Cell Phones, Rumors, and Internal Displacement in Civil War *

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Abstract

Cell phones have become ubiquitous in conflict zones. However, little is known about the effect of communication technology on migration during civil war. I hypothesize that access to cell phone networks causes people to flee by facilitating the rapid spread of rumors of violence within insecure populations. This may increase the impact of violence on civilian displacement as uncertain but plausible information about violence travels through social networks. To identify the effect of cell phone coverage on displacement during conflict I combine maps of cell phone coverage in Colombia with detailed data on insurgent violence against civilians and internal displacement and employ a spatial regression discontinuity research design along the cell phone coverage boundary. I find that access to cell phone networks causes an average of over 100 more people to flee from the hundreds of municipalities with cell phone coverage. In support of rumors as a mechanism, I show that this effect is not driven by changes in insurgent violence, which is unaffected by network coverage.

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1 Introduction

Over 68 million people remain forcibly displaced around the world, as refugees or internally displaced persons, having fled their homes in the midst of civil conflict (Office of the United Nations High Commissioner for Refugees, 2018). This global humanitarian crisis continues to increase in magnitude and has profound consequences for the lives of displaced people (Ibáñez and Vélez, 2008), international institutions (Loescher, 1996), and receiving countries (Dancygier and Laitin, 2014; Salehyan and Gleditsch, 2006; Salehyan, 2008). Thus it is vital to understand why individuals flee their homes and become displaced in order. A large literature points to violence as a primary reason for displacement (Davenport, Moore and Poe, 2003; Melander and Öberg, 2006, 2007; Moore and Shellman, 2004, 2006; Schmeidl, 1997; Adhikari, 2013, 2012; Bohra-Mishra and Massey, 2011; Engel and Ibáñez, 2007; Lozano-Gracia et al., 2010; Ibáñez and Vélez, 2008; Steele, 2011). However, during insurgencies many displaced persons flee from locations without violence (Laughlin, 2018), so it is important to understand how individuals living in conflict zones hear about the potential for violence and how they make decisions about if and when to leave their homes.

In this paper I propose that rumors about violence play an important role in decisions to flee or stay. Insecure environments are rife with rumors (Larson and Lewis, 2018). Emblematically, the first sentence of Jeremy Weinsteins *Inside Rebellion* reads, "Word of the rebels came first in the form of rumors" (Weinstein, 2006, 1). Uncertainty about the veracity of information shared through social networks and the life or death stakes of decisions about fleeing increases the power of rumors. Rumors' spread through social networks also enables technology to further magnify their effect.

At the same time that the number of forcibly displaced persons has exploded, the global expansion of mobile communications technology has been transformative. Cell phone technology has lowered the cost of communication and has connected millions of previously unconnected people (GSM Association, 2018). Cell networks have even spread into conflict zones, profoundly changing conflict (Gohdes, 2018). Has the expansion of cell phone coverage impacted civilian displacement in civil war by facilitating the spread of rumors about violence? I hypothesis that by making it easier for people to rapidly learn about more distant violence, cell phone networks have caused more people to flee the same violence. This has increased the impact of violence as a cause of

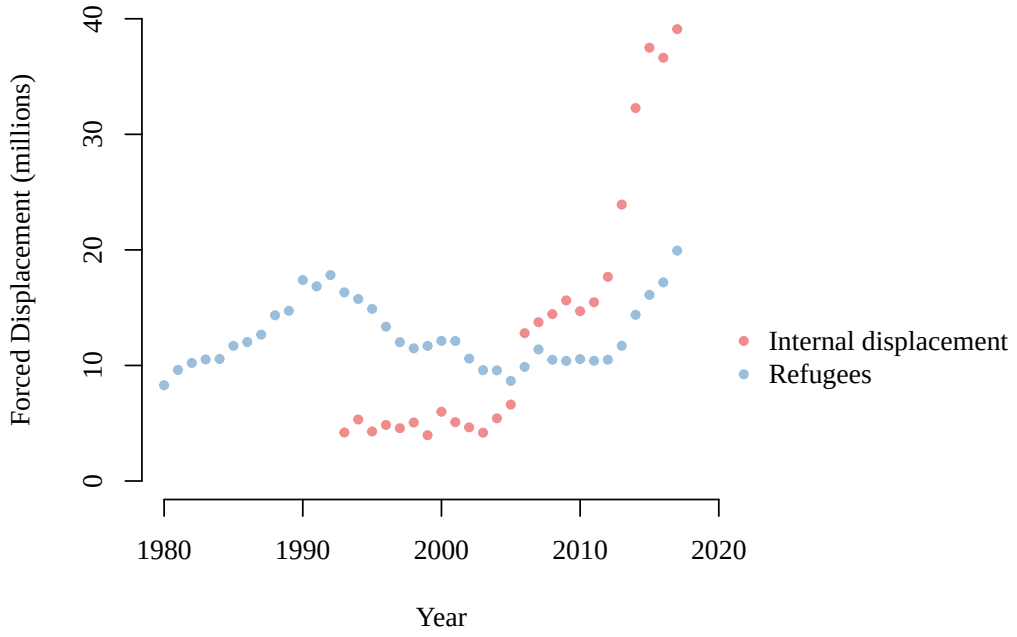


Figure 1: Global trends in forced migration.

displacement.

To test this proposition, I focus on cell phone access in the Colombian civil war. I combine detailed geospatial data on cell coverage provided by the GSM Association with geocoded data on internal displacement and violence. Detailed data compiled by the Colombian government counts the number of internally displaced persons who fled each municipality in Colombia annually. Displaced persons were required to register and be counted to receive government benefits, so this provides a consistent measure of internal displacement across the country. In order to determine the causal effect of cell phone coverage on internal displacement I use a geographic regression discontinuity design along the cell network coverage boundary. The assumption underlying this method is that cell phone coverage is as-if-randomly determined for the subset of individuals who live near the mobile coverage boundary.

Analyses using this research design consistently demonstrate that cell phone coverage increases the number of internally displaced individuals, causing an average of over one hundred more people to become internally displaced per municipality for municipalities on the cell coverage boundary. I test and reject an alternate mechanism, that cell phone coverage causes more internal displacement by changing the production of violence by armed groups. If insurgents use mobile phone technology

to better coordinate attacks on civilian populations or to target individuals more precisely, changes in insurgent violence caused by cell coverage could be the cause of increased fleeing, rather than rumors playing the hypothesized role in internal displacement. However, this is not the case. Using the same geographic regression discontinuity design, I show that cell phone coverage has no effect on multiple different measures of selective and indiscriminate violence.

This finding contributes to our understanding of the origins of humanitarian crises. My findings suggest that the impact of new communication technologies interacts with existing dynamics within social networks. Where communication technology facilitates the spread of rumors, it can exacerbate humanitarian crises and increase the impact of violence on displacement. This finding also has implications for our understanding of the consequences of cell phone coverage. I highlight that despite its many benefits, the expansion of cell phone networks can unintentionally enable the spread of uncertain and misleading information, rather than helping people make better informed decisions.

2 Theory and Hypotheses

How does the introduction of new communications technologies affect the decision-making of people caught in humanitarian crises? I argue that the expansion of cell phone networks in conflict zones has the potential to increase the number of people displaced by a given quantity of violence by facilitating the rapid spread of rumors about violence. Rumors in such insecure environments have added potency because of the dilemma created by the reality of the possibility of violence combined with the difficulty of getting fast and accurate information.

For individuals living in the midst of conflict, the dilemma of when and if to flee ones' home is both difficult and of great importance. As Adhikari (2013) notes, "people make a decision to flee or stay even under highly dangerous circumstances." No one wants to be a victim of violence, but in many insurgencies the likelihood of violence targeting the average person is low. People living in rural areas, where most insurgencies are located, often have substantial ties to local communities and much of their wealth tied up in assets that are not easily moveable: houses, land, or livestock. They may also have locally relevant human and social capital that would be lost if they were to leave. Therefore, there can be significant reasons to remain in an area with the potential for

violence.[1] Yet for the millions of people living insecure environments around the world it can be difficult to know whether it is safe and if or when an attack might come.[2] Even if infrequent, an individual living in the midst of an insurgency is always at risk of becoming a victim of a false denunciation or indiscriminate violence (Kalyvas, 2006). This constant risk makes it important to pay attention to any information available on the changing risk of violence.

For people deciding whether to flee or stay, information about the risk of violence is vital. A long literature argues that violence is a major cause of refugees and internal displacement (Apodaca, 1998; Davenport, Moore and Poe, 2003; Gibney, Apodaca and McCann, 1996; Jonassohn, 1993; Moore and Shellman, 2004, 2006; Rummel, 1994; Schmeidl, 1997; Weiner, 1998). More recent micro-level approaches confirm that violence causes displacement (Adhikari, 2013, 2012; Bohra-Mishra and Massey, 2011; Lozano-Gracia et al., 2010).[3] However, violence perpetrated against civilians will only causes fleeing if other individuals know about it. Rumors provide information about violence, albiet with substantial uncertainty.

