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Warren, T. Camber

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Explosive Connections?

Mass Media, Social Media, and the Geography of Collective Violence in African States[§]

T Camber Warren

Department of Defense Analysis
Naval Postgraduate School

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ABSTRACT

Growing evidence indicates that the diffusion of information and communication technologies (ICTs) can substantially alter the contours of collective violence in developing nations. However, empirical investigations of such effects have generally been hampered by an inability to systematically measure geographic variation in ICT penetration, across multiple technologies and multiple countries. In this paper, I show that geo-referenced household surveys can be used to estimate sub-national differences in the spatial reach of radio and cellular communications infrastructures in 24 African states. By combining these estimates with geo-referenced measures of the location of disaggregated events of collective violence, I show that there are important differences between centralized ‘mass’ communication technologies – such as radios – that foster vertical linkages between state and society, and decentralized ‘social’ communication technologies – such as cell phones – that foster horizontal linkages between the members of a society. The evidence demonstrates that the geographic reach of mass media penetration generates substantial pacifying effects, while the reach of social media penetration generates substantial increases in collective violence, especially in areas lacking access to mass media infrastructure. I argue that these findings are consistent with a theory of ICT effects which focuses on the strengthening and weakening of *economies of scale in the marketplace of ideas*.

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Introduction

State influence, and the difficulties associated with extending such influence over space, have long been noted as central forces underlying the geography of collective peace and collective violence. Drawing on this insight, a wide array of studies have sought to develop more rigorous approaches to the measurement of state capacity as a means of enhancing our understanding of the complex mobilizational dynamics underlying the emergence of civil conflict (Buhaug, Gates, & Lujala, 2009; Collier & Hoeffler, 2004; Gleditsch, 2007; Fearon & Laitin, 2003; Fjelde & de Soysa, 2009; Hendrix, 2010; Lacina, 2006; Thies, 2010; Sobek, 2010). Moreover, recent quantitative work has highlighted the importance of ‘soft power’ mechanisms, rooted in the spread of information and communication technologies (ICTs), as central to both the production and disruption of domestic stability (Baillard, 2015; Pierskalla & Hollenbach, 2013; Shaprio & Weidmann, 2012; Warren, 2014; Weidmann, 2015). However, the limitations of data availability have generally forced such studies to focus their attention either on a single technology or a single country, or to rely on national aggregates that ignore within-country variation in the reach of communication infrastructures.

In contrast, the approach presented here makes possible the systematic examination of geographic variation in the reach of ICT networks, in a manner which facilitates comparisons within countries, across countries, and across technologies. The approach is based on the use of geo-coded household surveys, which record ownership of multiple kinds of media reception devices, in particular: radios and cell phones. Using spatially-explicit interpolation techniques to adjust for the uneven spacing of the survey locations, I show that it is possible to estimate local differences in the spatial reach of ICT infrastructures across 24 African states. Combining these estimates with geo-referenced measures of the location of

disaggregated events of armed collective violence, I seek to show that patterns of political violence are strongly conditioned by the spatial reach of technologies of communication.

In doing so, I seek also to provide evidence of the important differences in effects between different forms of communication technology. Extending the theoretical account presented in previous work (Warren, 2014), I argue that we can make sense of these differences by focusing on whether a given technological form generates a strengthening or weakening of *economies of scale in the marketplace of ideas*. Whereas ‘mass’ communication technologies, such as radio, have been observed to foster *vertical* linkages between state and society, by increasing the ease with which centralized authorities can broadly disseminate symbolic appeals to national unity, decentralized ‘social’ communication technologies, such as cell phones, instead foster *horizontal* flows of information between the members of a society. Because such linkages tend to form along socially segregated lines, these technologies may therefore serve to heighten, rather than suppress, the ease with which social divisions can be promoted and exploited. This account also implies that the processes through which such effects arise may be subject to a substantial degree of path dependence. African states are characterized by diverse historical legacies, and the contemporary arrival of social communication technologies may carry very different implications in areas previously untouched by mass communication technologies.

The empirical results presented below utilize the enormous diversity of state-making projects across continental Africa to provide new evidence in support of this general theoretical account. Estimating covariate effects through the application of spatial point-process models – which flexibly account for the spatial interdependence between violent event locations without relying on pre-specified spatial units of analysis – the results show that the geographic reach of mass media penetration generates substantial pacifying effects, reducing the occurrence of collective violence events across a broad sample of African states.

