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Mobile phone coverage and violent conflict[♣]

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Abstract

We examine the effects of mobile phone coverage on violent conflicts in Africa using a new monthly panel dataset on mobile phone coverage at 55x55km grid cell levels for 32 African countries covering the period from 2008 to 2018. The base rate of a conflict event in a month across our data set is 0.0039 with a standard deviation of 0.0620. We find that access to mobile phone coverage increases the probability of a conflict occurring in the next month by 0.0028. This finding is robust to a suite of sensitivity checks including the use of various specifications and alternative datasets. We examine heterogeneity on the impact of mobile phone coverage across state-based conflict, non-state-based conflict and one-sided conflict, and find that our results are being driven by non-state conflicts. We examine economic growth as a channel through which mobile phone coverage influences conflict. In doing so, we construct new satellite data for night-time light activity as a proxy for economic growth. We find that economic activity is a channel through which mobile phone coverage influences conflicts, and that higher economic growth weakens the positive effect of mobile phone coverage on conflict.

Keywords: mobile phones, cell phone coverage, violence, conflict, Africa

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1. Introduction

What is the effect of mobile phone coverage and use on violent conflict? Large literatures exist on the determinants of violent conflict and the impact of mobile phones for a range of economic outcomes. Some studies have started to examine the relationship between mobile phone use or communication technologies more generally and violent conflict (see, e.g., Pierskalla & Hollenbach, 2013; Warren, 2014; Dafoe & Lyall, 2015; Gohdes, 2015; Weidmann, 2015a, 2015b; Shapiro & Weidmann, 2015; Bailard, 2015; Absher & Grier, 2019). Yet, what we know about the relationship between mobile phone use and violent conflict is largely based on employing cross-sectional data or short panels. A major shortcoming is the lack of robust evidence on mobile phone use and violent conflict over longer periods. Another problem is that some of the studies on mobile phone use and violent conflict have used datasets that are not publicly available (e.g., Pierskalla & Hollenbach, 2013; Shapiro & Weidmann, 2015), impeding replication and further research. Additionally, we know very little about the mechanism that underpins the relationship between mobile phone coverage and conflict.

We examine the effects of mobile phone coverage on violent conflict in Africa using monthly panel data over the period from 2008 to 2018. We present the first study to employ longitudinal data to provide evidence on the relationship between mobile phone coverage and violent conflict over a decade. We construct a new panel on mobile phone coverage in Africa based on the PRIO-GRID.[1] We match this panel with violent conflict data drawn from the Uppsala Conflict Data Program (UCDP) (Croicu & Sundberg, 2017; Sundberg & Melander, 2013). The advantage of doing this is that all the data that we employ is publicly available, facilitating replication and extension. Our approach addresses issues with typical distortions and artefacts in the data to compute robust estimates of cell positions and localization error distributions. We match cell towers to a lattice of 55x55km grid cells. We also empirically examine economic growth as a channel through which mobile phone coverage influences conflict and, in doing so, we construct a novel night-time light dataset to measure economic growth.

To identify the causal effect of mobile phone coverage, we exploit the sources of exogeneity created by supply shocks. Given various supply shocks, mobile phone coverage is rolled out across different locations over time; thus, causing significant variation in access to mobile phone coverage in the grid cells that we consider across time. The supply shocks, and the resulting variation in mobile phone coverage across the grid cells, provide us with a quasi-experimental setting that allows us to divide the grid cells into treated and control grid cells. In our main estimates, we employ a difference-in-difference strategy. In the period studied, both our conflict measure and mobile phone coverage increase over time. Both trends can be attributed to common causes, such as population growth or urbanization. While we attempt to address this issue in the difference-in-difference estimates by controlling for population size, as an alternative to the difference-in-difference estimates, we employ a regression discontinuity design (RDD). To do so, we match each conflict event in our dataset based on the location and date to be either inside or outside the reception area for each cell tower. The difficulty with employing RDD in this context is that conflicts are rare events; thus, there will not always be

[1] See https://www.prio.org/Data/PRIO-GRID/ (Tollefson et al., 2012).

conflict events across both sides of the discontinuity in the RDD. For this reason, difference-in-differences estimates are often preferred in the literature to RDD in addressing the research question that we seek to answer. This said, our RDD estimates also show that access to mobile phones is robustly associated with an increase in the number of deaths from conflicts, reinforcing the main finding from the difference-in-differences estimation strategy.

Controlling for grid cell fixed effects and spatial spillovers using spatial clustering, we find robust evidence of a long-run positive effect of mobile phone coverage on violent conflict. Specifically, the base rate of a conflict event in a month across our data set is 0.0039 with a standard deviation of 0.0620. Getting access to mobile phones increases the probability of a conflict occurring in the next month by 0.0028 We examine heterogeneity on the impact of mobile phone coverage across state-based conflict, non-state-based conflict and one-sided conflict, and find that our results are being driven by non-state conflicts. Further, our results suggest that economic activity is a mechanism through which mobile phone access transmits to conflict, and that higher levels of economic growth dampen the effects of mobile phone coverage on conflict. This finding has important implications for developing policies that address the effect of the rollout of mobile phone networks on the escalation of violent conflict in Africa. Specifically, it suggests that the adverse effects of mobile phone coverage on conflict in Africa can be mitigated by policies designed to promote economic growth.

We contribute to multiple literatures. The first are studies linking mobile phone use to economic and political outcomes. Most of this literature has focused on the economic benefits of increased mobile phone coverage. Studies have shown that greater mobile phone coverage is associated with enhanced market performance (Jensen, 2007), improved institutional quality (Bailard, 2009; Kanyam et al., 2017), wealth (Tadesse & Bahiigwa, 2015), economic growth (Aker & Mbiti, 2010; Lee et al., 2012), financial inclusion (Lashitew et al., 2019); improved civic education and increased political involvement (Aker et al., 2017). However, the emergence of technology and mobile phones has often been cited as an important factor that aids in mass mobilization and the organization of violent protest (Manacorda & Tesei, 2020).

The second strand of literature to which we contribute are studies on the determinants of violent conflict. This literature attributes violent conflicts to myriad factors, including poverty and income level (Freytag et al., 2011; Tadjoeddin & Murshed, 2007), population density (Buhaug & Rød, 2006), level of education (Humphreys & Weinstein, 2008), climate change and geography (Barnett & Adger, 2007; Do & Iyer, 2010), inequality (Alesina & Perotti, 1996), institutional quality (Collier & Hoeffler, 2004), ethnicity and religion (Fearon & Laitin, 2003), among others. A small subset of this literature has examined the implications of communication technology and, in particular, mobile phone communication on violent conflict.

The evidence on the relationship between phones and violent conflict is mixed. Weidmann (2015a) finds that the level of international phone calls between countries is positively related to international diffusion of conflict. Shapiro and Weidmann (2015) find that increased mobile phone usage and related technologies reduced insurgent violence in Iraq. Absher and Grier (2019) examine the effects of mobile phones on violent collective action in the Libyan Revolution and find evidence of a negative effect. Pierskalla and Hollenbach (2013) study the impact of mobile phones on conflict in Africa and find that the introduction of new mobile coverage is associated with an increase in the probability of armed conflict.

Our study is closest to Pierskalla and Hollenbach (2013), who use data from the GSM Association on the spatial extent of GSM2 mobile network coverage in Africa to examine the impact of mobile coverage on 55x55km grid cells. Their finding of a positive effect of phone coverage on violent conflict is, however, based on cross-sectional data for 2008, and a short panel covering only three years. They argue that the positive effect of mobile phone coverage could represent a short-term shock, and, thus, more favourable or beneficial effects (i.e., conflict reducing effects) could be expected in the long run when the positive effects of communication technologies on economic development and political behaviour mitigate the root causes of conflict. Accordingly, Pierskalla and Hollenbach (2013) suggest the need for more research to determine and understand how technologies, such as mobile phones, affect violent and non-violent conflict in Africa, particularly in the longer run.

Africa represents an ideal setting in which to examine the relationship between mobile phone coverage and violent conflict. Africa has the fastest growing mobile phone market in the world with very high take-up rates over the last two decades. Between 1999 and 2008, the estimated number of mobile phone users in Africa increased from 80 million to 477 million (Aker & Mbiti, 2010), and by 2012, this number was estimated to be 732 million (Pierskalla & Hollenbach, 2013). This growth in the mobile phone market has occurred against the backdrop of very limited, or non-existent, fixed-phone infrastructure (Manacorda & Tesei, 2020). Thus, in addition to being used for voice communication, mobile phones are the most commonly used way to access social media and the internet (Stork et al., 2013). At the same time, Africa has been home to several internal violent conflicts (Adamson, 2019). The economic and human cost of violent conflict in Africa has been huge (Ncube et al., 2014). Better understanding of the causes of violent conflict in Africa is important in addressing these costs.

