our starting point is the definition and conceptualization of territorial control introduced in Kalyvas (2006, pp. 210-212). "Control" is the degree to which an actor has a non-temporary armed presence sufficient to mount a credible defense of and/or counter the infiltration of enemy combatants in a location. Such control is often a necessary precondition for many other actions in that a combatant might undertake, including policing and governing the nearby population, providing social services, recruiting and training soldiers, and so on.

Following Kalyvas (2006), we conceptualize control as ordinal rather than dichotomous, meaning that combatants can exercise degrees of control over a location. At one extreme are zones of complete control, where the incumbent has demonstrated an ability to prevent an opposing combatant from maintaining an organized military presence. In zones of incomplete control, the incumbent can prevent the other from massing forces, but cannot completely stop their opponent from maintaining some armed presence nearby. Rebels can maintain clandestine cells in locations incompletely controlled by the government, but are constrained by the presence of government forces from operating openly. Both combatants are able to maintain an armed presence in zones of contested control. An example is when military and police forces patrol the location, but irregularly or only during the daytime, while rebels have a permanent if clandestine presence but do not mass their forces to confront government troops.

In many civil conflicts, not all locations are subject to complete or incomplete control by either combatant. Rebels may not operate or maintain permanent forces in large areas of the country, while the government may patrol episodically but choose not to keep military or police units in the location on a permanent basis. To account for this, we add three categories to the conceptualization in Kalyvas (2006). The first is areas of interest, where one combatant initiates an attack on enemy forces, but the target of this attack does not maintain a permanent presence in the location. An example would be a rebel attack on a military convoy in the countryside. The attack by the rebels indicates their presence and desire to drive out the government, while the fact that the government forces are transiting the location suggests they do not have the intention or ability to control the location. The second are unclear clashes, in which there is evidence that government and rebel forces engaged in armed conflict, but it is not clear which side initiated the combat or controls the location. The third category we add is uncontested sovereignty, meaning that there is no evidence from battle events that either combatant maintains forces in the location on a regular basis. One important implication of this last category is that we do not assume locations without conflict events are controlled by the government. Many approaches that rely on event data or subject matter experts to identify areas of control assume that locations without conflict events are under the full control of the government. The definition of control we employ means that a combatant has an armed presence in a location. We think it is more consistent with this definition, and likely a better reflection of actual conditions on the ground, to not assume that the absence of conflict events means that the government exercises full control over a location.

For this reason, we have created the category of "uncontested sovereignty" to indicate such locations.

Our approach to measuring territorial control relies on geo-coded event data that records information about battles between combatants. The onset and outcome of battles are the clearest indication that one, both, or neither combatant exercises some degree of control at a particular location at a point in time. Event data about battles identifies if a combatant is present, captures, or fends off the attack of an armed opponent. Our source of event data is the Uppsala Conflict Data Programs Georeferenced Event Data (GED), which uses information from media and other sources to identify the date, location, and combatants involved in battles (Sundberg & Melander, 2013). For each battle event, we located and coded from the original media reports four nominal variables. The first two variables indicate whether the battle event was initiated by the government (labeled Side A in the GED) or a rebel organization (Side B). These variables identify the presence and offensive intention of a combatant in a location. We name these variables *A Attack* and *B Attack*.

Each can take one of three values: 1 (indicating that the combatant in question initiated the battle), 0 (indicating that the combatant did not initiate), or 9 (for cases where the original source does not provide sufficient information to determine the initiator, but does record the presence of and conflict between both combatants at the location). Eight combinations of these two variables are logically possible. In practice, it is often the case that when one side initiates a battle, the other side does not. But it is possible for both sides to initiate (for example, if Side A immediately counter-attacks Side B, or if Side B intercepts Side A while it is moving towards Side B's location). The remaining two variables (*A Control* and *B Control*) measure if each combatant controlled the location after the conclusion of the battle. These variables can also take three values: 1 (the combatant controls the location), 0 (the combatant does not control the location), and 9 (the original source does not provide enough information to determine if the combatant controlled the location).