The problem faced by people living in the middle of a civil war is that timely and accurate information can be especially difficult to obtain. Insecure environments are rife with rumors. They can be true or false, but are usually unverified. Rumors have been shown to be particularly pervasive in situations where accurate information is scarce, including periods of economic turbulence, conflict, or social unrest (Allport and Postman, 1947; Shibutani, 1966; Fine, Heath and Campion-Vincent, 2005; Fine and Ellis, 2010). Beyond simply spreading in such environments, rumors can change the behavior of large numbers of people, motivating them to engage in interethnic violence (Bhavnani, Findley and Kuklinski, 2009; Varshney, 2003), to support insurgent groups (Larson and Lewis, 2018) or avoid the use of government services during a refugee crises (Carlson, Jakli and Linos, 2017). Recent work by Greenhill and Oppenheim (2017) finds that belief in rumors in insurgency-affected areas crosses class, age, and gender divides and that security-related anxiety

[1]The cost of fleeing is not insignificant. Ibáñez and Vélez (2008) estimate that the welfare loss of internal displacement in Columbia, the case also considered here, is 37 percent of the net present value of rural lifetime aggregate consumption.

[2]Nordstrom (1997) illustrates the dilemma facing civilians living in war zones with a quote from a man in Mozambique: "if you try to protect yourself and flee you lose everything. If you stay you may keep your possessions and lose your life."

[3]Though violence is the dominant explanation for forced displacement in the literature a number of studies have proposed other mechanisms for displacement. These include economic factors (Adhikari, 2013, 2012; Czaika and Kis-Katos, 2009; Engel and Ibáñez, 2007), social capital (Ibáñez and Vélez, 2008; Engel and Ibáñez, 2007), and political support (Balcells and Steele, 2016; Steele, 2011).

drives belief in rumors. This suggests that rumors should be especially powerful in environments with legitimate security concerns. Like people in other insecure environments, residents of conflict zones faced with the daily decision to flee or remain listen to rumors because of the lack of better sources of information and the serious consequences on the line.

Rumors have always been ubiquitous during civil war, but their ability to spread has been dramatically transformed by the global spread of mobile phone networks. Cell phones allow rumors to travel greater distances and to rapidly reach far more people. In contrast to other communication technologies, cell phone networks foster horizontal social connections rather than creating vertical links between the state and society (Warren, 2015). These horizontal social connections are vital because social networks aid the spread of rumors (Larson, 2013). Mass media has been used to mobilize for violence during conflict (e.g., Yanagizawa-Drott, 2014), but because these are one-way communication technologies, they do not allow the propagation of rumors through social networks cell phone networks facilitate.

A growing literature addresses the ways in which cell phones are transforming multiple aspects of conflict. Cell phone networks have been shown to increase the likelihood of political violence by lowering the cost of collective action (Christensen and Garfias, 2015; Pierskalla and Hollenbach, 2013), increase informing by civilians (Shapiro and Weidmann, 2015), and to affect conflict intensity through audience costs (Jones and Mattiacci, 2017; Zeitzoff, 2018). Gohdes (2015) shows that governments have strategically used cell network shutdowns to hide atrocities. This line of research focuses on the decreased communications costs due to cell phone networks for combatants. It also decreases communications costs for non-combatants in conflict zones. For example, Weidmann (2015) traces the spread of information about ethnic violence spread via cell phone calls and SMS and shows that it affects civilian behavior through communication networks and Berger, Kalyanaraman and Linardi (2015) show that cell phones are used to share information about low-level political violence during civil unrest.

Two features of cell phone networks facilitate the spread of rumors and cause fleeing. First, the ability to communicate with cell phones increases the geographic spread of information about violence. Relevant information about the risk of violence is very local, so communication technology allowing rumors to spread far beyond their locations of origin is unlikely to be helpful. However, the origins of rumors are often obscured as they travel through social networks, so geographically

dispersed rumors can cause fleeing. Second, cell phones increase the speed at which information can spread. In the absence of cell phone coverage people may still learn about violence, either through face to face communication or traditional media, but the lag can reduce its impact. Learning of nearby violence several days after the fact is different from immediate news because individuals already the lack of violence in their village or town in the intervening period. The rapid spread of information with cell phones may also reduce the quality of the rumors, which can now pass through many more people since their origins.

My primary hypothesis follows from the above discussion. I anticipate that access to cell phone networks will increase the likelihood of fleeing for a constant level of violence. The spread of rumors between non-combatants is not expected to affect insurgent violence, so I do not expect cell phone coverage to increase the likelihood of indiscriminate, selective, or collective violence.

3 Data

To estimate the effect of new communication technology on internal displacement, I combine data on internal displacement, violence and demographics in Colombian municipalities with data on the geographic extend of cell phone coverage. To determine the treatment status of each municipality and its distance to the coverage boundary I overlay the 2007 cell phone coverage map with maps of the geographic extent of Colombian municipalities. Data were compiled from multiple sources. Table 1 shows descriptive statistics for Colombian municipalities between 2007 and 2008.

Information on internal displacement was provided by Acción Social, a Colombian government agency that provides social services for people displaced by the civil war. Counts of internally displaced people by municipality of origin were compiled from administrative data on individuals vetted and approved as internally displaced by government officials. Figure 2 shows the geographic distribution of the origins of internally displaced people in Colombia. The presence of an active insurgency in many different parts of the country has caused internal displacement across Colombia, rather than being concentrated in only a single region.

In order to rule out alternative mechanisms, this was combined with municipality-year data on violence against civilians provided by another Colombian Government agency, the Centro Nacional de Memoria Histórica. This includes data on multiple forms of violence, including massacres,

Table 1: Descriptive Statistics across Municipalities

Statistic	N	Mean	St. Dev.	Min	Max
Treated (cell phone coverage)	2,232	0.34	0.47	0	1
Distance to coverage boundary (m)	2,232	44,281.25	97,703.45	47.21	831,298.40
Internally displaced deople	2,232	402.36	1,054.47	0	21,068
Massacres	2,232	0.01	0.12	0	2
Massacres deaths	2,232	0.06	0.60	0	11
Collateral damage incidents	2,232	0.004	0.08	0	3
Collateral damage deaths	2,232	0.01	0.16	0	5
Civilian assassination incidents	2,232	0.13	0.78	0	17
Civilians assassination deaths	2,232	0.17	1.03	0	21
Attacks on settlements	2,232	0.003	0.05	0	1
Deaths during attacks on settlements	2,232	0.001	0.04	0	2
Property damage	2,232	0.01	0.13	0	3
Population (2005)	2,232	38,367.42	233,461.90	225	6,840,116

collateral damage, assassinations, attacks on settlements, and property damage. The perpetrators of violent acts are not specified but are most likely to be the FARC and ELN, the largest paramilitary group, the AUC, having disbanded in 2006. In addition, I collected municipal population data from the 2005 census. Importantly, these data were sourced through face to face interactions, independently of cell phones, which could cause bias, with results driven by increased reporting in areas with cell phone coverage (Weidmann, 2016).

Data on the spatial extent of cell phone coverage were provided by Collins Bartholomew and the GSM Association, which have compiled coverage data from network providers. This map shows the geographic extent of 2G cell phone coverage at the beginning of 2007, representing the ability to make phone calls and send text messages, the primary forms of mobile communication in the mid-2000s. I consider a municipality treated if the geographic centroid of the municipality has cell phone coverage. Similarly, the distance to the cell phone coverage boundary is calculated as the shortest distance from the municipalities' centroid to the closest point on the cell phone coverage boundary. This is necessary because there is no information available on the exact origins of internally displaced people or of violent acts within municipalities. Figure 3 shows the 2007 cell phone coverage map overlaying the data on internal displacement.