The remainder of the paper is structured as follows. The next section presents a conceptual overview of how mobile phone coverage could influence violent conflict. Section 3 discusses the data and empirical methods, while Section 4 presents the results. Section 5 concludes.

2. Conflict in Africa

Of the 32 African Countries that we consider in our analysis, Somalia, Nigeria, and the Democratic Republic of Congo (DRC) have had the most conflicts, followed by Libya, South Sudan, Sudan, Cameroon, Algeria, Mali and Kenya. Djibuti, Madagascar and Guinea Bissau have the least conflicts. Overall, the intensity of conflict is on the rise in Africa. In West Africa alone, the civilian cost of conflict between 2011 and 2018 increased by over 500% (Trémolières et al., 2020). While many conflicts have historical roots, since the early 2000s a combination of independent militias, rebel groups and extremist organizations have generated increased instability in African states (Trémolières et al., 2020). The UCDP identifies three forms of conflict, which are typical of Africa and other conflict-afflicted regions. These are: 1) non-state conflict, in which the government of a state is not a party to conflict, 2) state-based conflict, in which the government of a state is a party to conflict, and 3) one-sided conflict, in which there is use of force by the state or non-state actors against civilians.[2]

Many conflicts in Africa tend to involve non-state actors, such as Boko Haram, the Lord's Resistance Army and Al-Qaeda in the Islamic Maghreb, whose motives and means of operation still remain unclear to the involved governments (Agbiboa, 2013; Walker, 2012). Other conflicts, however, are political. For instance, the Somalian Civil War which has been ongoing for three decades, and which has resulted in the deaths of over a million Somalis and caused significant displacement, health issues and famine, was sparked by a coup that overthrew Siad Barre (Ighobor, 2019). The ongoing conflict in Libya, which commenced in 2011, had its origins with the overthrow and death of Muammar Gaddafi and the collapse of his regime. In recent years, most conflicts in Nigeria are linked with attacks by Boko Haram against religious bodies, traditional leaders, local militias, government forces and the civilian population. This has also meant state-instigated counterinsurgency attacks, which has led to spikes in conflicts across all conflict types (i.e., state-based, non-state and one-sided conflicts). The Boko Haram insurgency has also extended to neighbouring countries including Niger, Chad and Cameroon.

Some conflicts are ethnic based. In some African countries, the existence of ethnically defined boundaries and multi-racial or tribal composition engenders lack of unity, perceived or actual exclusion from political processes and lack of access to public goods. Figure 1 and Table A1 suggest that some countries with the most conflicts events also have very high levels of ethnic diversity. For example, the most conflict events occur in Somalia, Nigeria, and the DRC and, according to indices of ethnic diversity constructed by Fearon (2003), these countries have ethnic fractionalization scores of at least 0.80, which makes them very diverse.[3] In Nigeria, although the conflicts are political, they are also related to ethnic divisions and ethnically defined regional boundaries that can be traced back to the circumstances surrounding the country's independence from Britain (Ikpe, 2009; Onwuzuruigbo, 2010). Similarly in the DRC, where the conflict has taken over 5 million lives since it started in the late 1990s, there are both ethnic and political elements with over 20 different armed groups involved, each with their own objectives, including armed groups from other countries that operate along the DRC borders (Ighobor, 2019). Religious divisions have been causes of conflict in North and West Africa (Basedau et al., 2011; Fox, 2000). Examples are Algeria, Mali and Niger (Al-Qaeda in the Islamic Maghreb); Egypt, Mali, Libya and Somalia (ISIS); and the Ansaroul Islam in Mali and Burkina Faso (Trémolières et al., 2020). Other conflicts are linked with disputes over natural resources, such as conflicts in Sudan and South Sudan (Ighobor, 2019).

3. Why should mobile phone coverage influence conflict?

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[2] The UCDP defines state-based conflict as: "a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths in a calendar year". Non-state conflict is defined as: "the use of armed force between two organized armed groups, neither of which is the government of a state, which results in at least 25 battle-related deaths in a year". One-sided violence is defined as "the use of armed force by the government of a state or by a formally organized group against civilians which results in at least 25 deaths".

[3] To put this into context, countries such as the United States and United Kingdom, widely known for their ethnic diversity, only have diversity score of 0.49 and 0.32, respectively.

3.1. Information flow and coordination

Information exchange is an important factor that influences conflict (Weidmann, 2015a). Information dissemination via communication technology such as mobile phones has emerged as the most popular form of information flow because information can be broadcast promptly and effectively. We posit that if information diffusion contributes to conflict, communication technology, including mobile phone coverage, should play a key role for several reasons.

When conflicts are localized, mobile phones make it easier for information about the dynamics of ongoing conflict to reach distant geographic locations. Such information can influence the beliefs of potential combatants regarding their allegiance, political and ethnic positions, all of which are known to influence the diffusion of conflict (Lake & Rothchild, 1998). In a model of ethnic identification and conflict diffusion, Kuran (1998) shows that, under normal conditions, the relevance, and political significance, of ethnic boundaries is minimal. However, when people are provided with information about ongoing ethnic conflict, sense of ethnic allegiance is heightened, and this contributes to fuelling ethnic antagonism. Further, information on the success of groups in waging conflicts can promote increased demand for conflict when such information alters beliefs about the likelihood of success (Forsberg, 2008; Weidmann, 2015a). For instance, in societies with poor institutions, and lack of accountability from public officials, aggrieved masses can become optimistic about their chances of pursuing political violence when information about conflict elsewhere is communicated. If individuals learn that aggrieved parties elsewhere are using violence to achieve their political goals, information flow can serve as a means of tactical learning and imitation for distant groups (Hill et al., 1998); thus, increasing their inclination to pursue violent behaviour (Weidmann, 2015a).

Increased mobile phone coverage also makes it easier for groups to overcome coordination and collective action problems; thus, enabling more organized events that lead to conflict (Pierskalla & Hollenbach, 2013). Mobile phones provide the platform for groups to communicate effectively, even across distant locations, promoting in-group coordination and cooperation that can generate increased conflict. For instance, in an experimental setting, Eisenkopf (2018) shows that it is typically unlikely to achieve cooperative outcomes without communication. In our context, we argue that the use of mobile phone makes such communication easier. By decreasing the costs associated with word of mouth communication, especially the time taken for information to circulate, mobile phones can lower communication costs between geographically distant group members. This can significantly increase participation in conflicts. The ease of communication which mobile phone coverage affords also aids in the transmission of tactical information (Bakke, 2013). Further, during an ongoing revolt or uprising, mobile communication technology could promote violence by making it easier for parties involved to mass forces and coordinate attacks.

In addition to facilitating the coordination of violent attacks, mobile phones have can also be directly related to bomb detonations during insurgencies. Several improvised explosive devices (IEDs) can be denoted using mobile phones and, thus, wide phone coverage makes it easier for insurgents to perpetuate violence (Weidmann, 2015a). Kaufman (1996) suggests that violent conflict can emerge as a result of manipulative escalation patterns that are aided by communication technologies. For instance, by using the media and instant messaging via mobile phones, political agents can manipulate public opinion with the aim of rallying the masses behind them and outbidding their political opponents. Thus, information exchange or manipulation through the use of mobile phones and other communication technologies, can increase the risk of violent conflict (De Figueiredo & Weingast, 1999; Kaufman, 1996).

Conceptually, increased mobile phone coverage could be associated with less conflict. Mobile networks have served as platforms for early warning messages to avert violent crimes. They have also been used to spread nonviolent strategies to manage conflict (Mancini et al., 2013). Mobile phones can be used to communicate information about casualties, which could cause groups on the verge of violence to reassess the costs of becoming involved in conflict, ultimately averting further conflict (Cederman et al., 2013; Weidmann, 2015a).