Table A.1: Categories of Territorial Control

Category	Description	Values
Side A Complete Control	Side B initiates attack; Side A controls location after battle.	A Attack = 0 B Attack = 1 or 9 A Control = 1 B Control = 0
Side A Incomplete Control	Side A initiates attack, or it is unclear which combatant initiated attack, and Side A controls location after battle.	A Attack = 1 B Attack = 0 or 9 A Control = 1 B Control = 0 or 9
Side A Area of Interest	Side A initiates attack, neither side controls location.	A Attack = 1 B Attack = 0 or 9 A Control = 0 or 9 B Control = 0 or 9
Contested control	Both sides control a location	A Attack = 0, 1, or 9 B Attack = 0, 1, or 9 A Control = 1 B Control = 1
Side B area of interest	Side B initiates attack, neither side controls location.	A Attack = 0 or 9 B Attack = 1 A Control = 0 or 9 B Control = 0 or 9
Side B incomplete control	Side B initiates attack, or it is unclear which combatant initiated attack, and Side B controls location after battle.	A Attack = 0 or 9 B Attack = 1 A Control = 0 or 9 B Control = 1
Side B complete control	Side A initiates attack; Side B controls location after battle.	A Attack = 1 B Attack = 0 or 9 A Control = 0 B Control = 1
Unclear clashes	Any battle that does not fit into another category, such as attacks initiated by both sides	
Uncontested sovereignty	Locations without battle events	

The values of these variables are then jointly used to identify which category of territorial control best characterizes the battle location (see Table A.1). One combatant exercises complete control when it controls the location after a battle initiated by its opponent. This indicates that the initiator intended to but was unable to seize the location, leaving the defender in control. A combatant exercises incomplete control when it initiates the battle and controls the location at its termination. This combination might suggest that the initiator exercises complete control. In our judgment, incomplete control is a more accurate description of this situation. The fact that the incumbent initiates the attack indicates it is aware of the presence of sufficient enemy forces nearby to constitute a threat to its efforts to control a location. A combatant has an interest in a location when it initiates a battle, but neither side establishes control. This indicates that the initiator has an armed presence in or near the location and has the intention but not the capability to drive out its opponent. Contested control occurs when both actors are able to establish control of a location. This occurs when, for example, both combatants are able to seize control of, and maintain forces in, different parts of an urban neighborhood. Unclear clashes are a residual category; it includes locations in which battles occur but where the values of the combination of the attack and control variables are not those listed for elsewhere in Table A.1. All remaining territory is then classified as uncontested sovereignty.

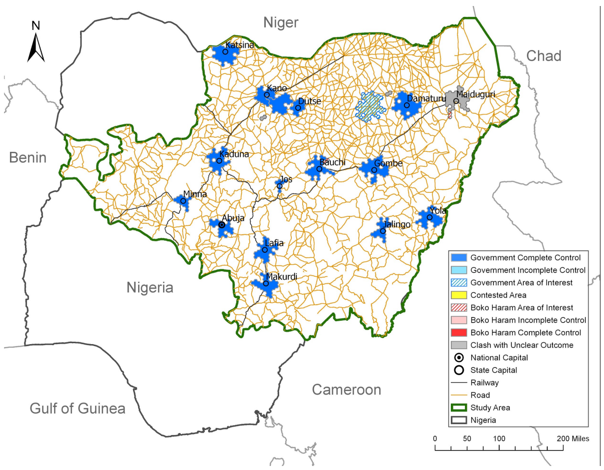
The onset and outcome of battles are an important, but imperfect, tool for identifying locations controlled by combatants. Combatants can exercise some degree of control of a location without engaging in battles with other armed actors. For example, a combatant may maintain military forces in a location where battles do not occur. Battles might be absent either because the opposing side has no interest in attacking or seizing the location, or because the fixed presence of opposing forces deters them from launching attacks. Addressing this possibility requires information on the positioning of government and rebel forces, which is typically difficult to obtain. Media reports are unlikely to systematically detail the location of forces that are not engaged in warfare. Combatants also have obvious incentives to conceal the location of some of their forces from the enemy. In the analysis below, we assume that major towns (specifically, the national capital and the capitals of first order administrative districts) are under the complete control of the government unless battle events indicate that this is not the case. Forms of violence other than battles between combatants also indicate the presence of a combatant in a location, and might also provide information on the degree to which a combatant exercises control. For example, attacks on civilians means a combatant is present, and additional information (such as the conduct of search-and-destroy missions, or detaining large numbers of civilians) could indicate the capacity to defend the location from attack.