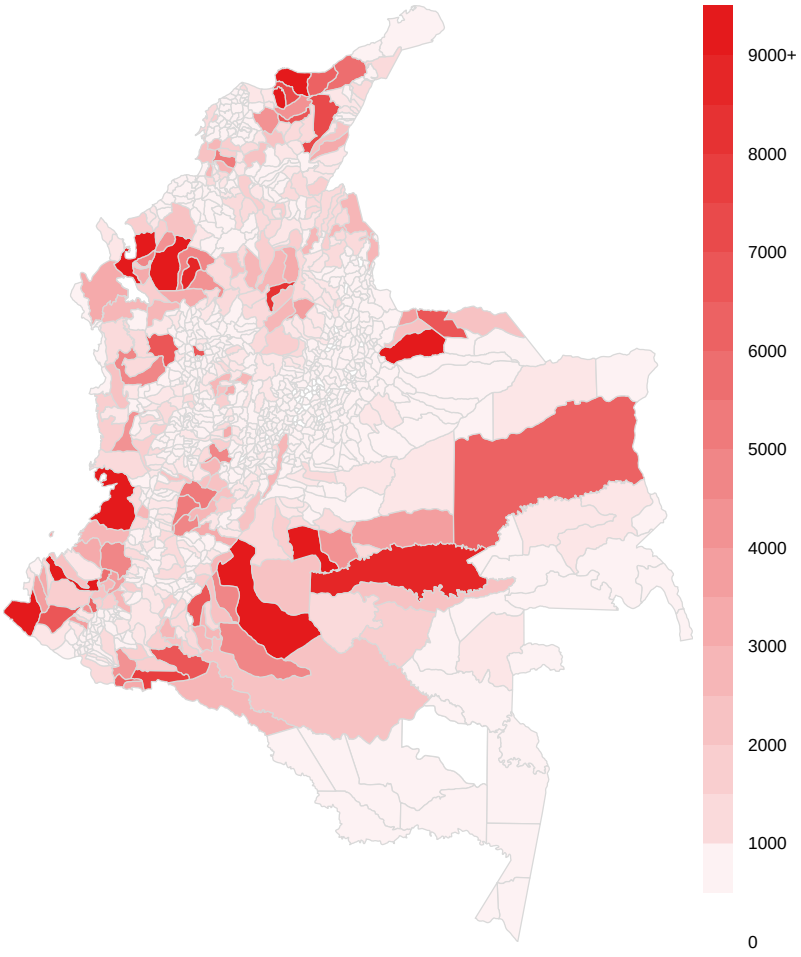


Figure 2: Internal Displacement, 2007-2008

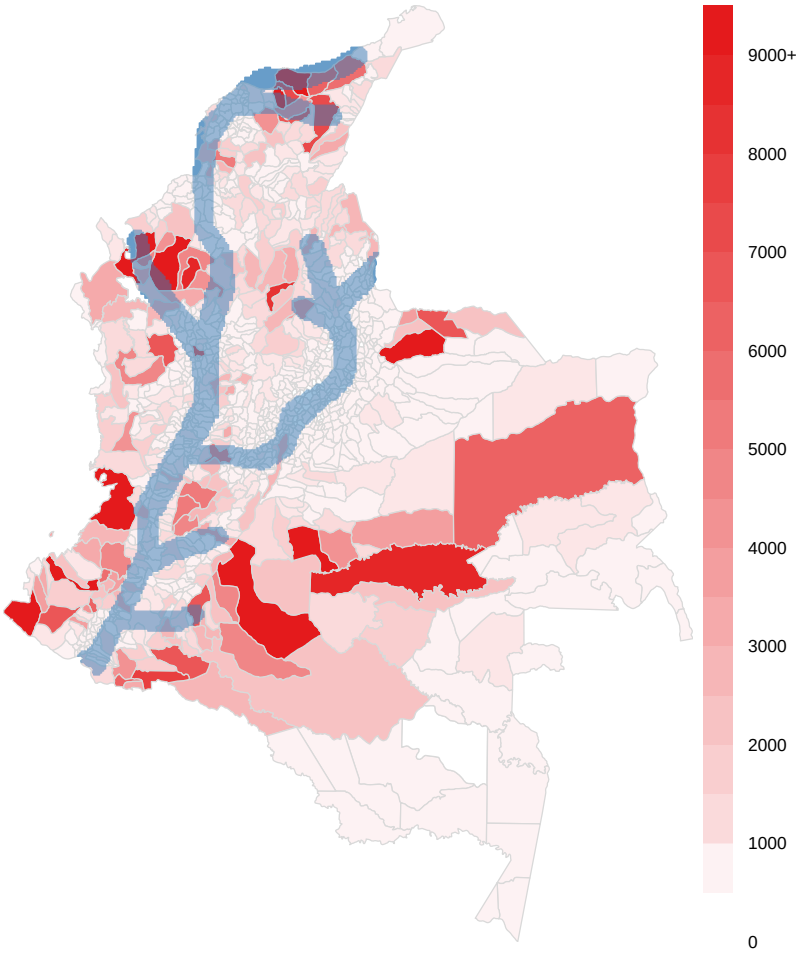


Figure 3: Cell Phone Coverage, 2007

4 Empirical Approach

In order to estimate the causal effect of access to cell phone coverage on internal displacement, I use a geographic regression discontinuity design first proposed by Dell (2010) and further developed by Keele and Titiunik (2015). The geographic regression discontinuity design exploits spatial proximity to the cell phone coverage boundary between treated and control units under the assumption that the boundary is not strategically drawn based on differing characteristics across the boundary.

Intuitively, individuals who live near each other and near the cell phone coverage boundary are expected to be similar. The exact path of the coverage boundary is a complex function of the placement of cell towers and terrain. Given the fixed topography, network providers seeking to provide coverage in urban areas have little ability to strategically draw the coverage boundary in ways that might be affected by the course of the conflict. People who barely have cell phone coverage and people who barely do not live near each other, so apart from differences in cell phone coverage they have similar experiences. Formally, the identifying assumption to estimate the average treatment effect at the boundary in the geographic regression discontinuity design requires that all relevant factors besides treatment vary smoothly at the boundary. It is possible that there are some differences between areas on either side of the coverage boundary. Cell phone networks are often build in areas with higher population density. Some of the literature suggests that combatants may alter their behavior in response to cell phone coverage, which might cause displacement independently from rumors of violence. I address these possibilities in two different ways. First I control for multiple measures of selective, indiscriminate and collective violence, property damage, and population in regression estimates. Second, I test the continuity assumption explicitly by estimating the effect of cell phone coverage on multiple factors that could affect internal displacement, especially the behavior of insurgents. This enables me to evaluate whether the effect of cell phone coverage operates through a different mechanism by changing insurgent violence rather than by facilitating the spread of rumors.

In order to identify cell phone coverage as the cause of internal displacement, there cannot be a compound treatment. This occurs if other relevant factors vary discontinuously across the boundary. In this case compound treatments are unlikely to be a concern because the shape of the cell phone coverage boundary is a function of the placement of cell towers, terrain features,

and technical limitations of the GSM standard. Therefore the boundary is unlikely to correspond to other boundaries, such are larger administrative units, where policies that affect migration may vary discontinuously.

Geographic boundaries are two-dimensional discontinuities, unlike the one-dimensional thresholds encountered in ordinary regression discontinuity designs. Dell (2010) develops a spatial regression discontinuity design that is analogous to the standard regression discontinuity design, but includes boundary segment fixed effects, μ_s, so that treated and untreated groups near each other are directly compared. This prevents comparing areas on either side of the boundary that are close to the coverage boundary but not near each other.

$$y_i = \alpha T_i + X_i\beta + f(\text{geographic location}_i) + \mu_s + \epsilon_i, \tag{1}$$

where y_i represents the outcome variable of interest, T_i represents the treatment, in this case cell network coverage, X_i represents a vector of controls, and $f(\text{geographic location}_i)$ is the regression discontinuity polynomial. The cell phone coverage boundary is divided into into ten equally spaced segments, μ_s. In this specification, α is the estimated local average treatment effect at the boundary.

The simplest version of this uses a linear measure of distance to the boundary as a forcing variable.

$$y_i = \alpha T_i + X_i\beta + \gamma Dist_i + \delta T_i Dist_i + \mu_s + \epsilon_i \tag{2}$$

Green et al. (2009) have compared different regression discontinuity specifications to a randomized experiment and found that the local linear approach produced the least biased estimates.

Similarly to Dell (2010), the dependent variable is specified within geographic areas rather than as individuals at exact points. This aggregation in the data reduces the sample size and prevents fully implementing the method in Keele and Titiunik (2015), who fully generalize the one-dimensional regression discontinuity design to two dimensions. They estimate local average treatment affects at many points along the boundary, which requires many data points near each of those boundary points. However, I incorporate Keele and Titiunik's recommendation of a triangular kernel in order to place higher weights on units closer to the boundary.

5 Results

5.1 The Effect of Cell Phone Coverage on Internal Displacement

I first estimate the effect of mobile coverage on internal displacement. To do so I estimate local linear regressions using a triangular kernel with boundary segment fixed effects to compare proximate treatment and control municipalities, as shown in equation 2. These regressions are estimated within different bandwidths between 25 and 75 km around the boundary. The dependent variables is the number of people internally displaced from a municipality-year.

As panel A of table 2 shows, I find a positive and precisely estimated effect of cell phone coverage on internal displacement. In these models no control variables are included. The magnitudes of the coefficients correspond to an increase of between 140 and 175 internally displaced people from municipalities that barely have cell phone coverage. This represents a local average treatment effect for a municipality along the coverage boundary, but it is a substantial effect given the 984 municipalities in Colombia at the time. Figure 4 shows the same results graphically. The linear regressions estimated on either side of the boundary are shown. The estimated effect is the vertical distance between the two regression lines at the boundary. This represents a large substantive effect given the levels of internal displacement shown.