In contrast, the results show that the reach of social media penetration generates substantial increases in collective violence. Moreover, the results show that this increase is especially pronounced in areas that experience the introduction of social communication technology without the prior stabilizing influence of mass communication technology. In addition, using the same techniques I show that these results are robust to controls for elevation, electrification, population density, local wealth, urbanization, prior violence, and state-level fixed effects, and thus cannot be easily attributed to the aggregate effects of economic development, modernization, or coercive state capacities. Finally, using longitudinal surveys to capture variation over time in the spread of ICTs in Uganda, I show that these results are not likely to have been driven by reverse causation, as there is no evidence that ICT expansion was conditioned by the location of previous violent events. Taken as a whole, this evidence thus provides strong support for the claim that the geography of collective violence is powerfully influenced by the geography of collective ideas.

The geography of state power

Approaches to defining and measuring the concept of state capacity have varied widely in the existing literature (Benson & Kugler, 1998; Buhaug, Gates & Lujala, 2009; Collier & Hoeffler, 2004; Gleditsch, 2007; Fearon & Laitin, 2003; Fjelde & de Soysa, 2009; Hendrix, 2010; Lacina, 2006; Nye 2004; Thies, 2010; Sobek, 2010). Early treatments tended to rely on measures of economic development (i.e. GDP per capita) measured at the level of national aggregates, either as a measure of economic competition for the labor of rebel recruits (Collier & Hoeffler, 2004), or as a proxy of the state's capacity to project coercive force (Fearon & Laitin, 2003). Some more recent efforts have sought to expand this conceptualization of state power, by pointing to the importance of non-material elements of state strength, derived from the 'soft power' of symbolic appeals to state legitimacy

(Cederman, Warren & Sornette, 2011; Warren, 2014). However, these works have generally relied on nationally aggregated measurements, and have therefore been unable to consider the effects of geographic variation in state reach within countries.

In contrast, the trend in recent quantitative work in the civil conflict literature has been towards greater disaggregation of both the independent and dependent variables. Such studies have substantially deepened the statistical analysis of civil conflict by replacing country-years with units of analysis defined by individual groups, center-periphery dyads, gridded cells, group settlement areas, and other sub-national geographic units (e.g. Cederman, Girardin & Gleditsch, 2010; Cederman, Gleditsch & Weidmann, 2011; Cederman, Wimmer & Min, 2010; Cunningham, Gleditsch & Salehyan, 2009; Hegre, Østby & Raleigh, 2009; Raleigh & Hegre, 2009; Urdal, 2008; Weidmann, 2009; Wimmer & Min, 2006). These approaches have made possible the investigation of state power on a number of dimensions that were previously impermeable to direct observation, while also highlighting the crucial importance of sub-national variation in the geography of state penetration. In particular, Shapiro and Weidmann (2014) have pioneered the examination of the security implications of geographic variation in communication infrastructure, by showing that the locations of violent events in Iraq were conditioned by the spread of cell phone towers over time. Along similar lines, Pierskalla and Hollenbach (2013) utilize geographic variation in cell phone coverage to predict the location of violent events in Africa. Interestingly, while both works argue that the effects of cell phones result from a reduction in the ‘transaction costs’ of communication, Shapiro and Weidmann (2014) find cellular coverage to be associated with reduced violence, whereas Pierskalla and Hollenbach (2013) find that cellular coverage is associated with increases in violence.

While such approaches have greatly advanced our empirical understanding of the relationship between communication technologies and political violence, they have also been

subject to several important limitations, which may partially explain the apparent inconsistencies in their findings. First, the difficulties involved in directly measuring ICT penetration have generally forced existing studies to examine a single technology in isolation, making it impossible to systematically examine differences across technological forms, or interactions between them. Second, current approaches have been subject to an important statistical limitation: in order to estimate the parameters of a spatial regression, they have generally been forced to rely on pre-specified geographic units of analysis, such as grid cells, group settlement polygons, or political districts. This necessarily raises the concern of whether different empirical inferences would have been made, if the analysis had been premised on alternative geographic units of analysis. This issue, well-known amongst geographers as the modifiable areal unit problem (MAUP), can generate severe statistical biases, with widely varying directions and intensities, rendering multivariate spatial regression estimates inherently unreliable (Openshaw, 1984; Fotheringham & Wong, 1991).