This approach allows us to identify the degree to which each combatant exercises control over a specific location, which we measure with latitude and longitude. A combatant's control of a location includes the geographic region which its forces can reach and take action within a certain response or reaction time. We account for this using the process described in Tao et al. (2016). To identify the extent to which territorial control radiates out from a point of control, we construct a hybrid transportation network using information about road and rail networks and topographical features. Standard speeds are assumed for movements on these modal infrastructures and for off-road movement. The completeness of transportation infrastructure network datasets is uncertain. Thus, off-network movement is simulated by assuming a dense network of artificial roads laid-out on a fine-mesh hexagonal grid. The speed of off-network movements is taken to be a function of slope and land cover. The resulting hybrid network, formed of these real and artificial links, is used to calculate drive times and ultimately delineate travel-time based service areas. For the present analysis, we define control territories on the basis of a one-hour drive time. Maximum speed is taken to be 35 km/h. We have developed and released software that allows other researchers to model territorial control once they have collected data for the two attack and two control variables described above. This software includes relevant shapefiles, road and rail network data, and the hexagonal grid used to create the artificial road network.[10]

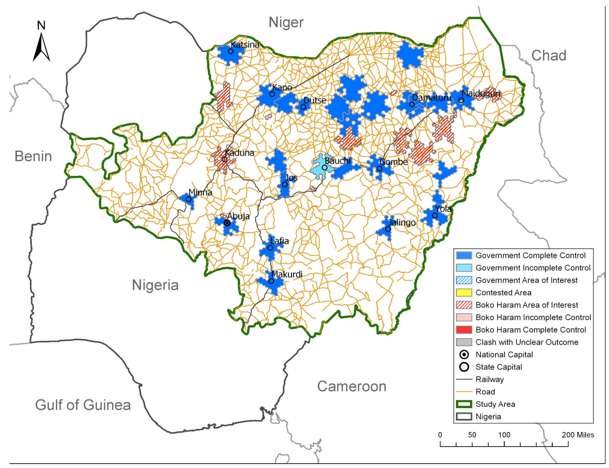
To this point, we have considered only the spatial delineation of combatants control of locations. Our measurement of territorial control also accounts for temporal variation. A territory generated by the process above many experience subsequent battle events. In such cases, we replace the parts of the previous territory with the territory generated by the subsequent battle. Other locations may experience only one battle event. We assume that the combatant retains control of this location until the end of our study period.

[10] The software is a plugin for the QGIS geospatial information system package. See Ran Tao, "TerrCtrl," version 0.1, July 21, 2020, available at https://plugins.qgis.org/plugins/territorial_control/

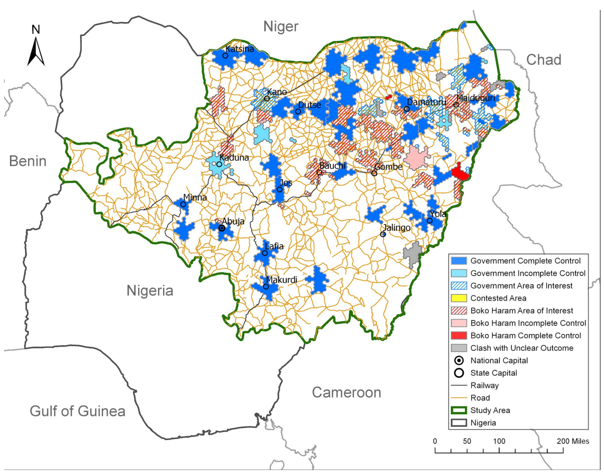
Figure A.1. Territorial Control in Boko Haram Conflict