Panel B of table 2 shows the same estimates controlling for variables that may cause different patterns of fleeing independently from rumors. These include measures of indiscriminate, selective, and collective violence, and property damage. These are included because the possibility that cell phone coverage causes insurgents to change their behavior in ways that also affects civilians' decisions to flee presents an alternate mechanism. Measures of indiscriminate violence consist of the number of massacres in the municipality, the number of people killed in massacres, the number of incidents of collateral damage, and the number of deaths from collateral damage. Selective violence is measured by variables counting the number of incidents of civilians being assassinated and the number of civilians killed in these incidents. Collective violence includes the number of attacks on settlements and the number of deaths during attacks on settlements. Finally, I include a variable measuring the number of incidents of property damage by insurgents. I also control for population because of the possibility that higher population density in areas with cell phone coverage could affect internal displacement. Data on insurgent violence are measured post-treatment, but it is

indicative that the estimated effects are substantively similar to the results from panel A, which exclude control variables, suggesting that changing patterns of insurgent violence are not driving and giving credence to the role of rumors. I further test for changing patterns of insurgent violence in section 5.2.

These results indicate a causal effect of cell phone coverage on internal displacement and are consistent with the hypothesized mechanism that cell phone networks facilitate the spread of rumors about violence, which increase the number of people who flee. To rule out alternate mechanisms that might mediate the relationship between cell network access and displacement, I examine whether cell phone coverage causes changes in insurgent violence in the next section.

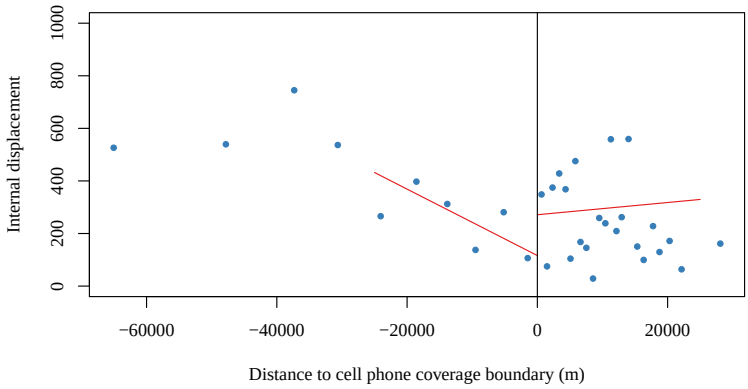
Table 2: Effect of Cell Phone Coverage on Internal Displacement

Panel A	Excluding Controls		
	(1)	(2)	(3)
Cell phone coverage	148.670***	175.494***	140.201***
	(47.448)	(43.732)	(41.400)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968
Panel B	Including Controls		
	(1)	(2)	(3)
Cell phone coverage	115.833***	137.060***	99.919**
	(46.870)	(44.304)	(43.549)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968

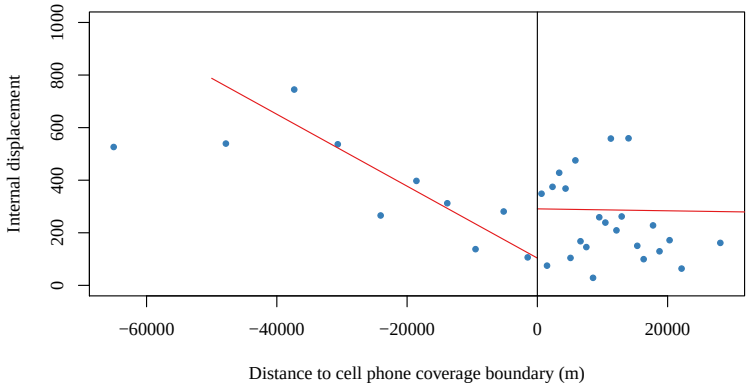
Note: Models are estimated using a local linear specification of distance to the coverage boundary as a forcing variable and a triangular kernel, both with and without controls for indiscriminate violence, selective violence, collective violence, property damage, and population, with standard errors in parenthesis. *p<0.1; **p<0.05; ***p<0.01. The outcome is the number of people internally displaced from the municipality.

5.2 Alternative Mechanisms

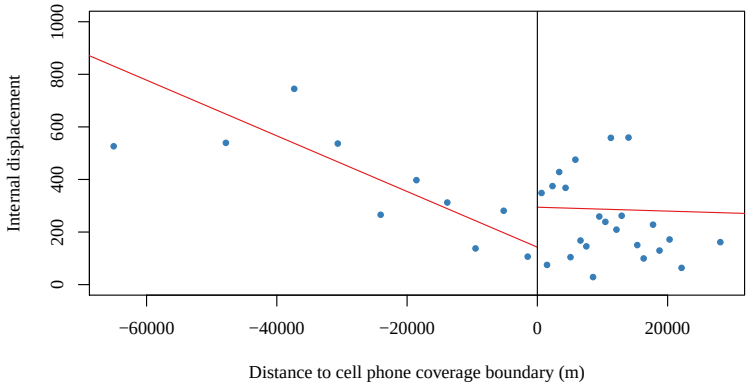
The previous results show that cell phone coverage does affect internal displacement, consistent with the theory. The hypothesized mechanism is that cell phone access facilitates the rapid spread



(a) Bandwidth: 25km



(b) Bandwidth: 50km



(c) Bandwidth: 75km

Figure 4: A graphical presentation of estimates of the effect of cell phone coverage on internal displacement shown in table 2 using a triangular kernel and a local linear specification.

of rumors, which cause individuals who would not have heard about the violence so rapidly in the absence of cell phones to flee and become internally displaced. However, cell phone coverage has the potential to affect internal displacement though other mechanisms. Chief among these is that cell phone coverage might change the behavior of armed groups. Though insurgents like the FARC have access to radio communication systems, they might use cell phones to communicate with each other or local communities when available. If access to cell phone networks affects how or where insurgents produce violence, this would provide another mechanism for the relationship between cell phone coverage and internal displacement, independent of the spread of rumors.

To evaluate whether this is the case, I use the same regression discontinuity design to estimate the effect of cell phone coverage on nine different measures of insurgent violence. Like in the estimates of the effect of cell phone coverage on internal displacement, I use a local linear specification with a triangular kernel for bandwidths between 25 and 75km. I do not include control variables in these regressions because the dependent variables used here are the control variables that were used in panel B of table 2. These estimates are also important because an assumption of the regression discontinuity design is the continuity of other causes of internal displacement across the coverage boundary. A discontinuity in these covariates could calls into question the validity of the regression discontinuity design in this context.

Table 3 shows the effect of cell phone coverage on two measures of selective violence and two measures of collective violence: the number of instances of assassinations of civilians, the number of people killed in these assassinations, the number of attacks on settlements, and the number of people killed during attacks on settlements. Of these twelve results, only one is statistically significant. A small negative effect of cell phone coverage on attacks on settlements was estimated only for the 75km bandwidth. Given the multiple comparison problem and the 27 regressions on the effect of cell phone coverage on insurgent tactics shown here, this single statistically significant result is consistent with a false positive result by chance. Even if valid, the possibility that cell phone coverage causes fewer attacks on settlements goes against the alternative mechanism of changes in insurgent violence mediating the relationship between cell phone coverage and internal displacement. It is well established that violence causes greater fleeing, so a reduction in attacks cannot be driving the result that cell phone coverage causes internal displacement. A graphical presentation of the same results are shown in figures 5-8.

Table 3: Effect of Cell Phone Coverage on Selective and Collective Violence

	Dependent Variable:		
Panel A	Civilians assassination incidents		
	(1)	(2)	(3)
Cell phone coverage	0.041	0.000	-0.004
	(0.033)	(0.029)	(0.029)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968
	Dependent Variable:		
Panel B	Civilians assassination deaths		
	(1)	(2)	(3)
Cell phone coverage	0.083	0.004	-0.005
	(0.054)	(0.049)	(0.049)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968
	Dependent Variable:		
Panel C	Attacks on settlements		
	(1)	(2)	(3)
Cell phone coverage	0.001	-0.004*	-0.006**
	(0.001)	(0.002)	(0.002)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968
	Dependent Variable:		
Panel D	Deaths during attacks on settlements		
	(1)	(2)	(3)
Cell phone coverage	0.002	-0.001	-0.002
	(0.002)	(0.001)	(0.002)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968

Note: Models are estimated using a triangular kernel, with standard errors in parenthesis. *p< 0.1; **p< 0.05; ***p< 0.01.

Table 4 shows the effect of cell phone coverage on four measures of indiscriminate violence: the number of massacres, the number of deaths during massacres, the number of incidents of collateral damage, and the number of deaths during from collateral damage. None of these results are statistically significant at the five percent level, providing no evidence that cell phone coverage affects indiscriminate violence. Finally, table 5 shows the effect of cell phone coverage on property damage committed by insurgents. Property damage could increase the likelihood of fleeing by removing some of the value in staying. However, again, there are no statistically significant results. A graphical presentation of these results are shown in figures 9-13.

Not only are there not statistically significant effects of cell coverage causing any increases in insurgent violence, but the insignificant point estimates are consistently small. Often estimates for different bandwidths change sign. This suggests that these null results are not simply caused by a lack of statistical power. Even if some results were statistically significant they would not be substantively significant.

5.3 Placebo Tests

To further validate the use of the geographic regression discontinuity along the cell network boundary, I conduct a placebo test, replicating the estimates of the effect of cell phone coverage in 2007 on internal displacement before the existence of cell phone networks in Colombia. Because rumors could not have spread through mobile phone networks before the networks were established, a significant result for the placebo test could indicate that the main results are spurious and are caused by violations of the assumptions underlying the regression discontinuity design.