Data on mobile phone and social media use is increasingly being used by policymakers to predict conflict and instability, and devise policies to avert conflicts. In a theoretical model of counterinsurgency, Berman et al. (2011) suggest that mobile phone technology can improve information gathering, which counterinsurgent forces can effectively use to avert violence. Evidence also suggests that data drawn from social media posts can be used to assess popular sentiment towards governments and other groups, and such data have been used to devise strategies to reduce violence (Corlazzoli, 2014; Muggah & Diniz, 2013). Mobile phone coverage and access also allows citizens to report known information about insurgents and their locations to authorities, thus enhancing counterinsurgency operations and limiting insurgents' ability to perpetuate violence (Shapiro & Weidmann, 2015).

The experimental literature on the role of communication in contests also provides insight into how communication and, by extension, communication devices such as mobile phones, can reduce conflict. Cason et al. (2012) show that intra-group communication leads to more aggressive competition and greater coordination, while inter-group communication leads to less destructive competition. Asymmetric communication can also be harmful and lead to more conflict than when there is no communication (Cason et al., 2017). Communication itself has been shown to influence the expenditure dynamics of conflicts (Eisenkopf, 2018; Leibbrandt and Saaksvuori, 2012). Findings from Leibbrandt and Saaksvuori (2012) suggest that communication structure is crucial in determining whether communication intensifies or mitigates conflict. Specifically, they find that the restriction of communication to one's own group, compared to a situation in which there is no communication, tends to increase expenditure on conflict. However, expenditure on conflict is significantly lower when communication is between one's own group and a rival group. Similarly, Eisenkopf (2018) shows that communication tends to reduce expenditure to a minimum level, whereas agents are willing to cooperate if they can effectively communicate and agree on a mutually beneficial resolution. Thus, while communication can promote conflict, when appropriate dialogue is initiated it can also lead to a compromise that curtails conflict. The costs associated with such dialogue can potentially be reduced by having access to mobile phones. The ease of communication which mobile phone coverage affords can, therefore, contribute to, or reduce, conflict depending on the level and nature of communication.

Overall, while it is possible that greater mobile phone coverage could increase, or reduce, the incidence of violent conflict, there are more reasons to think that it will increase it. While previous empirical evidence is mixed, our general expectation is consistent with the findings for the previous related study for Africa (Pierskalla & Hollenbach, 2013)

3.2. Economic growth

Economic growth is a potential channel through which mobile phone use influences conflict. Studies suggest that mobile phone use has a positive effect on economic growth (Aker & Mbiti, 2010; Lee et al., 2012), which has been attributed to more efficient markets (Jensen, 2007) and improved institutional quality (Bailard, 2009; Kanyam et al., 2017).

Economic growth can be expected to reduce the prevalence of violent conflict. One major cause of violent conflict is that relative social deprivation in which the group(s) that are worse off seek economic and political redress through conflict (Alexander & McGregor, 2000; Robert, 1993; Stewart, 2002a). Another major cause of violent conflict is relative private deprivation in which marginalised individuals engage in looting and other criminal activities for private gain (Stewart, 2002b). Feelings of relative deprivation, and motivation to engage in violent conflict, are exacerbated when there are few economic opportunities (Stewart, 2002b).

Conflicts also generate economic opportunities for individuals to profit from activities such as arms trading and the illicit production and trade of drugs and other commodities. Consistent with rational choice theory, where there are fewer economic opportunities resulting from poor economic growth, the incidence of conflict can be beneficial for rent-seeking agents, who ensure that conflict continues (Collier & Hoeffler, 2004; Hirshleifer, 1994).

Social contract theory suggests that social stability, and the absence of conflict, is based on a hypothetical contract between governments and their citizens that people recognize state authority as long as there is an effective delivery of services and provision of economic conditions that maintain a reasonable standard of life (Stewart, 2002b). Low economic growth, characterised by stagnation and poor public goods provision, is interpreted as a breach of the social contract, which can be redressed through conflict (Nafziger & Auvinen, 2000).

Overall, we expect economic growth to mediate and moderate the relationship between mobile phone coverage and conflict. Our general expectation of a direct positive effect of mobile phone coverage on conflict, should be offset, or be reduced over time, reflecting the indirect effect of mobile phone coverage on conflict via economic growth. Given that mobile phone coverage and communication technologies have been linked with higher economic growth, and that higher economic growth is associated with less conflict, we expect that the direct positive relationship between mobile phone use and violent conflict to be weaker in regions with higher economic growth. In regions with high levels of economic growth, we expect economic growth to offset the direct positive effect of mobile phone coverage on conflict, while in regions with low levels of economic growth, we expect that, over time, mobile phone coverage will result in higher economic growth, which should have a negative effect on conflict and, thus, dampen the direct positive effect of mobile phone coverage on conflict.

4. Data, identification strategy and mechanism analysis

4.1. Dataset

We construct a dataset on mobile phone availability using publicly available data for Africa based on the PRIO-GRID. The mobile phone data is drawn from a community project, known as OpenCellID, to geolocate all available cell towers in the world.[4] OpenCellID, which is an open source project, presents a representative sample for cell phone coverage and access. Specifically, the OpenCellID database collects cell tower information from all telecommunication network providers, which constitutes a representative sample of cell phone coverage in the areas in which each provider covers. Existing research has confirmed the representativeness of OpenCellID data on cell phone coverage compared to other sources (Ulm et al., 2015). The OpenCellID data for mobile phone coverage has been shown to be more reliable than GPS data which relies on satellites that are often not available and also on users keeping the GPS on, which they often do not.[5] Ulm et al. (2015) developed a methodology to assess the quality of crowd sourced data from OpenCellID. The raw data consists of the latitude and longitude of each cell tower, the date and time it was first detected and the number of samples collected. Assessed accuracy ranges from a mode of 200 meters with a 90th percentile of around 5km. Ulm et al. (2015) set a threshold of at least 100 samples for a tower to be included, which is considered to be conservative. We follow their data cleaning methodology and match the cell towers to a lattice of 55 km × 55 km grid cells (PRIO-GRID), consistent with existing studies (see Tollefsen et al., 2012). We employ the same conservative thresholds for mobile phone towers. We consider a cell to have mobile phone reception if the total sum of samples exceeds 100, which leaves us with data for mobile phone coverage from 2008 to 2018.

The mobile phone data is aggregated by grid cell and by month. We match this panel with measures of violent conflict drawn from the UCDP dataset (Croicu & Sundberg, 2017; Sundberg & Melander, 2013). We closely follow Pierskalla and Hollenbach (2013) in matching the conflict data to the PRIO-GRID. The conflict dataset has different encodings for precision in timing and location. For location we only include conflict events with highest precision to correctly assign the events to the cell. We match the conflict data based on the earliest possible date (date_start in the codebook), and a data precision of three (this equates to precision of a week). To account for inaccuracies in timing and avoid simultaneity bias, we introduce a one-month lag between mobile phone coverage and conflict. We intersect every grid cell with country boundaries and retain all countries in which there was at least one conflict.

Figure 1 presents the distribution of conflicts across 32 countries in Africa, in which one or more conflicts were recorded between 2008 and 2018. There were 8475 conflicts, resulting in 73,155 deaths. Figure 2 presents the coordinates of each mobile phone tower in the dataset.

We also examine if economic growth is a channel through which mobile phone access affects conflict. Given that we do not have data on GDP per capita at the grid cell level, we use night-

[4] This is available at https://opencellid.org
[5] See http://unwiredlabs.com/use-case for more information.

time light data as a proxy, which is a commonly used measure of economic growth in the literature (see, e.g., Awaworyi Churchill et al., 2020; Doll et al., 2006; Henderson et al., 2012; Hodler and Raschky 2014; Sutton & Costanza, 2002).[6] We create our own dataset using the Visible Infrared Imaging Radiometer Suite (VIIRS) night-time lights (Elvidge et al 2017). The raw satellite data is available freely from the Earth Observations Group at monthly intervals starting from April 2012.[7] Data before 2012 is available from the Defense Meteorological Satellite Program (DMSP) weather program, which was discontinued in 2013. For every pixel measurement, we discard all measurements below 5 $nWcm^{-2}sr^{-1}$, which could be used to infer moonlight reflection (Kyba et al., 2017). We follow Hodler and Raschky (2014) in matching night-time light data, with the key difference that we use newer sattelite data and match the sum of night-time light to the PRIO-GRID per month. We use the natual log of the resulting light data.

4.2. Identification strategy

The key assumption underpinning our identification strategy, which is consistent with the literature (Pierskalla & Hollenbach, 2013; Shapiro & Weidmann, 2015), is that the reasons for the expansion of mobile phone coverage can be captured with space and time fixed effects.