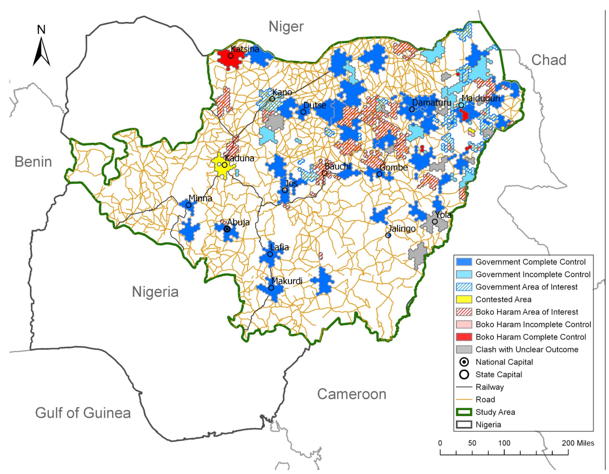
2009



2011

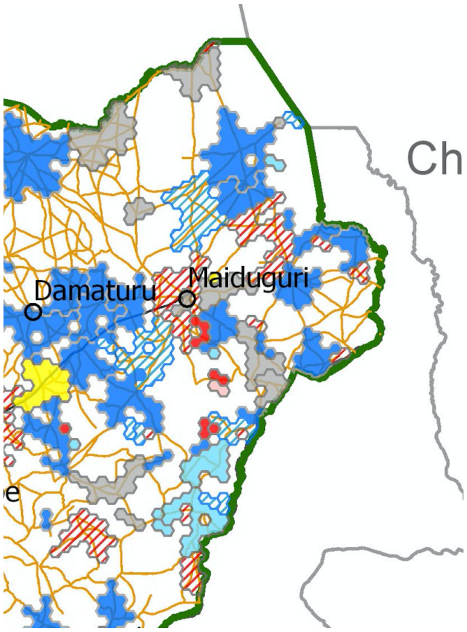


2013



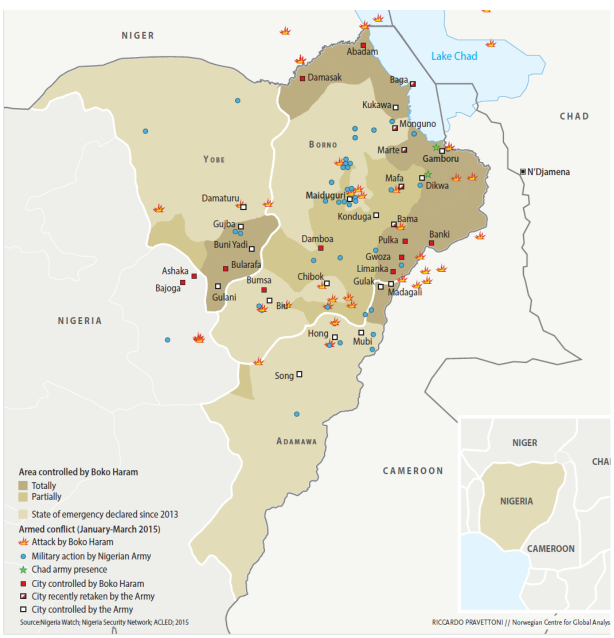
2015

Figure A.2. Comparisons of Measurements of Territorial Control



31 December 2015

23 February 2015[1]



17 March 2015[1]

A.3 Face Validity

The maps in Figure A.1 illustrate our data. These maps depict territorial control by Nigerian government forces and Boko Haram rebels in northeastern Nigeria on the last day of every other year from 2009 to 2015. The GED records 696 battles between government forces and Boko Haram during this period. The zones of complete government control are state capitals, which our approach assumes are under government control unless challenged by rebel forces. We see that by late 2009, Boko Haram hit-and-run attacks in and near the city of Maiduguri, the capital of Borno state, changed its status to "clash with unclear outcome". By the end of 2011, further Boko Haram attacks lead our approach to classify the city as an area of interest for the rebels, and in subsequent years the government would reinforce the area, fight off rebel attacks, and reestablish control over the city. A number of other areas become Boko Haram areas of interest by the end of 2012, and by December 2013 the group has established complete and incomplete control in the far north and east of the study area. Counterattacks by government forces during 2014 and early 2015 eliminate most of the areas fully and incompletely controlled by the rebel group. This pattern seems consistent with accounts of the conflict (citations).

Figure A.2 compares a map generated by our approach with two maps created by subject-matter experts that document the extent of rebel control in 2015. All three maps indicate that Boko Haram completely or incompletely controlled territory along Nigeria's northeastern border and west of Maiduguri. However, there are three important differences between the map generated using our data and those created by subject matter experts. First, the map we generate indicates areas of both government and rebel control, while the subject matter expert map at the bottom of Figure A.2 only indicates areas of rebel control. The experts' depictions suggest, perhaps unintentionally, that the government is capable of exerting control in areas without a rebel presence. Our approach, in contrast, recognizes that there may be areas where neither the government nor rebels have armed forces--areas of what we have termed uncontested sovereignty. This distinction is an important one because it has the potential to identify these areas that the government is capable of controlling, and also areas where both rebel and government forces could enter unimpeded by their opponents. Second, our approach produces more fine-grained depictions of government and rebel control. Some expert-drawn maps, such as the one on the right of Figure A.2, classify entire administrative districts as under varying degrees of combatant control. Our approach, in contrast, uses a smaller spatial area to depict control, and allows this control to radiate out from points where battles have occurred along roadways. This can produce quite different measures of control at the local level.