In the sections that follow, I demonstrate an alternative approach which captures multivariate spatial effects without reliance on arbitrary spatial units, by using spatially-explicit interpolation (i.e. 'kriging') to characterize survey-derived independent variables as continuous spatial surfaces, and then using point-process models to simulate the emergence of point-like events in this continuous space. In addition to avoiding the statistical biases generated by arbitrary geographic units, I show that this approach also provides a rigorous means of directly comparing and contrasting the impacts of different forms of ICT penetration on the generation of collective violence, while controlling for the broader effects of modernization and development.

Technology, capacity, and the marketplace of ideas

State capacity, as I use the term here, can be defined as a state's ability to both project coercive force where needed in order to ensure the security of its citizens, while at the same time generating sufficient collective attachments so as to render internal coercion largely unnecessary. As Wintrobe (1998) argues, state power exists at the intersection of 'loyalty' and 'repression.' Different theories of state strength have emphasized these two dimensions to different degrees. Some theorists focus on the coercive instruments of surveillance, deterrence, and outright force in the development of effective state institutions (Herbst, 2000; Tilly, 1992). Others emphasize the use of public goods to gain support from politically relevant communities (Azam, 1995; Bueno de Mesquita et al., 2003; Gandhi & Przeworski, 2006; Berman, Shapiro & Felter, 2011) or the broader development of sympathies and attachments that lead citizens to willingly sacrifice for an imagined 'nation' (Anderson, 1991; Gellner, 1983; Levi, 1988, 2006).

It is important to remember that, underlying each of these processes, there is frequently substantial resistance against state encroachment on the part of peripheral populations (Scott, 2009). As a result, state capacity is never a static quantity, but rather a continual process of *state-making*. Moreover, substantial evidence exists that this process of state-making has been powerfully constrained by the forces of geography (Buhaug, 2010; Buhaug & Gates, 2002; Buhaug, Gates & Lujala, 2009; Buhaug & Rød, 2006; Lemke, 1995; Raleigh & Hegre, 2009; Weidmann, 2009). As Boulding (1962) recognized, state power must extend itself over physical space and is therefore subject to a 'loss of strength gradient' in which capacity degrades as a function of distance. Importantly, the cost of such efforts is not simply a function of physical distance, but rather a function of the cost of projecting influence, which can be powerfully constrained by the geography of both physical and social barriers (see Wood 2008).

Of course, such constraints are also rarely static. The arrival of new technologies and capacities, ranging from roads and electrification, to mass communication infrastructure, have repeatedly allowed states to extend their abilities to provide goods and project influence in previously remote locations. In the contemporary world, we find a whole spectrum of states at different stages in this process. In some states, all areas are fully incorporated into the state-making project and respect the legitimacy of state dictates, while others find themselves in the midst of incomplete projects of nation-state creation. Studying within-country variation in state penetration is therefore especially important in weak and developing states, which are often characterized by an uneven extension of national attachments (Kalyvas, 2006), and which because of their inability to pacify all, are forced to integrate some while ostracizing others (Wimmer, 2002). Indeed, this tension at the heart of nation-state creation has driven much of the conflict dynamics of the post-Cold War world (Wimmer & Min, 2006).

In such contexts, the generation and suppression of collective violence is far more complex than the mere application of military force, revolving around the extension of integrative identities as much as the extension of coercive capacities. Seen from this perspective, political violence and political communication are intimately linked, as the *idea* of collective violence must always be communicated before it can be enacted. The production of synchronized killing is necessarily preceded by the production of enemies, and the successful dissemination of the idea that killing ‘them’ is just. Moreover, given the multisided nature of most political arenas, success in this pursuit generally also requires the defeat of political rivals who would challenge the legitimacy of such divisions through the promotion countervailing notions of state loyalty and national unity (Smith , 2003). The dynamics thus pivot on the question of which side will come to dominate this ideational contest.

While the dynamics surrounding such competition are complex, both qualitative historical studies and contemporary statistical studies converge in finding that the forces underlying this process of nation-state construction have been powerfully impacted by the arrival of technologies of mass communication (Anderson, 1991; Deutsch, 1953; Warren, 2014). Of course, the increased communicative power generated by such technologies can be used as a means to a wide range of ends. For instance, radio broadcasts by Hutu extremists were found to have accelerated the production of violence during the Rwandan genocide (Yanagizawa-Drott, 2014),¹ but radio broadcasts of reconciliation narratives were shown to increase perceptions of social norms of empathy and cooperation between ethnic communities in the post-conflict environment (Paluck, 2009). Such observations imply that the aggregate effects of the introduction of new communication technologies will hinge crucially on which forms of political communication are most powerfully facilitated through their arrival.