We first specify the problem as a difference in difference estimation, in which the unit of observation is a grid cell (c) in a given month (t). The outcome $Y_{c,t+1}$, is 1 if the best estimate of the number of deaths is greater than zero, otherwise it is zero. Specifically, our identification strategy relies on exogenous variation in the mobile phone network rollout in Africa in a difference in difference setting. Similar approaches have been used by Aker (2010) to study price formation in markets in Nigeria and by Jack and Tavneet (2014) to study the mobile money market in Kenya. Our specification for a PRIO-GRID cell is:

$$Y_{c,t+1} = \beta_0 + \beta_1 D_{c,t} + \beta_2\, pop_{c,t} + \alpha_t + \gamma_c + \epsilon_{c,t} \quad (1)$$

where D_{ct} is the treatment of interest - getting access to mobile phones in a given month and cell; $pop_{c,t}$ is the interpolated population grid cell estimate based on the Gridded Population of the World (GPWv4) from Columbia University[8]; and α_t *and* γ_c represent time and grid cell fixed effects, respectively. Following Shapiro and Weidmann (2015), we explore different specifications across time, but, in addition to this, we also account for spatial spill overs. The standard errors are clustered at the grid cell level. In a robustness check we also account for cross sectional spatial dependence and panel specific serial correlation (Conley, 2008).[9]

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[6] One limitation with using night-time light is that more light could possibly reflect increased security because of conflict, as opposed to increased economic activity. Accordingly, per-capita output still remains a more appropriate indicator of economic growth, but this data is not available at the grid cell level.

[7] https://eogdata.mines.edu/download_dnb_composites.html

[8] The GPWv4 population data is a time-variant population estimate, which is modelled following data collected from population census tables, taking into account corresponding geographic boundaries. The GPWv4 models the distribution of population densities and counts on a continuous global raster surface. The interpolated grid cell estimates, thus, vary over time (CIESIN, 2020).

[9] Given that our analysis is at the grid level, it is not possible to control for other potential correlates with conflict. Previous studies that have controlled for such correlates have been for larger geographical areas, such

For equation (1) to identify the causal effect of mobile phone coverage on violent conflict, we must assume that the treatment, access to mobile phone coverage, D_{ct}, is exogenous or uncorrelated with the error, $\epsilon_{c,t}$, conditional on population size. We posit that mobile phone coverage is likely to be exogenous because the pace of installation, the rollout of coverage and the chosen locations for infrastructure installation typically depend on supply shocks, which are exogenous factors such as land elevation and slopes (Buys et al., 2009). That mobile phone infrastructure, which determines access to mobile phone coverage, was rolled out at different times in different locations, generates significant variations in access to mobile phone coverage in the grid cells that we consider across time.[10] We contend that this essentially results in a quasi-experimental division of the grid cells into treated and control grid cells that facilitates the use of a difference-in-difference estimation strategy to examine the effects of mobile phone access. In our sampled countries, communication infrastructure that provides mobile phone coverage is provided by telecommunication companies, which are either state owned or privately owned. There is no evidence to suggest that there are independent networks installed by rebel groups for the purposes of enhancing communications relating to conflict strategizing.

A potential threat to our identification strategy would be if either there is less conflict in areas with greater elevation or slope because either fighting is more difficult in such areas or there is more conflict in such areas because elevated terrain provides a relatively secure base for rebel forces. The available evidence at the subnational level suggests at best mixed evidence about the relationship between terrain and violent conflict in Africa (Buhaug & Rød, 2006). To explore whether there is a relationship between terrain and violent conflict in our sample, we use a global elevation dataset (see, Jarvis et al., 2008) and calculate the average elevation and slope for our grid cells. Given that land elevation and slope is not time-varying, we aggregate our conflict variable across all years, and examine the impact of land elevation and slope on violent conflict in our dataset. The results, which are presented in Appendix Table A2, suggest that average elevation and slope are not correlated with violent conflict.

Another potential threat to our identification strategy is the fact that demographic change and urbanization are important factors that influence the supply of communication infrastructure and, at the same time, are known to be correlated with conflict. (Aker and Mbiti, 2010; Buys et al., 2009). To address this concern, in our difference in difference estimates we attempt to isolate the effect of mobile phone coverage by specifically controlling for population size. However, we do not entirely rule out that our treatment and control grid cells may be non-randomly sorted. We address this issue by accounting for any time-invariant differences across grid cells in our model. Accordingly, our difference in difference approach eliminates any time-invariant heterogeneity between the treated and control grid cells while the main confounder which we consider to be population, varies across both grid cells and time.

as regions or countries, for which data on other correlates are available. Variables such as ethnic diversity are time invariant at the country level and would be dropped from our specification.

[10] To illustrate this point, in Appendix Figure A1 we graph how cell phone coverage was rolled out across the grid cells in East Africa throughout 2015. It clearly shows increasing coverage between the beginning, mid and end of the year. Similar depictions could be given for other regions and time periods.

As an alternative to controlling for population size in our difference-in-difference estimates, to account for the possibility that trends in mobile phone coverage and conflict can be attributed to common causes, such as population growth or urbanization, we adopt a RDD. To do this, we look at a subset of all conflict events that occur around the mobile phone expansion border. We aggregate all cell towers to 2 km grids and enforce the same restrictions as in section 4.1. For a mobile to connect to a cell phone tower, it must fall within a determined distance that is dependent on the terrain. The cell phone reception is approximated with different types of path loss propagation models (Hoomod et al., 2018). A commonly used model is the Hata path loss model, which has been applied with a maximum distance of 10km (see, Michel and Emmanuel, 2015). In our data, the average distance between neighbouring cell towers is 8.8km and the median is around 8.5km. Thus, for each cell tower, we use a maximum of 10km of signal strength, as it unlikely for there to be phone access beyond that distance.

We match each conflict event in our dataset based on the location and date to be either inside or outside the reception area. In Figure 3, we present a raw scatterplot based on the number of casualties. This sample restrictions dramatically reduces our conflict events as we are now only able to examine pairs of events that occur in the same month either inside or outside of a coverage area. Following Dell (2010), we use a cubic polynomial in latitude and longitude, as well as a cubic polynomial in the straight distance to the border. Based on Figure 3, there is an imbalance between conflict events inside and outside of the phone coverage zone. We, therefore, run three separate models including events 10, 20 and 30 km within the border. In estimating our RDD model, the unit of observation is a conflict event in a given month that is matched to the closest cell phone coverage border and we consider actual number of casualties as our outcome. We estimate a spatial RDD of the follow form:

$$Y_{ltb} = \beta_0 + \beta_1 D_{lt} + \beta_2\, pop_{lt} + f(geographic\ location_l) + \gamma_b + \epsilon_{ltb} \qquad (2)$$

where D_{lt} is the variable that captures areas with mobile phone coverage; $pop_{l,t}$ is the population in a 5km radius around the conflict event cell estimate based on the Gridded Population of the World (GPWv4); γ_b represents a mobile phone border fixed effect; $f(geographic\ location_l)$ is the regression discontinuity polynomial, which controls for smooth functions based on the geographic location. The main RDD assumption is that all other possible factors causing conflict vary smoothly at the mobile phone coverage border, with the only difference being that some of the events are inside, while others are outside.

4.3. Economic growth as a channel

To examine if night-time light qualifies as a mediator (or potential channel) through which mobile phone access transmits to conflict, we follow the approach in studies such as Alesina and Zhuravskaya (2011) and Awaworyi Churchill and Smyth (2020). Specifically, for night-time light to qualify as a mechanism in addition to being correlated with mobile phone access, it should also be correlated with conflict, and the inclusion of night-time light as an additional control variable in the regression of conflict on mobile phone access should decrease the magnitude of the coefficient on mobile phone access or render it statistically insignificant.

As a check on our mediation results, we also examine if economic growth moderates the relationship between mobile phone access and conflict. To do so, we augment equation (1) to include the interaction between mobile phone access and night-time light.

5. Results

5.1. Preliminary estimates

We begin our analysis with a basic regression that provides benchmark estimates for the relationship between mobile phone access in a given month and conflict in that month. These estimates, which are reported in Table 1, indicate that there is a positive association between mobile phone access and violent conflict. Specifically, we find that getting access to mobile phone coverage in a 55km x 55km grid cell in a given geographic area is associated with a 1.3 percentage point increase in the probability that a violent conflict will occur.