The third difference concerns transparency and reproducibility. Subject matter expert assessments of control are typically not transparent about how variables are measured or the underlying data that informs these measurements is collected or assessed. Our approach is more transparent, meaning that researchers can more clearly identify its suitability for their research questions, strengths and weaknesses, and improve on it. Our approach can also be reproduced, meaning that other researchers could take our measurement scheme and software to generate data on territorial control for other conflicts. Our approach shares these advantages with the latent variable approach for measuring territorial control described in (Anders 2019), and in future work we plan to compare these two approaches more systematically.

B Measuring Natural Resources

We draw on the Global Resources Dataset (GRD) to measure the value of natural resource wealth at the local level (Denly, Findley, Hall, Stravers, & Walsh, 2019). The GRD documents the spatial location (i.e. latitude and longitude) and values of individual natural resource extraction sites and production facilities over time. For each site or facility, the dataset records the resource, location, output, country-specific and global prices, as well as many other attributes. The GRD contains time-varying information from more than 70,000 natural resource locations in over 100 countries from 1994 to 2015 for 192 unique natural resources. These resources include not only ``natural'' resources such as diamonds, oil, and gold, but also downstream products such as petrochemicals, steel, and cement. Tin, copper, cobalt, uranium, iron ore, and phosphates encompass just some of the additional resources in the GRD.

The dataset is based on country reports of mineral industries produced by the National Minerals Information Center of the United States Geological Survey (USGS).[11] USGS experts who maintain links with their counterparts in industry and government agencies compile the respective country reports. Since USGS experts do not present the country reports in a way that facilitates spatial analysis, multiple coders read each of these reports and extracted the information into a machine-readable format. The USGS country reports most often simply give the name of the location or the city/general vicinity in which it is located. These location-years constitute the unit of analysis for the dataset. To code these location-years, we first recorded the facility or location name in the dataset. We then took this information and used Geonames, Google Maps, Mindat as well as other databases to identify the most precise longitude/latitude possible.

The GRD's inclusion of output for the above marks an advance over existing natural resource datasets, but researchers often want to estimate the value of such output, which requires price data. To respond to this need, the GRD provides up to three prices for each natural resource. The first price corresponds to the US price of the resource using data from the USGS (Matos,

[11] Available at https://www.usgs.gov/centers/nmic/international-minerals-statistics-and-information

2015). The second price corresponds to the world price, obtained from the World Bank Global Economic Monitor (World Bank, 2018) and, in some cases, Multicolour.[12] The third price corresponds to the country-specific export prices of each resource obtained from the UN Comtrade database (United Nations Statistics Division, 2018). Since the initial outputs units often do not match the initial price units, we created numerous multipliers so as to ensure congruence between outputs and prices.

The GRD also distinguishes resources based on if they are lootable or nonlootable. A lootable resource is defined as having high value and low barriers to entry (Snyder R. , 2005; Findley & Marineau, 2015). Although the GRD cannot classify lootability as precisely as Gilmore et al. (2005) do for diamonds, it does classify all 192 minerals in the dataset according to whether they could potentially have high values and low barriers to entry.

[12] Multicolour is a Hong Kong-based auction house that provides pricing information on many rare gemstones that are not available in other datasets.

C Coefficient Tables for Robustness Tests

This appendix presents two additional tables that show the coefficients for all variables in the statistical models that we use. Table C1 corresponds to the results presented in Table 2 of the manuscript while Table C2 corresponds to the results presented in Table 3 of the manuscript.