The first cell phone network in Colombia was created in 1994.[4] No information is available on the precise extent of the mobile phone network before 2007, but there is a possibility that older cell tower locations remained in use in 2007, which could cause some portions of the mobile coverage boundary between 1994 and 2006 to correspond to the boundary in 2007. Therefore, I use data on internal displacement between 1992 and 1993, right before the establishment of the cell network, as a dependent variable for the placebo test. If the estimated effect of cell phone coverage is driven by differences between places that have and no one have cell phone coverage rather than because of the ability to communicate using cell phones, there could be an estimated effect even before the

[4] http://caracol.com.co/radio/2013/05/31/tecnologia/1370007960_908446.html

Table 4: Effect of Cell Phone Coverage on Indiscriminate Violence

	Dependent Variable:		
Panel A	Massacres		
	(1)	(2)	(3)
Cell phone coverage	-0.002	-0.003	-0.004
	(0.009)	(0.009)	(0.008)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968
	Dependent Variable:		
Panel B	Massacre deaths		
	(1)	(2)	(3)
Cell phone coverage	-0.010	-0.006	-0.011
	(0.045)	(0.041)	(0.039)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968
	Dependent Variable:		
Panel C	Collateral damage incidents		
	(1)	(2)	(3)
Cell phone coverage	0.006	0.003	0.001
	(0.004)	(0.005)	(0.005)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968
	Dependent Variable:		
Panel D	Collateral damage deaths		
	(1)	(2)	(3)
Cell phone coverage	0.007*	0.001	-0.002
	(0.004)	(0.007)	(0.007)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968

Note: Models are estimated using a triangular kernel, with standard errors in parenthesis. *p< 0.1; **p< 0.05; ***p< 0.01.

Table 5: Effect of Cell Phone Coverage on Property Damage

	Dependent Variable:		
	Property damage		
	(1)	(2)	(3)
Cell phone coverage	-0.008	-0.011	-0.008
	(0.007)	(0.007)	(0.007)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968

Note: Models are estimated using a triangular kernel, with standard errors in parenthesis. *p< 0.1; **p< 0.05; ***p< 0.01.

existence of the cell network.

As expected, the placebo test fails to find any statistically significant effects. Table 6 and Figure 5 show the results of the placebo test, which were estimated identically to the main results. Panel A shows the regression discontinuity results without control variables other than boundary segment fixed effects and panel B shows the same results controlling for insurgent violence and population 1992-1993. Not only are there no statistically significant results, the point estimates are consistently small and negative. Even if the lack of significance resulted from a lack of statistical power, the placebo test would show very different effects from the effect of cell phone coverage on internal displacement shown in table 2.

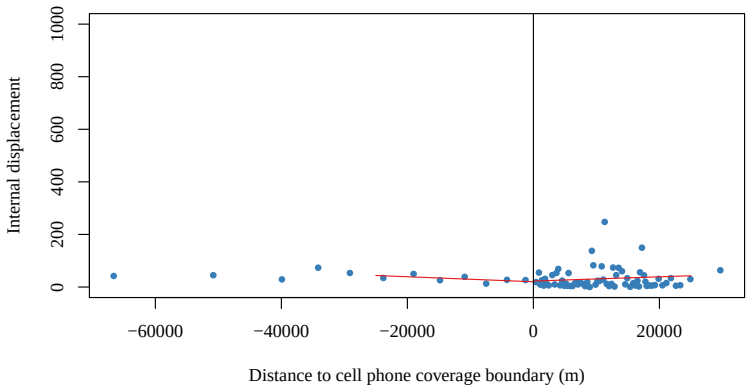
6 Conclusion

Existing research and popular discourse on cell phone technology often emphasizes the positive impacts communication technology can have in the developing world. For example, the global expansion of cell phone networks has been shown to reduce inefficiencies caused by information asymmetries (Aker, 2010) and increase opportunities for political access for marginalized populations (Grossman, Humphreys and Sacramone-Lutz, 2014; Grossman, Michelitch and Santamaria, 2017; Grossman, Platas and Rodden, 2017). This paper, however, demonstrates a negative externality associated with the rapid expansion of communication technology. Using a geographic discontinuity, I have shown that cell phone coverage significantly and substantially increases the

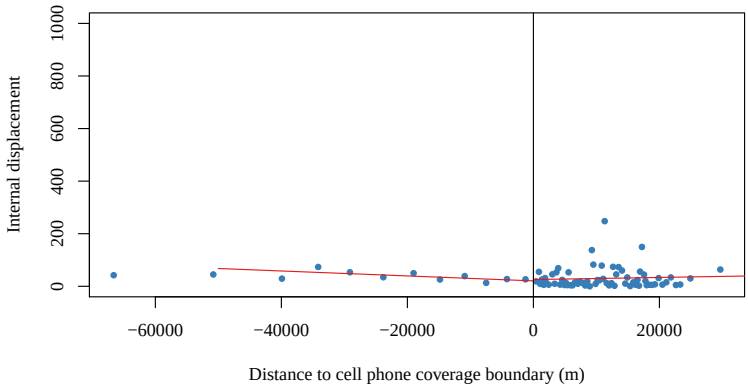
Table 6: Placebo test for the Effect of 2007 Cell Phone Coverage on Internal Displacement in 1992-1993

Panel A	Excluding Controls		
	(1)	(2)	(3)
Cell phone coverage	-3.829	-0.778	-4.726
	(5.798)	(5.470)	(5.162)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968
Panel B	Including Controls		
	(1)	(2)	(3)
Cell phone coverage	-4.512	-2.378	-6.846
	(5.846)	(5.538)	(5.251)
Bandwidth	25km	50km	75km
Observations	1424	1818	1968

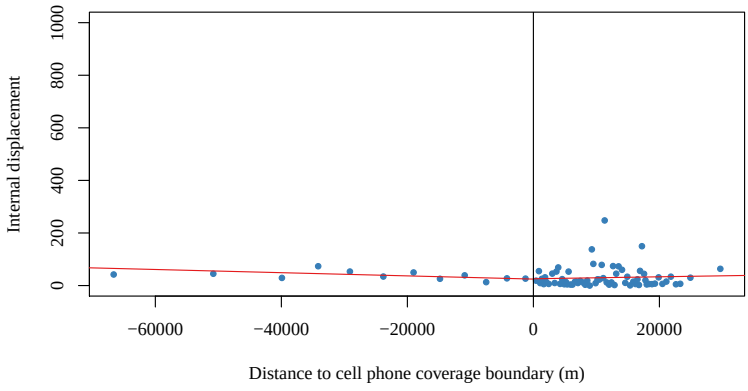
Note: Models are estimated using a local linear specification of distance to the coverage boundary as a forcing variable and a triangular kernel, both with and without controls for indiscriminate violence, selective violence, collective violence, property damage, and population, with standard errors in parenthesis. *p<0.1; **p<0.05; ***p<0.01. The outcome is the number of people internally displaced from the municipality.



(a) Bandwidth: 25km



(b) Bandwidth: 50km



(c) Bandwidth: 75km

Figure 5: A graphical presentation of estimates of the placebo test for the effect of cell phone coverage in 2007 on forced displacement 1992-1993 that are shown in table 6 using a triangular kernel and a local linear specification.

number of people fleeing their homes during war. Furthermore, I have shown that increase in forced displacement is not caused by changes in the production of violence by insurgents, rather it is a result of lowered costs of communication. This provides evidence that the mechanism underlying this strong effect is the rapid spread of rumors that these communication technologies can facilitate. The mechanism allows cell phone technology to boost the impact of violence during war and increase the magnitude of humanitarian crises.

My findings provide some important avenues for extension. First, further analysis of the mechanisms underlying the positive relationship between cell phone coverage and internal displacement is warranted. While I have described how cell phone coverage can facilitate the spread of rumors that are ubiquitous in wartime and which can cause fleeing, the empirical analysis is limited to ruling out alternative mechanisms because of the inability to measure the content of rumors and their flow through social networks in this context. Further work should therefore be done to examine the content of rumors during wars, how they spread through social networks, and when and why rumors are believed and acted upon. More broadly, more effort should be invested in understanding the nature of the communication networks created and transformed by mobile technologies and how people living in insecure environments use these social networks to learn about the risk of violence and make difficult decisions.

Second, further analysis into the generalizability of my findings is also necessary. My results are limited in that I examined the effects of cell phone coverage over a short time period in a single country. While these are causal effects, it is unclear whether there might be heterogeneous effects across different time periods and geographic contexts. For example, has the relationship between cell phone coverage and changed in the past decade as mobile phones have transformed from being solely used to make voice calls and send sms messages to devices used to access the internet and online social networks. An attempt to examine this effect with more data spanning a longer time period and covering different regions of the world would provide more confidence as to the temporal and geographic external validity of these findings.