5.2. Difference-in-difference results

Table 2 presents our main estimates from the difference in difference specification. It is likely that more violence is recorded during certain periods. To ensure that specific periods with more violence are not driving our results, we consider different time fixed effects in alternating models. Column 1 reports results in which we control for yearly fixed effects. In Column 2 we report results that control for half-yearly fixed effects and Column 3 reports results that control for quarter-yearly fixed effects. Results in Column 4 control for monthly fixed effects and space fixed effects. Our results are robust to the control of different time fixed effects and spatial dependence. Specifically, results from Columns 1 to 4 show that getting access to mobile phone coverage in a 55km x 55km grid cell in a given geographic areas is associated with a 0.3 percentage point increase in the probability that a violent conflict will occur in the next month.

Table 3 replicates the specifications in Table 2, but in each column, we add population in each grid cell as a covariate. The effect of access to mobile phone coverage is positive and significant with an effect size of 0.003, which is identical to results in Table 2.

In Table 4, we examine heterogeneity across state-based conflict, non-state-based conflict and one-sided conflict. Panel A of Table 4 reports results for state-based conflict. Panels B and C report results for non-state-based conflict and one-sided conflict, respectively. We find that except for state-based conflict, for which the results are statistically insignificant, our results for conflict types are consistent with a positive relationship between mobile phone access and conflict. This suggests that our results are being driven by non-state conflicts. This could be because governments tend to have more established communication structures and may not need to rely heavily on mobile phone access to plan conflicts (Chin, 2019; Roach, 1993).

5.3. Regression discontinuity design (RDD) results

We examine the sensitivity of our results to RDD as an alternative estimation approach. Following Dell (2010), we use a cubic polynomial in latitude and longitude, as well as a cubic polynomial in the straight distance to the border. Figure 3 suggests that there is an imbalance between conflict events inside and outside of the phone coverage zone. Hence, we run three separate models including events 10, 20 and 30 km within the border. In estimating our RDD model, the unit of observation is a conflict event in a given month that is matched to the closest cell phone coverage border and we consider actual number of casualties as our outcome. Quite robustly, the RDD results presented in Table 5 show that access to mobile phones is associated with an increase the number of death casualties from conflict events. This finding is consistent with the results employing the difference-in-difference estimation strategy.

5.4 *Economic growth as a channel*

While it is impossible to isolate the effect of all possible channels through which mobile phone coverage influences conflict, and we do not have the data to do so, we are able to examine the role of economic growth using satellite data for grid cells. Thus, in this section, we examine if economic growth is a mechanism through which mobile phone access transmits to conflict.

Column 1 of Table 6 reports results for the relationship between mobile phone access and night-time light. We find that getting access to mobile phone coverage is associated with an increase in economic activity. Specifically, access to mobile phone coverage is associated with a 3.26 percent change in night-time light intensity. Given that we have fewer observations for night-time light, we also rerun the specification in which conflict is regressed on mobile phone access to ensure that the same sample is used when we relate night-time light to conflict in the transmission mechanism analysis. Results for this subsample regression, which are reported in Column 2, are consistent with mobile phone access being positively related to conflict.

Panel A of Table 7 includes night-time light as an additional covariate in the conflict regressions. Night-time light is negatively associated with conflict, meaning that an increase in economic activity is associated with a reduction in the probability of a conflict. Further, with the inclusion of night-time light as an additional covariate, the coefficient on mobile phone access reduces in magnitude and becomes statistically insignificant, meaning that economic activity is a mechanism through which mobile phone access transmits to conflict. The direct positive effect of coverage on conflict is reduced in the presence of higher growth.

In Panel B of Table 7, the interaction between mobile phone access and economic growth is negative and significant. These findings suggest that economic growth also moderates the relationship between mobile phone access and conflict. The findings for economic growth as a moderator are consistent with the mediated relationship. Specifically, accounting for space and time fixed effects, the relationship between mobile phone access and conflict is lower in grid cell areas with higher economic activity. Put differently, in a high economic growth environment, access to mobile phone is linked with a decline in conflict, and thus, economic growth dampens the effects of mobile phone coverage on conflict.

While economic growth dampens the effect of mobile phone coverage on conflict, the dominating net positive effect of mobile phone coverage suggests that there are other potential channels that outweigh the effects of economic growth. For instance, as discussed in Section 3, mobile phone coverage could influence conflict via its effect on information flow and coordination. By easing how information is passed on and overcoming coordination problems, mobile phone coverage can promote conflict. Thus, information flow and coordination are potential channels that could dominate the weakening effect of economic growth. However, we are not able to proxy these potential mechanisms to accurately confirm this conjecture.

5.3. Robustness checks

One might be worried that potentially long running time trends could drive our results. For instance, some regions might have persistent conflict and such conflicts may increase in intensity over time. To ensure that our results are not driven by a few regions that have escalating conflicts year after year, in appendix Table A3, we re-estimate our models to include time trends. We find that our results are not driven by potential long running conflict trends.

Our main results do not include spatial clustering. In appendix Table A4, we examine the robustness of our results to spatial clustering (Conley, 2008). There might be the concern that conflict is driven by adjacent, or close by, events; thus, deflating our standard error estimates. We account for this by reporting estimates from high dimensional regressions in which we control for spatial clustering (Fetzer, 2014; Hsiang, 2010). We find that our results are robust.

In our main results, we followed Ulm et al. (2015) and set a threshold of at least 100 samples for a tower to be included in the grid cells of mobile phone coverage. In excluding grid cells with towers with less than 100 samples, we lose about 15 per cent of observations. In another check, we examine the sensitivity of our results to the use of the full sample without restrictions on the cell tower. The results, which are reported in appendix Table A5, are consistent with there being a positive relationship between mobile phone access and conflict.

In Table A6, we examine the robustness of our results using an alternative conflict dataset. Specifically, we use conflict data from the Armed Conflict Location & Event Data Project (ACLED) database (Raleigh et all 2019), which employs a different conflict reporting approach than UDCP. While it has also been widely used in the literature, the ACLED database is considered to have higher levels of reporting bias than our preferred UDCP database (Berman et all 2017). The results based on the ACLED database, which are reported in Table A6, nonetheless also suggest a positive relationship between mobile phone access and conflict.

In our main results, standard errors are clustered at the grid cell level, which is relatively conservative. In further checks, we examine the robustness of our results to clustering at higher levels. Specifically, we examine the robustness of our results to clustering standard errors at the regional (adm2) and state (adm1) administrative levels. The findings for different clustering, which are reported in Table A7, show that our main results are robust.

Next, we focus on the persistence of the effects of mobile phone coverage over time. In our main results, we examine the effects of mobile phone coverage on conflict in the next period (month). However, the effects of mobile phone coverage may persist over time. Thus, we examine the sensitivity of our results to longer horizons. We consider the effects of mobile phone coverage on conflict in the next quarter, six months and year. The results, reported in

Tables A8 and A9, show that the effects of mobile phone access persist and that the finding of a positive relationship between mobile phone access and conflict is consistent.

In a final check, we conduct a placebo test using the future arrival of cell phone towers at six months and a year into the future. These tests allow us to examine if there are any potential threats to our identification strategy that may emerge from omitted variable bias that may have evaded the range of fixed effects that we control for. The placebo test results, reported in Table A10, show that the future arrival of cell phone towers is statistically insignificant.

6. Conclusion

Few studies examine how communication technologies influence conflict. We contribute to this embryonic literature by examining the impact of mobile phone coverage on violent conflict in Africa using 11 years of panel data, covering the period 2008 to 2018. To do so we construct a new dataset on mobile phone coverage that employs data for Africa based on the PRIO-GRID. We also construct a new dataset on night-time light, in order to examine the role of economic growth as both a mediator and moderator of the coverage-conflict relationship.

Our results suggest that access to mobile phone coverage increases violent conflict. Specifically, getting access to mobile phone coverage increases the probability of having a violent conflict in the next month by 0.3 percentage points. The finding that cell phone coverage increases the probability of conflict is consistent with findings from Pierskalla and Hollenbach (2013), who show that in Africa, in the short run, cell phone coverage increases the probability of conflict by 0.5 to 1 percentage points in the next year. Our finding of a positive effect using 11 years of panel data suggests that the effects of cell phone coverage on violent conflict is not a short run phenomenon, but rather is persistent.