Hence, while communication technologies are always subject to a wide range of potential uses, I have argued that we can best understand their aggregate impacts on the production of collective violence by considering their capacity to systematically alter the incentives facing competing producers of political ideas (Warren, 2014). The key factor in this account is the *scale* at which communication is facilitated. Technological forces which facilitate segregated appeals to narrowly constituted audiences can be expected to ease the production divisive identities and hence the generation of collective violence, whereas technological forces which facilitate broad appeals to national audiences can be expected to ease the production of integrative identities and thus render the generation of collective violence more difficult. In other words, we should expect that the aggregate impact of ICT

¹ Along similar lines, see Adena et al.(2013) for a discussion of the use of radio to deploy divisive appeals in Nazi Germany, but see also Kern & Hainmueller (2009) for evidence of the stabilizing effect of foreign broadcasts in East Germany.

penetration will depend on whether a given technological form generates a strengthening or weakening of *economies of scale in the marketplace of ideas*.

This further implies that different forms of ICT penetration should have quite different effects on the production of collective violence. ‘Mass’ communication technologies – such as radio broadcast towers – are characterized by one-to-many network structures, and therefore tend to facilitate lines of communication which cross-cut existing social cleavages, especially as the increasing density of receivers brings accessibility to greater proportions of the population (Briggs & Burke, 2002). In addition, such systems force messages to be transmitted and received publicly, generating broad awareness of experiences and perspectives shared by many others in the same society. Such technologies thus increase the relative ease with which centralized authorities can disseminate broad symbolic appeals for state loyalty and national unity, and can therefore be expected to foster *vertical* linkages between state and society,

In contrast, ‘social’ communication technologies – such as cell phones – are characterized by many-to-many network structures composed of *horizontal* linkages between individuals,² and therefore tend to facilitate lines of communication which flow along political and social divisions, rather than across them. Studies of cellular communication patterns have shown that while such technologies dramatically reduce the costs of long distance communication between individuals, the resulting connections nevertheless tend to be strongly segregated along existing sociodemographic cleavages, showing the same tendencies towards clustering and homophily long observed in other forms of interpersonal communication (McPherson, Smith-Lovin & Cook, 2001; Blumenstock & Fratamico, 2013; Kovanen et al., 2013). Moreover, because messages sent through social communication technologies can easily be directed to specific individuals, who can receive them in private,

² For an optimistic view of the social consequences of this increase in horizontal connectivity, see Shirky (2008).

such technological forms tend to incentivize the production and dissemination of divisive, sectarian appeals which resonate strongly only with the members of narrow sub-communities.

Thus, while mass communication technologies have been observed to generate an *increase* in the strength of economies of scale in the marketplace of ideas (Anderson, 1991; Deutsch, 1953; Warren, 2014), social communication technologies should instead be expected to heighten the relevance of socially-segregated flows of information, thereby *decreasing* the strength of economies of scale in the marketplace of ideas.³ In other words, whereas mass communication technologies have generally represented powerful forces for the centralization of state authority and national unity, social media technologies may instead serve to incentivize the promotion of the kinds of narrowly construed sectarian appeals and extremist ideologies which ultimately render collective violence imaginable and feasible (Brass, 1997; Des Forges, 1999; Tambiah, 1997; Thompson, 1999). If this is correct, then we should expect that the spatial reach of mass communication infrastructure will be associated with the successful extension of state influence and a corresponding reduction in the locally observed frequency of events of collective violence. In contrast, we should expect that the spatial reach of social communication infrastructure will be associated with greater difficulties in the extension of state influence and a corresponding increase in the locally observed frequency of events of collective violence.

Thus we have the following main hypotheses:

H1. *Ceteris paribus*, geographic regions with greater penetration of radio transmission capabilities will experience lower rates of collective violence.

³ See Snyder (2000) for an insightful examination of the violent consequences of segregation in the marketplace of ideas in new democracies.

H2. *Ceteris paribus*, geographic regions with greater penetration of cellular transmission capabilities will experience higher rates of collective violence.

Moreover, this basic causal mechanism generates an additional observable implication. If the effects of radio penetration and cellular penetration occur through their generation of divergent incentives for the production and dissemination of political ideas, then the processes through which such effects arise may be subject to a substantial degree of path dependence. In this regard, the diverse historical legacies of African states provide a uniquely powerful laboratory for examining the effects of ICT penetration. While most Western states experienced the introduction of radio infrastructure well before the introduction of cellular infrastructure, the order and timing of the introduction of these technologies has varied greatly across the African continent. Given the mechanisms outlined above, it seems likely that the contemporary arrival of social communication technologies would carry very different implications in areas previously untouched by the stabilizing influence of mass communication technologies. That is, we should observe an interaction between their effects at the local level, in which the centrifugal forces generated by social communication technologies are weakened by the centripetal forces generated by mass communication technologies. Hence, we should expect that:

H3. *Ceteris paribus*, the violence promoting effects of cellular technologies will be stronger in geographic regions with lower penetration of radio transmission capabilities.