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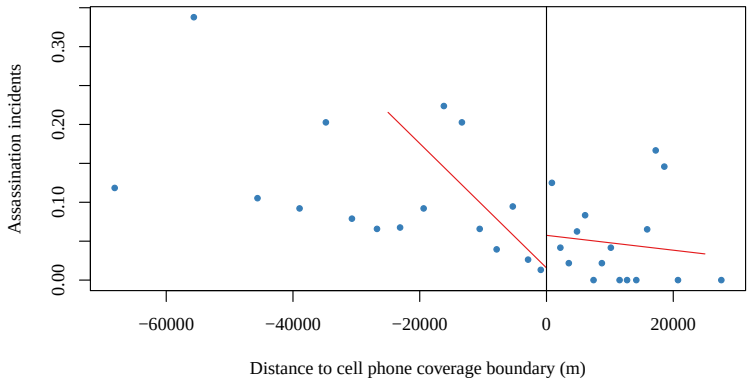

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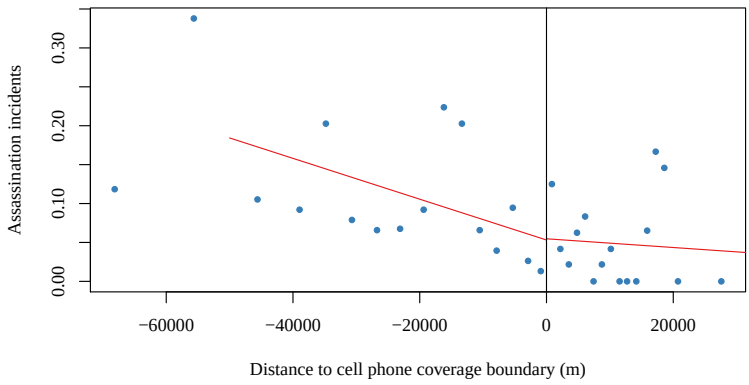

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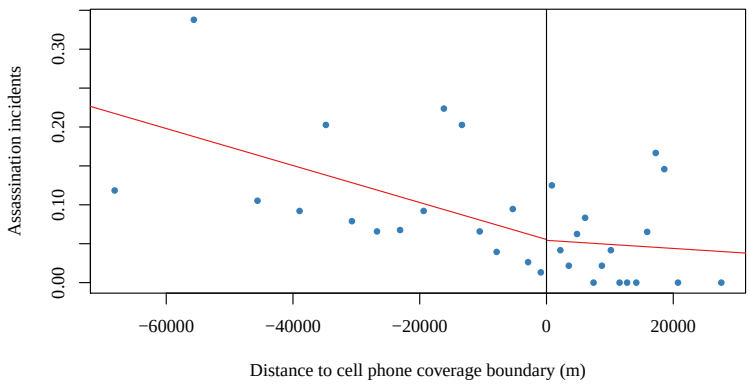
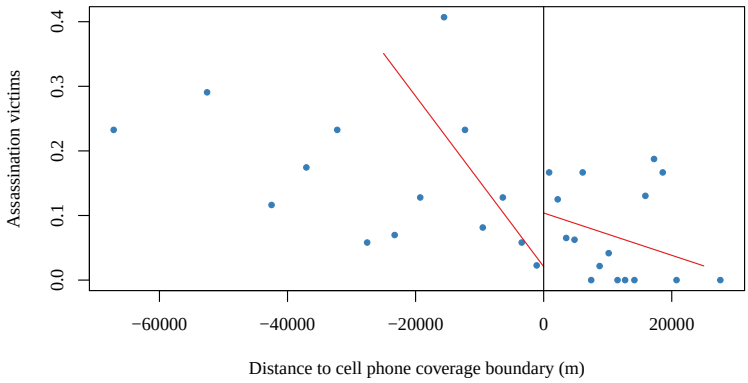


(c) Bandwidth: 75km

Figure 6: A graphical presentation of estimates of the effect of cell phone coverage on civilians assassination incidents shown in table 3 using a triangular kernel and a local linear specification.



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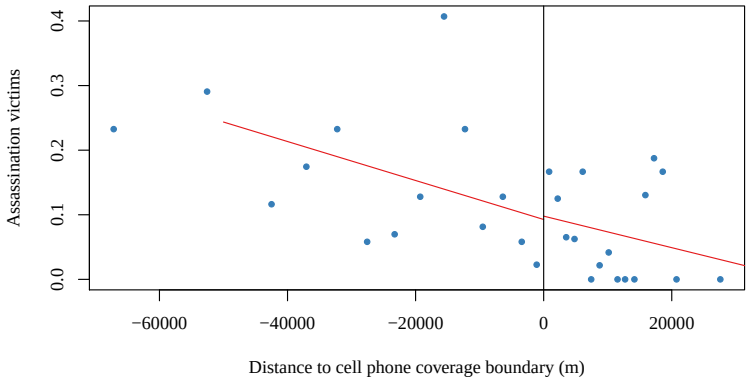

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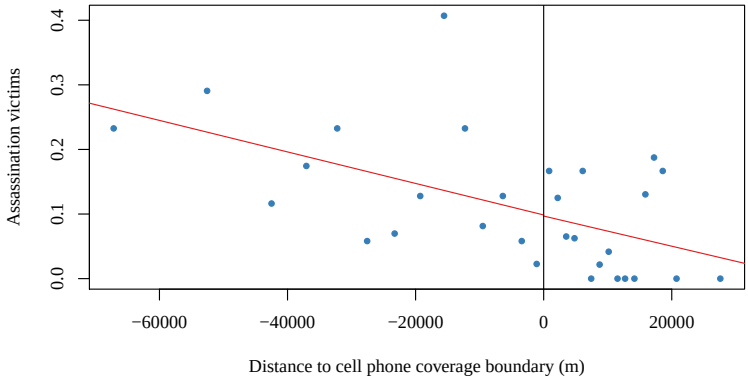

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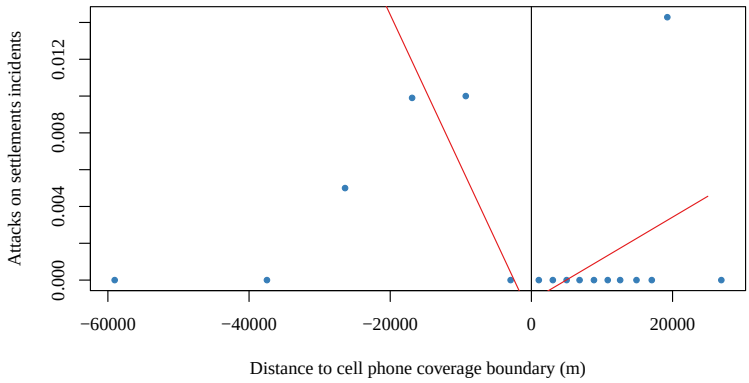
Figure 7: A graphical presentation of estimates of the effect of cell phone coverage on civilians assassination deaths shown in table 3 using a triangular kernel and a local linear specification.



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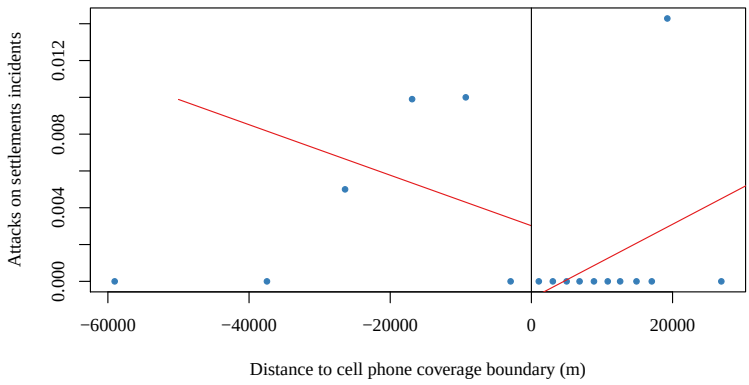

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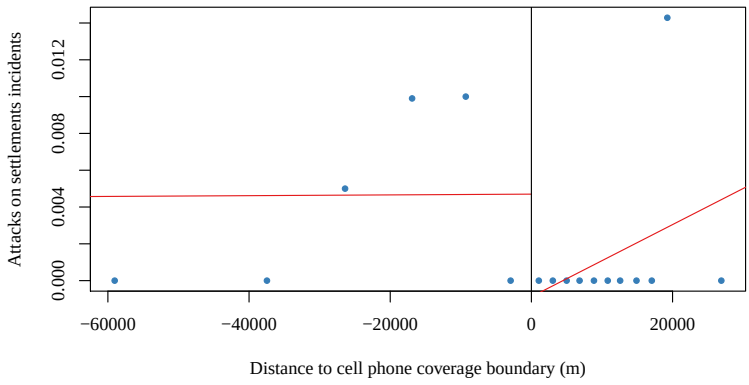

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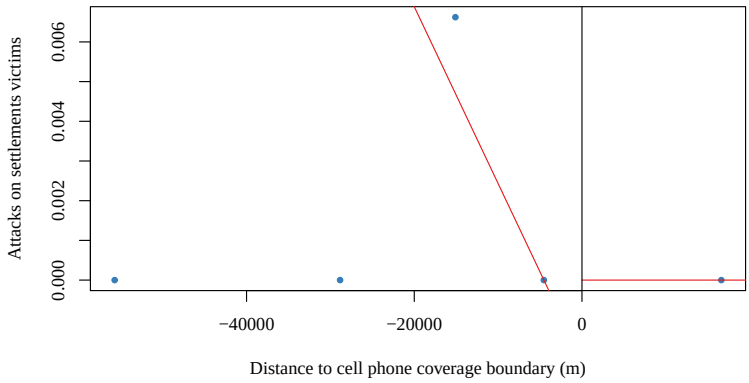
Figure 8: A graphical presentation of estimates of the effect of cell phone coverage on attacks on settlements shown in table 3 using a triangular kernel and a local linear specification.