However, given that economic growth is a channel through which mobile phone coverage transmits to conflict, and the effect of mobile phone coverage on economic growth is positive, the effect of mobile phone coverage on conflict is weakened via this channel. Consistent with the observed mediated effect, we also find that economic growth plays a moderating role in the mobile phone coverage-conflict relationship, such that higher levels of economic growth dampen the positive effects of mobile phone coverage on conflict. These findings suggest that policies designed to promote economic growth can help to reduce the intensity of conflicts in Africa by offsetting the positive effect of mobile phone coverage on conflict.

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Table 1: Baseline estimation

VARIABLES	(1) *Violent conflict*
Access to mobile phones	0.0131***
	(0.0003)
Observations	1,106,363
R-squared	0.0024

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Direct effect, mobile phone access and conflict

	(1)	(2)	(3)	(4)
VARIABLES	*Violent conflict in the next month (t+1)*			
Access to mobile phones	0.0028**	0.0028**	0.0028**	0.0028**
	(0.0012)	(0.0012)	(0.0012)	(0.0012)
Observations	1,094,862	1,094,862	1,094,862	1,094,862
R-squared	0.1581	0.1582	0.1582	0.1583
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month

Clustered standard errors on grid cell level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Mobile phone access and conflict, controlling for population

	(1)	(2)	(3)	(4)
VARIABLES	*Violent conflict in the next month (t+1)*			
Access to mobile phones	0.0028**	0.0028**	0.0028**	0.0028**
	(0.0012)	(0.0012)	(0.0012)	(0.0012)
Population	0.0006	0.0007	0.0006	0.0006
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Observations	1,092,504	1,092,504	1,092,504	1,092,504
R-squared	0.1581	0.1582	0.1582	0.1583
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month

Clustered standard errors on grid cell level in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: Heterogeneous effects of Mobile phone access and conflict by conflict type

	(1)	(2)	(3)	(4)
VARIABLES	*Violent conflict in the next month (t+1)*			
Panel A: State-based conflict				
Access to mobile phones	0.0007	0.0007	0.0007	0.0007
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Observations	978,218	978,218	978,218	978,218
R-squared	0.1678	0.1678	0.1678	0.1679
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month
Panel B: Nonstate-based conflict				
Access to mobile phones	0.0016***	0.0016***	0.0016***	0.0016***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Observations	819,998	819,998	819,998	819,998
R-squared	0.0740	0.0740	0.0740	0.0742
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month
Panel C: One-sided conflict				
Access to mobile phones	0.0017**	0.0017**	0.0017**	0.0017**
	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Population	0.0010**	0.0010**	0.0009**	0.0009*
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Observations	1,086,025	1,086,025	1,086,025	1,086,025
R-squared	0.1372	0.1373	0.1373	0.1374
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month

Clustered standard errors on grid cell level in parentheses
All regressions control for population
Some conflicts overlap in terms of conflict type. For instance, a state-based conflict could also be a non-state based conflict depending on the parties involved.
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Mobile phone and conflict (Spatial RDD results)

	(1)	(2)	(3)
Sample Within km:	<30	<20	<10
Panel A: Cubic Polynomial in Latitude and Longitude			
Access to mobile phones	2.3745*	2.2678*	2.8641*
	(1.2969)	(1.3080)	(1.5706)
Population	-0.0949	0.0740	0.3008
	(0.6094)	(0.5848)	(0.6750)
Observations	2,592	2,385	1,880
R-squared	0.0933	0.0906	0.0873
Border fixed effect	Yes	Yes	Yes
Panel B: Cubic Polynomial in Distance to Mobile Phone Border			
Access to mobile phones	3.2926**	2.6959*	3.9982**
	(1.3909)	(1.4526)	(1.8481)
Population	-0.2063	0.0208	0.3327
	(0.5296)	(0.5191)	(0.5149)
Observations	2,592	2,385	1,880
R-squared	0.0931	0.0906	0.0879
Border fixed effect	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Panel A includes a cubic polynomial in the latitude and longitude of the conflict event, panel B includes a cubic polynomial in the distance in km to the mobile phone coverage border.

Table 6: Channel analysis, mobile phone and night-time light

	(1)	(2)
VARIABLES	Night-time light	Conflict
Access to mobile phones	0.0326***	0.0115***
	(0.0015)	(0.0005)
Observations	676,928	678,386
R-squared	0.0011	0.0022

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Mediating and moderating effects of economic growth

	(1)	(2)	(3)	(4)
VARIABLES	*Violent conflict in the next month (t+1)*			
Panel A				
Access to mobile phones	0.0017	0.0018	0.0017	0.0017
	(0.0012)	(0.0012)	(0.0012)	(0.0012)
Night-time light per capita	-0.0022*	-0.0022*	-0.0022*	-0.0022*
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Observations	666,237	666,237	666,237	666,237
R-squared	0.2146	0.2146	0.2146	0.2147
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month
Panel B				
Access to mobile phones	0.0021	0.0021	0.0021	0.0021
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Night-time light per capita	-0.0018*	-0.0018*	-0.0018*	-0.0018*
	(0.0010)	(0.0010)	(0.0010)	(0.0010)
Access to mobile phones X Night-time light per capita	-0.0073*	-0.0073*	-0.0073*	-0.0073*
	(0.0038)	(0.0038)	(0.0038)	(0.0038)
Observations	666,237	666,237	666,237	666,237
R-squared	0.2146	0.2146	0.2146	0.2147
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month

Clustered standard errors on grid cell level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