Estimating ICT penetration through optimized spatial interpolation

To test these hypotheses, I begin with geo-coded household surveys collected by the MEASURE Demographic and Health Surveys (DHS) Project (2012). These data record the

ownership of radio receivers and cellular phones at the level of individual households, across 24 African states, which were surveyed between 2005 and 2010.⁴ Households are sampled in nationally-representative geographic clusters, with cluster centroids spaced throughout the populated territories of each country. In total, the data record the characteristics of 286,299 households in 11,556 geographic clusters.

To convert these measurements into usable covariates for statistical analysis, we require a means of accurately interpolating measurements across unequally-spaced survey cluster locations, allowing us to represent the data as a continuous surface. Common approaches to this problem include inverse distance weighting, and various forms of non-linear splines. However, such techniques treat each measurement location as independent, and thus ignore the effects of spatial autocorrelation. Here I employ an alternative, spatially-explicit approach to interpolation, known by geographers as ‘kriging’, which directly models the spatial dependence between sample locations as a function of distance. This allows the interpolation algorithm to explicitly incorporate information about the degree of spatial autocorrelation present in the data when forming predictions about unsampled locations, greatly increasing the accuracy of the resulting estimates.

The estimation procedure begins by specifying a decay function which parameterizes the relationship between the semivariance of the covariate sample (the average squared difference in measurement values), and the geographic distance between sample locations. This function, the empirical variogram, is fit using a Matern functional form (Stein, 1999). The key parameters governing the shape of the function, the range parameter (δ) and the smoothing parameter (κ), are fit using a Nelder-Mead optimization algorithm, seeking values which minimize the sum of squared errors.

⁴ The countries included are: Burkina Faso, Burundi, Democratic Republic of Congo, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Liberia, Lesotho, Madagascar, Mali, Malawi, Mozambique, Nigeria, Namibia, Rwanda, Sierra Leone, Senegal, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe.

These optimal parameter values are then used to estimate a continuous-surface representation of geographic variation in the variable of interest, through locally-weighted interpolation of the sample values – a procedure known as ‘ordinary kriging’ (Matheron, 1963; Oliver & Webster, 1990; Cressie, 1993). The key parameter governing this process is the size of the interpolation neighborhood; that is, the number of sampled locations used to predict the estimated value at each unsampled location. In principle, this could be the entire set of sampled locations, but in practice performance is generally optimized with local neighborhoods that include only some fraction of the available sample points. In order to select optimal neighborhood sizes for each sample, I utilize a leave-one-out cross-validation procedure, which repeatedly generates the interpolated surface, iteratively excluding each sampled point from the estimation. Residuals are calculated by comparing the measured value at each sampled location to the interpolated value estimated when that point was excluded from the estimation sample. The optimal neighborhood size is then selected by utilizing a numeric search algorithm⁵ to find the parameter value which minimizes the mean squared prediction error (MSPE) of the cross-validation estimates.

Adapting this approach to the current problem, sample locations are defined by the centroid of each geographic survey cluster. For each survey cluster location, the variable of interest is measured as the proportion of households within the cluster reporting access to a particular technology. For instance, if a cluster contained 20 surveyed households, 5 of which reported ownership of a radio receiver, then that cluster's value for the radio variable would be 0.25. For each location, locally interpolated values are estimated using the distance dependence parameters estimated from the full set of survey cluster locations, and neighborhood sizes optimized separately for each surveyed country, thereby allowing for differences in sampling or spacing between survey waves to be captured by the kriging

⁵ The search algorithm uses a combination of golden section search and successive parabolic interpolation, a solution known to converge relatively quickly even for functions which lack known derivatives (see the online appendix for details).

algorithm and incorporated into the resulting interpolated surface. The values estimated for each country are then merged into a single continuous surface. In this manner, interpolated surfaces are estimated for both forms of communication technology, generating our two main independent variables: *Radio penetration* and *Cellular penetration*. In the same manner, I also generate estimates geographic variation in rates of *Electrification*, which is included as a control variable to account for the general effects of wealth and economic development.