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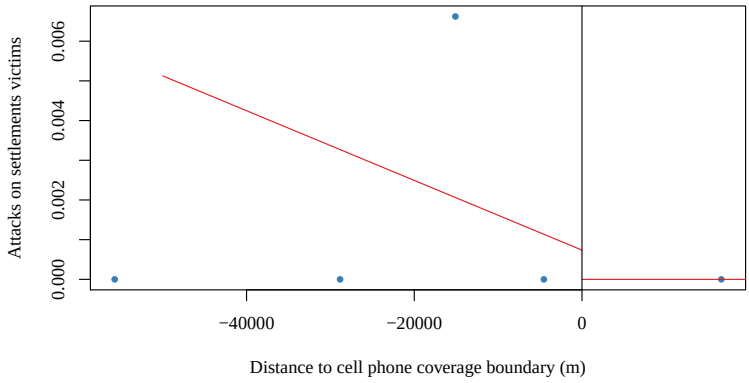

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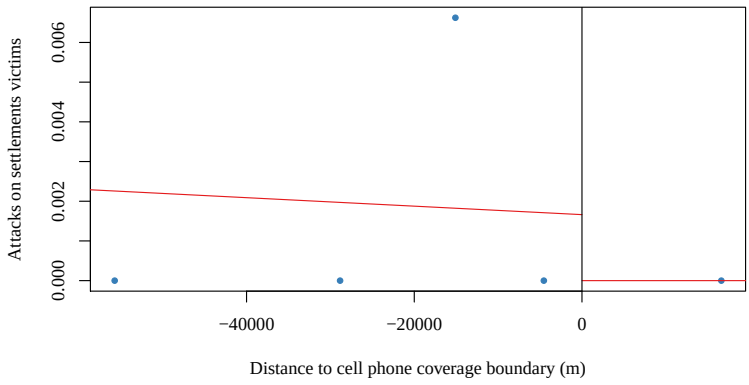

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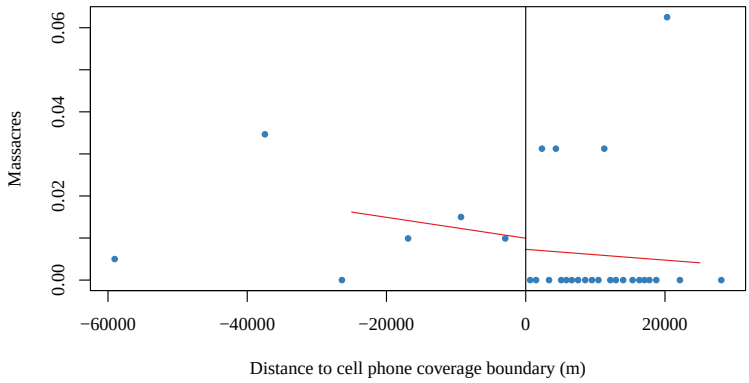
Figure 9: A graphical presentation of estimates of the effect of cell phone coverage on deaths during attacks on settlements shown in table 3 using a triangular kernel and a local linear specification.



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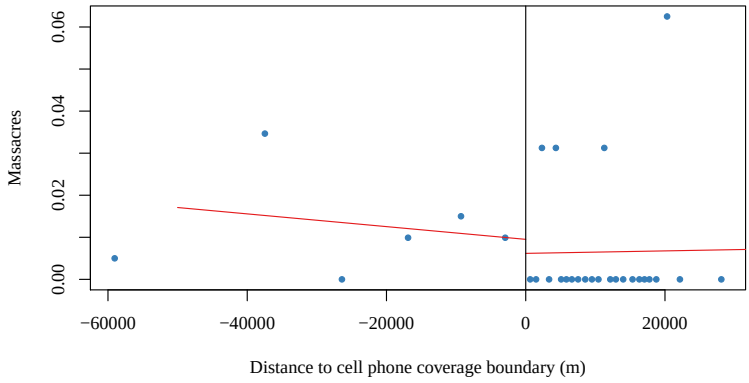

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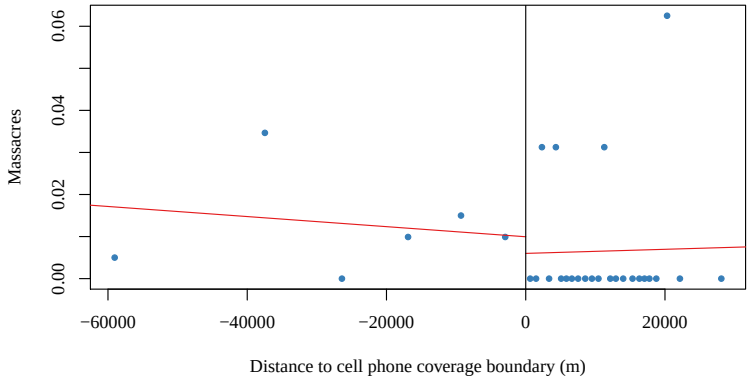

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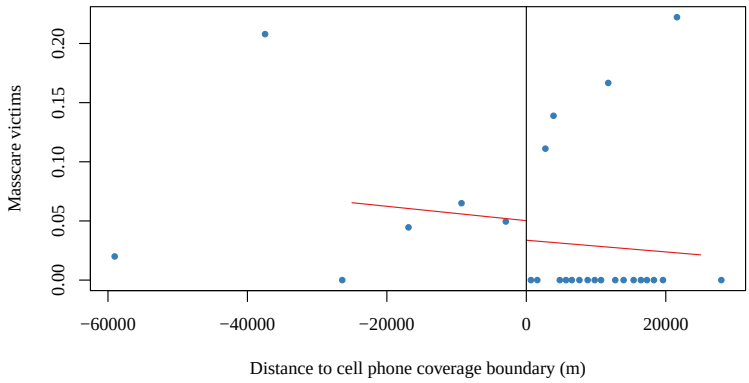
Figure 10: A graphical presentation of estimates of the effect of cell phone coverage on massacres shown in table 4 using a triangular kernel and a local linear specification.



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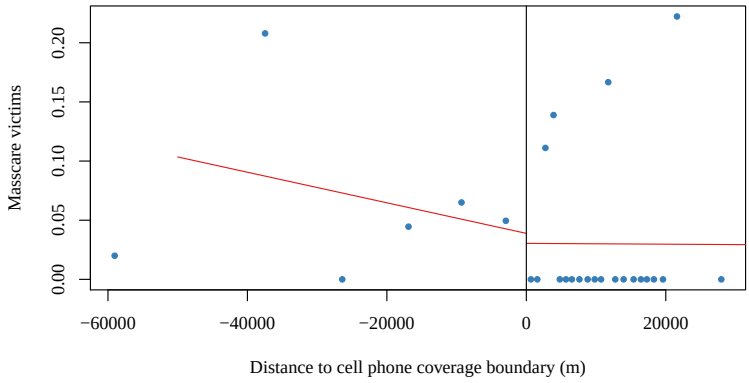

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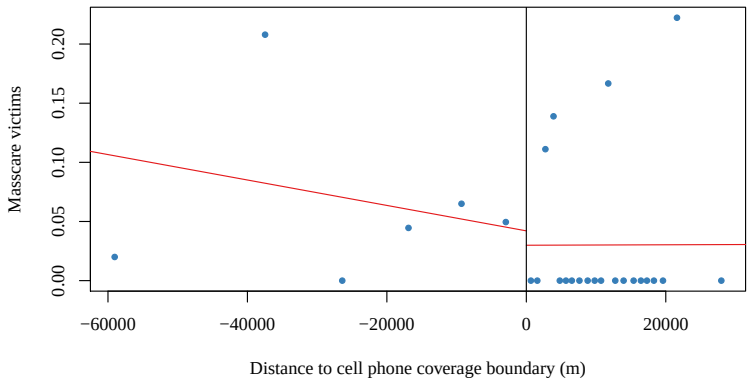

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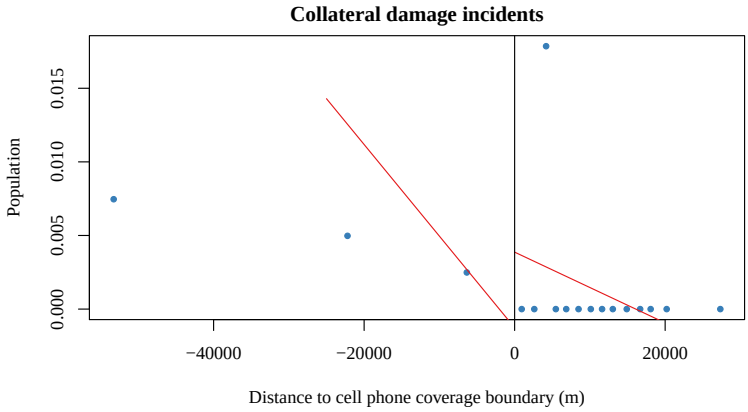
Figure 11: A graphical presentation of estimates of the effect of cell phone coverage on massacre deaths shown in table 4 using a triangular kernel and a local linear specification.