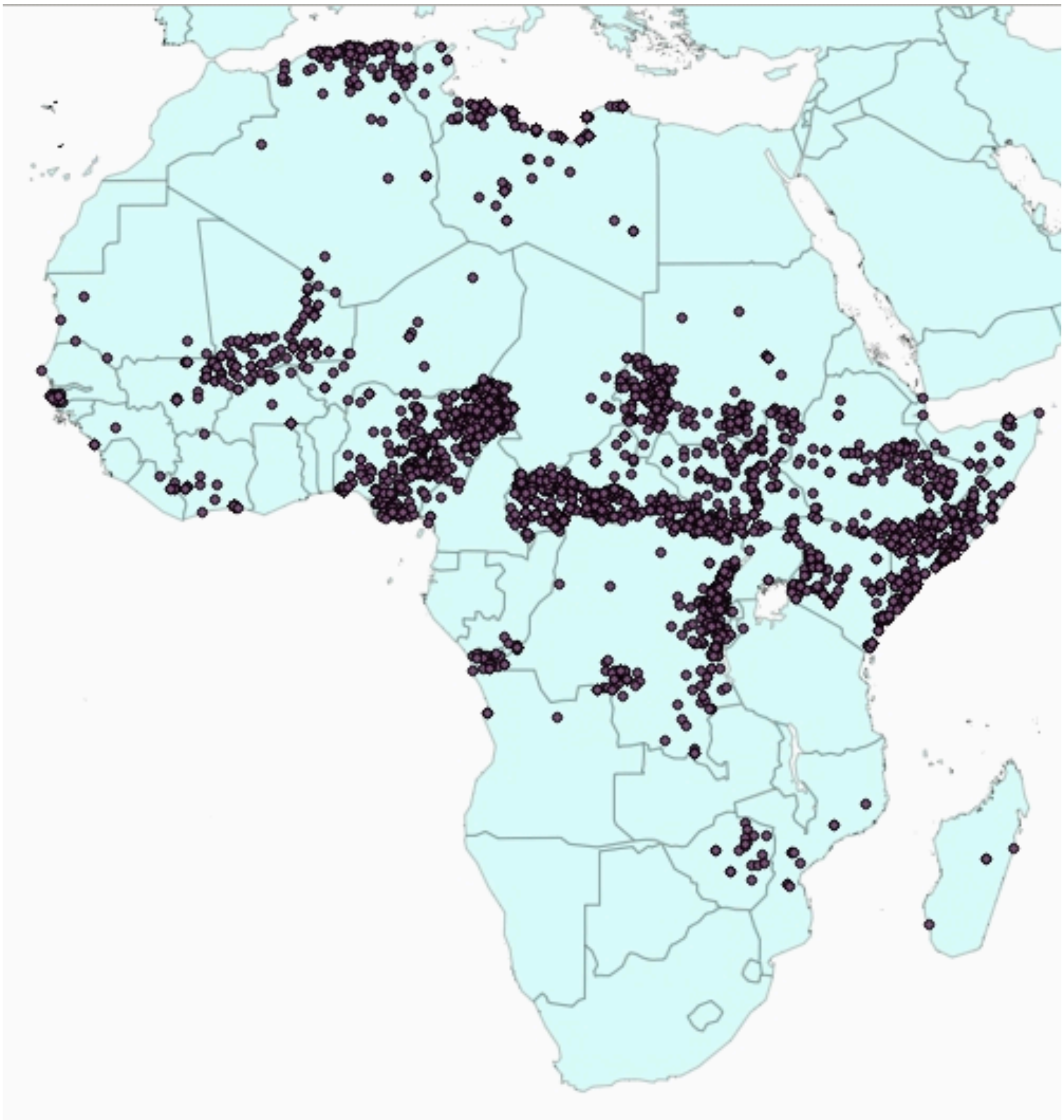


Figure 1: Conflicts in Africa 2008 - 2018

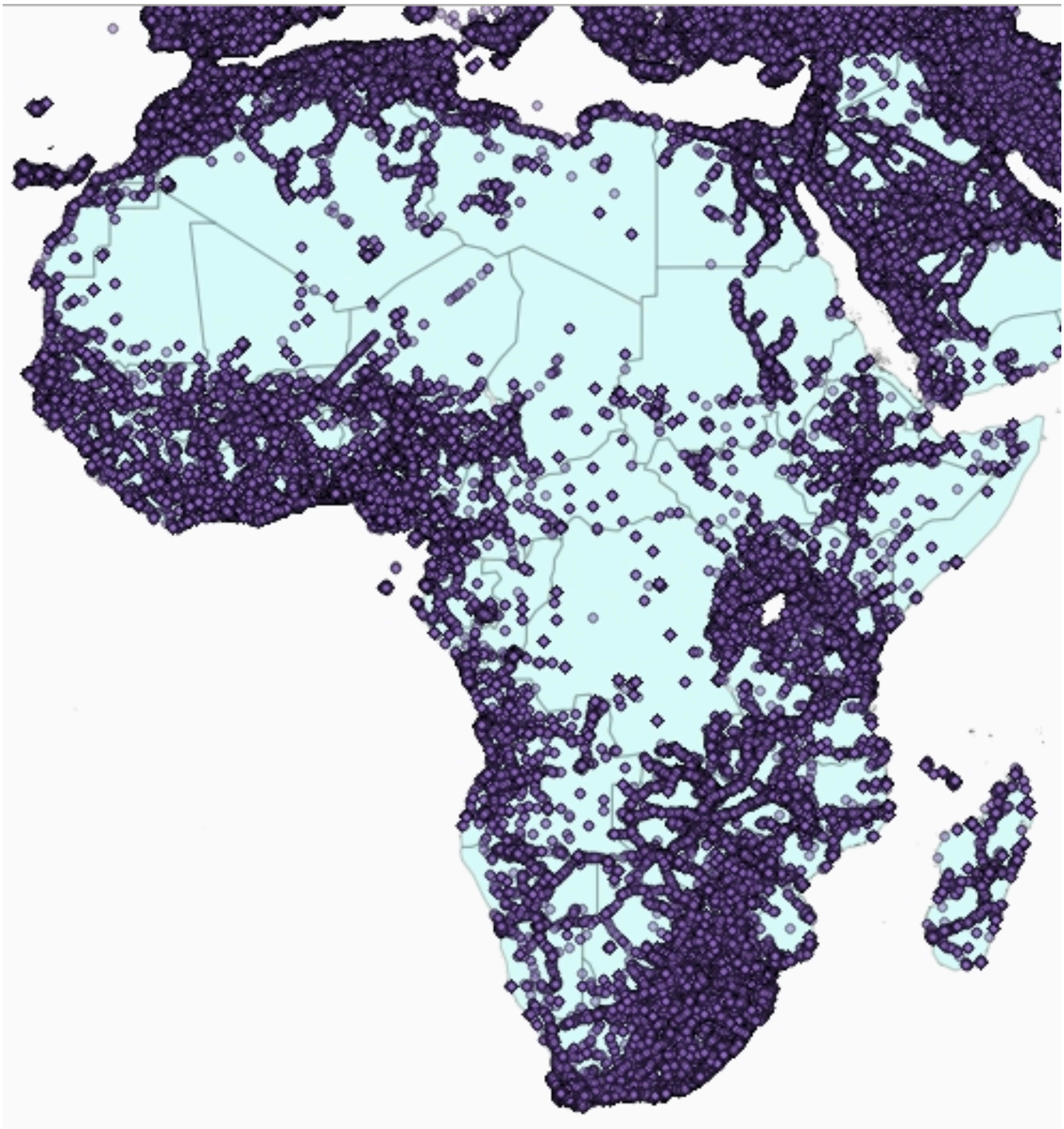


Figure 2: Mobile phone towers December 2018

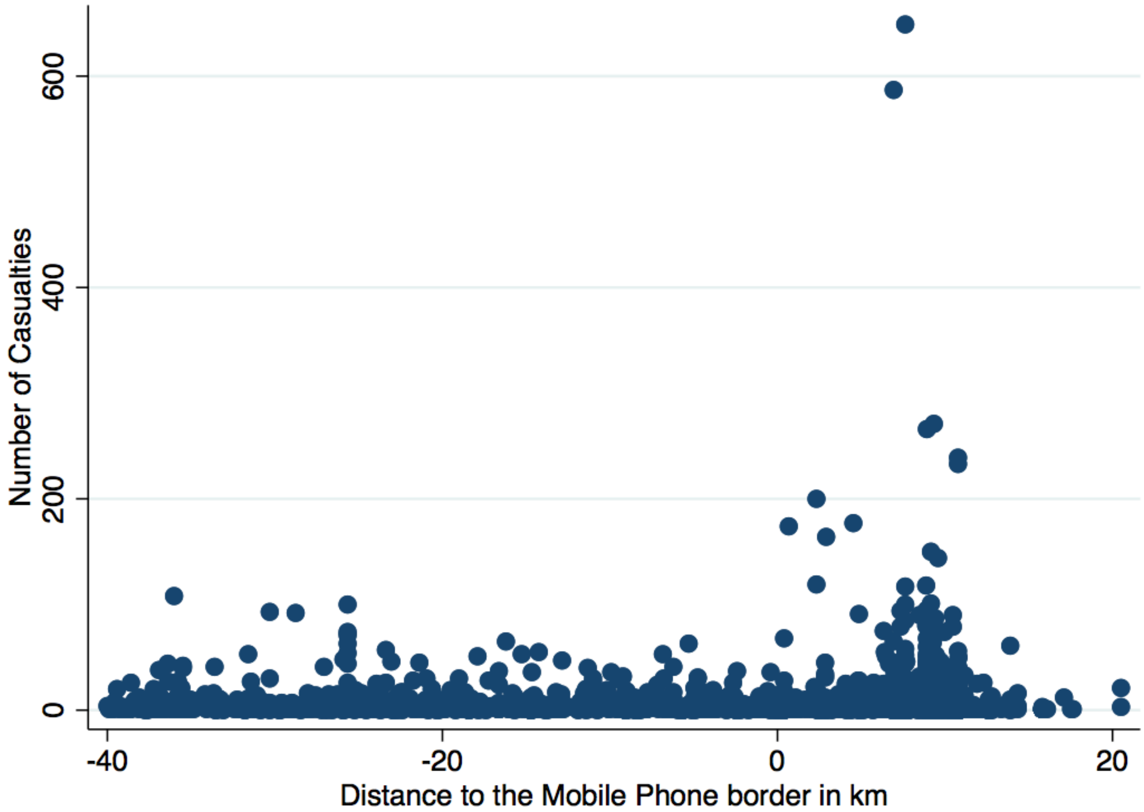


Figure 3: Scatter plot of raw data for the Spatial RDD, positive distance denotes a value inside the mobile phone coverage area.