Table C1: Coefficient Tables for Main Model Specifications

	Main Model (1)	Main Model (No correction) (2)	Main Model (Full Sample) (3)
Main Variables			
Lootable Resources	0.041***	-0.018	0.005**
	(0.022, 0.061)	(-0.054, 0.019)	(0.000, 0.009)
Non-lootable Resources	-0.024***	-0.020***	-0.002***
	(-0.041, -0.008)	(-0.034, -0.006)	(-0.003, -0.001)
Alternative Explanations			
Co-ethnic Recruits	-0.387***	0.068***	0.015***
	(-0.650, -0.125)	(0.058, 0.078)	(0.014, 0.016)
Co-ethnic Support	0.109*	-0.076***	0.019***
	(-0.009, 0.228)	(-0.086, -0.065)	(0.017, 0.020)
State/Other Capabilities			
Other Control	-1.367***	-0.600***	-0.057***
	(-2.108, -0.627)	(-0.607, -0.592)	(-0.059, -0.055)
State-initiated Attacks	0.036***	0.031***	0.036***
	(0.026, 0.045)	(0.027, 0.036)	(0.034, 0.037)
Urbanization	-3.940*	2.505***	1.098***
	(-8.256, 0.376)	(1.985, 3.026)	(0.986, 1.209)
Harsh Terrain	-0.325**	0.085***	0.028***
	(-0.602, -0.048)	(0.071, 0.098)	(0.026, 0.030)
Distance to Urban Center	0.055***	0.007***	-0.007***
	(0.019, 0.090)	(0.003, 0.010)	(-0.008, -0.007)
Distance to Border	0.023***	0.008***	0.001***
	(0.006, 0.039)	(0.006, 0.009)	(0.000, 0.001)
Spatial Controls			
Lootable Resources (Neighbor)	-0.006	-0.001	0.000
	(-0.016, 0.004)	(-0.002, 0.001)	(0.000, 0.001)
Non-lootable Resources (Neighbor)	-0.017**	-0.003***	0.000**
	(-0.033, -0.001)	(-0.005, -0.001)	(-0.001, 0.000)
Rebel Control (Neighbor)	0.371	0.920***	0.286***
	(-0.084, 0.825)	(0.911, 0.929)	(0.284, 0.287)
Other Control (Neighbor)	0.067	0.286***	0.019***
	(-0.164, 0.299)	(0.276, 0.296)	(0.017, 0.020)
Other Terms			
(Inverse Mills Ratio)	-0.553***		
	(-0.952, -0.155)		
(Intercept)	0.972**	-0.016	0.033***
	(0.070, 1.873)	(-0.064, 0.032)	(0.025, 0.041)

Significance Level (95% CI in parentheses): * $p < .1$, ** $p < .05$, *** $p < .01$.

Table C2: Coefficient Tables for Robustness Tests

	Fixed Effects (Selection) (1)	Logit + FE (Selection) (2)	Fixed Effects (Full Sample) (3)
Main Variables			
Lootable Resources	0.041*** (0.018, 0.063)	0.516* (-0.061, 1.093)	0.001 (0.000, 0.003)
Non-lootable Resources	-0.020** (-0.035, -0.005)	-0.103 (-0.395, 0.190)	-0.001 (-0.004, 0.001)
Alternative Explanations			
Co-ethnic Recruits	-0.341** (-0.608, -0.075)	0.427 (-1.257, 2.110)	0.015*** (0.004, 0.026)
Co-ethnic Support	0.003 (-0.153, 0.160)	-0.155 (-1.893, 1.583)	0.019** (0.000, 0.037)
State/Other Capabilities			
Other Control	-1.536*** (-2.258, -0.815)	-1.569** (-2.898, -0.240)	-0.057** (-0.105, -0.008)
State-initiated Attacks	0.030*** (0.020, 0.039)	0.301*** (0.164, 0.438)	0.036*** (0.015, 0.056)
Urbanization	-4.854** (-8.695, -1.012)	55.235** (6.912, 103.558)	1.110 (-0.489, 2.708)
Harsh Terrain	-0.230** (-0.453, -0.007)	1.074 (-0.392, 2.540)	0.028* (-0.005, 0.060)
Distance to Urban Center	0.070*** (0.048, 0.091)	-0.097 (-0.519, 0.326)	-0.007 (-0.017, 0.003)
Distance to Border	0.022** (0.004, 0.041)	0.072 (-0.185, 0.329)	0.001 (-0.004, 0.005)
Spatial Controls			
Lootable Resources (Neighbor)	-0.004** (-0.007, 0.000)	0.048 (-0.056, 0.151)	0.000 (-0.001, 0.001)
Non-lootable Resources (Neighbor)	-0.017** (-0.031, -0.003)	0.024 (-0.342, 0.389)	0.000 (-0.001, 0.000)
Rebel Control (Neighbor)	0.050 (-0.392, 0.492)	8.215*** (6.546, 9.883)	0.286*** (0.102, 0.470)
Other Control (Neighbor)	-0.096 (-0.334, 0.141)	3.123*** (1.925, 4.320)	0.019*** (0.005, 0.033)
Other Terms			
(Inverse Mills Ratio)	-0.624*** (-1.027, -0.222)		
(Intercept)	1.211*** (0.354, 2.069)	-3.378** (-6.316, -0.440)	0.041 (-0.020, 0.102)

Significance Level (95% CI in parentheses): * p < .1, ** p < .05, *** p < .01.