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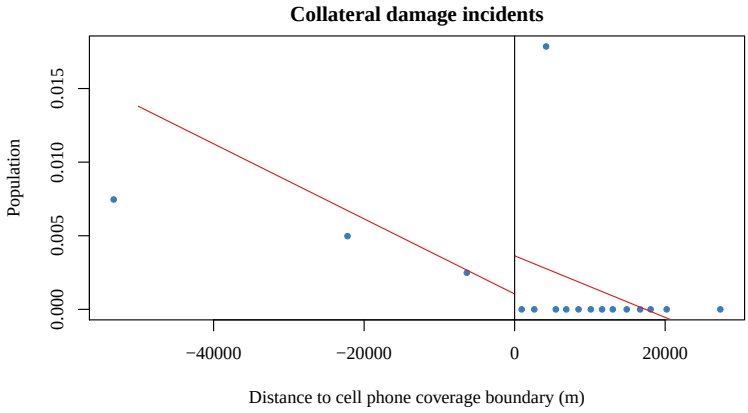

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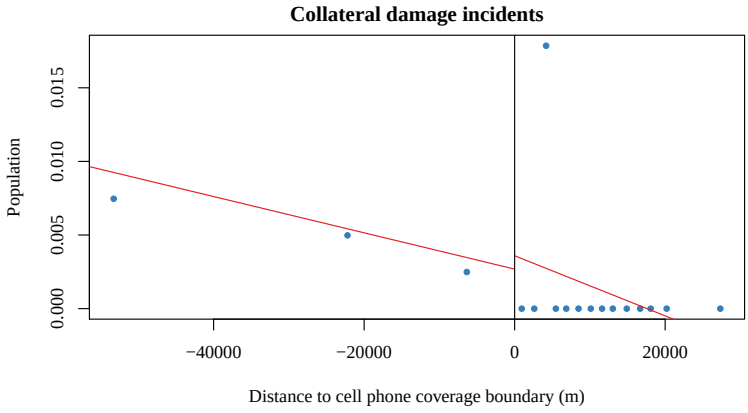

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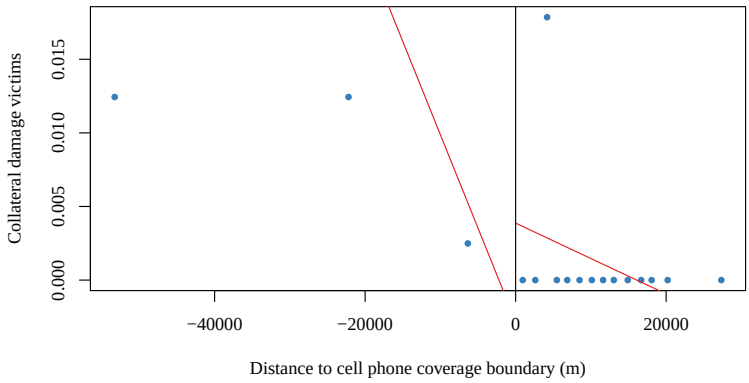
Figure 12: A graphical presentation of estimates of the effect of cell phone coverage on collateral damage incidents shown in table 4 using a triangular kernel and a local linear specification.



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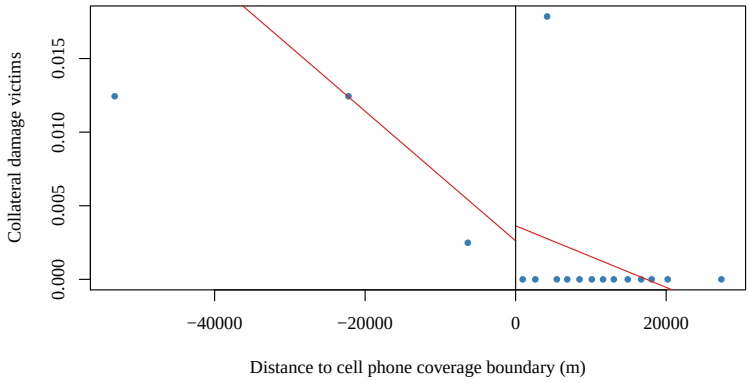

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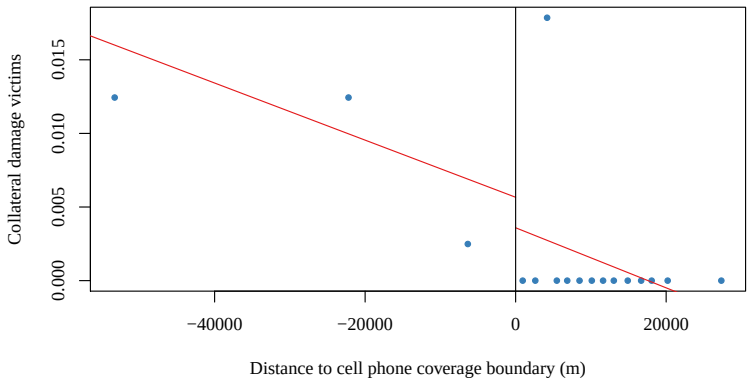
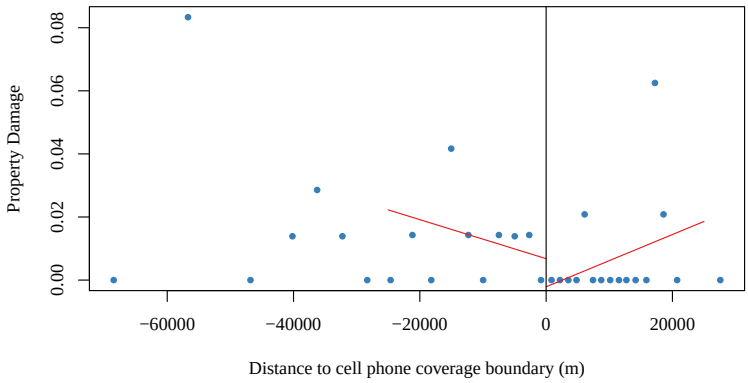
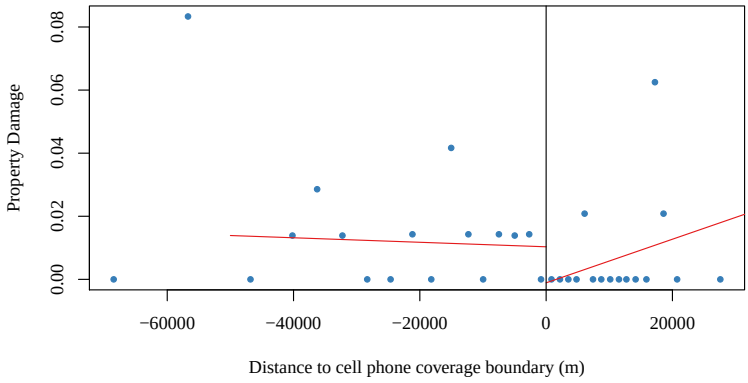


(c) Bandwidth: 75km

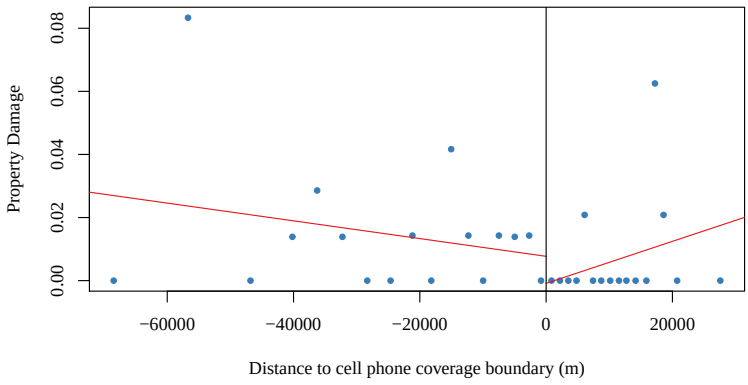
Figure 13: A graphical presentation of estimates of the effect of cell phone coverage on collateral damage deaths shown in table 4 using a triangular kernel and a local linear specification.



(a) Bandwidth: 25km



(b) Bandwidth: 50km



(c) Bandwidth: 75km

Figure 14: A graphical presentation of estimates of the effect of cell phone coverage on property damage shown in table 5 using a triangular kernel and a local linear specification.