Table A1: Conflict by country

Country	Number of incidents			
	Total	State Based	Nonstate based	One-sided
Algeria	274	250	1	23
Angola	20	10	0	10
Burkina Faso	39	8	9	22
Burundi	10	0	0	10
Cote d'Ivoire	138	14	5	119
Cameroon	299	168	7	124
Chad	40	22	6	12
Democratic Republic of the Congo	1184	364	177	643
Djibouti	5	4	0	1
Ethiopia	86	15	25	46
Guinea	8	0	1	7
Guinea-Bissau	1	1	0	0
Kenya	216	44	94	78
Liberia	6	0	0	6
Libya	640	299	315	26
Madagascar	4	0	3	1
Mali	236	164	32	40
Mauritania	7	3	0	4
Mozambique	32	13	0	19
Niger	79	51	3	25
Nigeria	1899	707	489	703
Republic of Congo	40	8	1	31
Rwanda	14	2	2	10
Senegal	18	11	0	7
Somalia	2449	1972	94	383
South Sudan	315	117	56	142
Sudan	315	150	33	132
Tanzania	8	0	0	8
Tunisia	14	10	0	4
Uganda	56	14	15	27
Zambia	7	6	0	1
Zimbabwe	15	0	0	15

Table A2: Land elevation and conflict

VARIABLES	(1) *Violent conflict*
Average elevation in log	-0.0021
	(0.0036)
Average slope in log	0.0030
	(0.0205)
Observations	9,878
R-squared	0.1751
Country fixed-effects	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A3: Mobile phone and conflict, controlling for regional specific time trends

	(1)	(2)	(3)	(4)
VARIABLES	*Violent conflict in the next month (t+1)*			
Access to mobile phones	0.0046***	0.0046***	0.0046***	0.0046***
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Population	0.0157***	0.0173***	0.0170***	0.0169***
	(0.0057)	(0.0060)	(0.0061)	(0.0061)
Observations	1,092,504	1,092,504	1,092,504	1,092,504
R-squared	0.1945	0.1945	0.1946	0.1947
Space fixed-effects	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month

Cluster standard errors on grid cell level in parentheses. Each model has a time trend on the regional level (administrative level 2) included.
*** p<0.01, ** p<0.05, * p<0.1

Table A4: Mobile phone and conflict, spatial clustering

	(1)	(2)	(3)	(4)
VARIABLES	*Violent conflict in the next month (t+1)*			
Access to mobile phones	0.0028**	0.0028**	0.0028***	0.0028***
	(0.0012)	(0.0011)	(0.0010)	(0.0009)
Population	0.0006	0.0007	0.0006	0.0006
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Observations	1,092,504	1,092,504	1,092,504	1,092,504
R-squared	0.1581	0.1582	0.1582	0.1583
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Quarter

Conley (2008) spatially clustered standard errors
*** p<0.01, ** p<0.05, * p<0.1

Table A5: Mobile phone and conflict, all African countries – no cell tower restrictions

	(1)	(2)	(3)	(4)
VARIABLES	*Violent conflict in the next month (t+1)*			
Access to mobile phones	0.0017***	0.0017***	0.0017***	0.0017***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Population	0.0019*	0.0020*	0.0019*	0.0019*
	(0.0011)	(0.0011)	(0.0011)	(0.0012)
Observations	1,287,945	1,287,945	1,287,945	1,287,945
R-squared	0.1491	0.1491	0.1491	0.1492
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month

Clustered standard errors on grid cell level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A6: Mobile phone and conflict using ACLED database

	(1)	(2)	(3)	(4)
VARIABLES	*Violent conflict in the next month (t+1)*			
Access to mobile phones	0.0083***	0.0083***	0.0083***	0.0083***
	(0.0015)	(0.0015)	(0.0015)	(0.0015)
Population	0.0039	0.0039	0.0037	0.0036
	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Observations	1,253,218	1,253,218	1,253,218	1,253,218
R-squared	0.1999	0.1999	0.1999	0.2000
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month

Clustered standard errors on grid cell level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A7: Mobile phone access and conflict, different clustering

	(1)	(2)	(3)
VARIABLES	*Violent conflict in the next month (t+1)*		
Access to mobile phones	0.0028**	0.0028**	0.0028**
	(0.0012)	(0.0012)	(0.0013)
Population	0.0006	0.0006	0.0006
	(0.0013)	(0.0018)	(0.0021)
Observations	1,092,504	1,092,504	1,092,504
R-squared	0.1583	0.1583	0.1583
Space fixed-effects	Yes	Yes	Yes
Time fixed-effects	Month	Month	Month
Cluster	Cell	Adm 2	Adm 1

Clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Results in Column 1 (clustered at the grid cell level) are presented for comparison only.

Table A8: Mobile phone access and conflict in the next quarter

	(1)	(2)	(3)
VARIABLES		*Violent conflict in the next quarter*	
Access to mobile phones	0.0041**	0.0041**	0.0040**
	(0.0020)	(0.0020)	(0.0020)
Population	0.0005	0.0001	-0.0002
	(0.0022)	(0.0022)	(0.0022)
Observations	360,729	360,729	360,729
R-squared	0.2032	0.2032	0.2034
Space fixed-effects	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter

Clustered standard errors on grid cell level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A9: Mobile phone access and conflict in the next 6 months and next year

	(1)	(2)	(3)
VARIABLES	*Violent conflict in the next 6 months*		*Next year*
Access to mobile phones	0.0060**	0.0059**	0.0095**
	(0.0028)	(0.0028)	(0.0046)
Population	0.0021	-0.0001	0.0014
	(0.0036)	(0.0036)	(0.0067)
Observations	176,226	176,226	83,920
R-squared	0.2563	0.2565	0.3394
Space fixed-effects	Yes	Yes	Yes
Time fixed-effects	Year	Half	Year

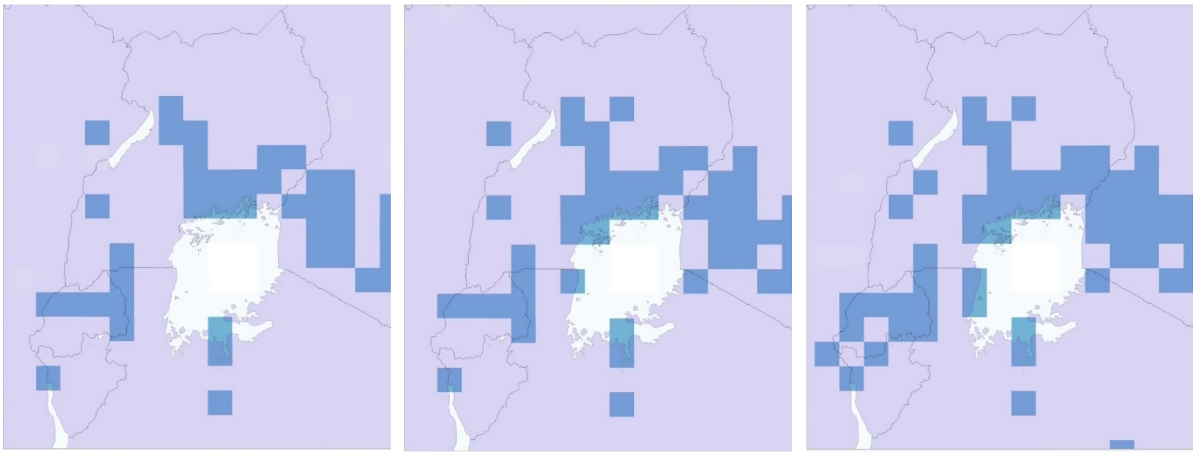
Clustered standard errors on grid cell level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A10: Placebo test, Mobile phone access six months in the future

	(1)	(2)	(3)	(4)
VARIABLES		*Violent conflict*		
Panel A: Mobile phone access in six months				
Access to mobile phones six months in the future	0.0015	0.0015	0.0015	0.0015
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Population	0.0002	0.0007	0.0008	0.0008
	(0.0012)	(0.0012)	(0.0012)	(0.0012)
Observations	1,050,611	1,050,611	1,050,611	1,050,611
R-squared	0.1568	0.1569	0.1569	0.1570
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month
Panel B: Mobile phone access in one year				
Access to mobile phones one year in the future	0.0006	0.0007	0.0007	0.0007
	(0.0011)	(0.0011)	(0.0011)	(0.0011)
Population	0.0008	0.0014	0.0015	0.0015
	(0.0013)	(0.0013)	(0.0014)	(0.0014)
Observations	1,000,602	1,000,602	1,000,602	1,000,602
R-squared	0.1603	0.1603	0.1604	0.1604
Space fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Year	Half	Quarter	Month

Clustered standard errors on grid cell level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix Figure A1: Mobile phone rollout in East Africa through 2015



Mobile phone coverage in East Africa (January 2015) | *Mobile phone coverage in East Africa (June 2015)* | *Mobile phone coverage in East Africa (December 2015)*

The darker shades represent mobile phone coverage