The resulting interpolated surfaces for both media penetration variables are displayed graphically in Figure 1. The upper left panel shows the density of radio ownership in purple, with darker values indicating greater density. The upper lower left panel shows the density of cell phone ownership in green, with darker values again indicating greater density. Finally, the right panel shows the relative density of the two technologies, with purple indicating greater local dominance of radio, and green indicating greater local dominance of cellular technologies. As can clearly be seen, there is substantial variation across technologies in the geographic spread of communications infrastructures, both between countries and within countries.

To get a better sense of the accuracy of these interpolated surfaces, I use the cross-validation approach described above to assess the predictive performance of the kriging procedure, by estimating separate MSPEs for each country, and for each form of communication technology. For comparison, I then perform the same cross-validation calculations using quadratic inverse distance weighted (IDW) interpolation, a procedure which incorporates distances, but not spatial autocorrelation.⁶ The results of this analysis are plotted in Figure 2. Each dot represents the errors calculated for one variable in one country, with purple dots representing estimates of *Radio penetration* and green dots representing estimates of *Cellular penetration*. Error values derived from the kriging interpolation are

⁶ Linear and cubic IDW functions were also tested, but were found to perform less well than the quadratic form.

given by vertical axis, while errors derived from the IDW interpolation are given by the horizontal axis. The diagonal reference line marks the locations where dots would fall if the errors generated by the two procedures were equal, with dots below the line indicating smaller errors for the kriging approach. The plot shows that the predictive accuracy of the kriging interpolation outperforms the IDW interpolation for every combination of country and communication technology, clearly demonstrating the advantages of incorporating detailed geostatistical information into our estimates of spatial covariates.

Point Process Modeling of Violent Event Locations

In the models presented below, the dependent variable is measured using UCDP's Georeferenced Event Dataset (GED). This database seeks to record the time and location of all events of collective violence in Africa which killed at least one person, and which arose in the context of an organized conflict which killed at least 25 people in a given calendar year, for the period from 1989 to 2010, recording 24,381 events in total.⁷ The goal is to use this information to examine the relationship between the spatial reach of communication infrastructures, and spatial variation in the production of collective violence.

In most recent work examining such questions in the quantitative literature on civil conflict, the underlying statistical approach has generally relied on the prior definition of spatial units of analysis, such as grid cells, settlement polygons, or political districts, which are then treated as separate observations in a spatial regression. The fundamental difficulty faced by this approach is known by geographers as the Modifiable Areal Unit Problem (MAUP). Put briefly, this work shows that multivariate spatial regression estimates tend to be inherently unreliable, because they are dependent on the choice of the spatial units (Openshaw, 1984; Fotheringham & Wong, 1991). Different spatial units can generate

⁷ This definition of the dependent variable combines events characterized by GED as anti-state violence, non-state violence, and one-sided violence against civilians, as the theoretical mechanisms proposed here appear likely to apply to all three forms. See Sundberg, Lindgren & Padsokocimaite (2010); Sundberg & Melander (2013).

different results, even when the underlying data remains the same, and these statistical biases exhibit widely varying directions and intensities. Moreover, because each redefinition of the spatial resolution necessarily entails a redefinition of the units of analysis in the resulting regression, there is no principled way to select between competing specifications.

To avoid such difficulties in examining the relationship between our measures of communication infrastructure and the location of violent events, I instead estimate covariate effects through the use of non-stationary, inhomogeneous, point process models. In contrast to the spatial regression techniques currently in common use in the field of conflict studies, this approach avoids the need to specify arbitrary spatial units of analysis by simulating the emergence of point-like events in a continuous space, while also providing a convenient means for parameterizing patterns of spatial interdependence between events (Diggle, 2003; Baddeley & Turner, 2005).

The point process modelling framework proceeds by treating each independent variable as a continuous spatial surface, and then simulates the emergence of point-like events within the space defined by these surfaces. These simulated points function essentially as randomized control observations, forming a statistical backdrop against which we can compare the properties of actual events. The algorithm proceeds, first, by recording the value of each independent variable at the location of each event observed within the 'dependent' portion of a given spatial-temporal window. Next, it records the values of the same independent variables at a set of 10,000 quadrature points, generated at randomly sampled locations across the observation window. Statistical inference then proceeds by comparing the distributions of covariates observed at the locations of actual events, to the distributions that would have been observed if events had emerged randomly within this space (Baddeley & Turner, 2000). Importantly, because the control locations are randomly sampled, they will be uncorrelated with the spatial characteristics of the data at *all scales*

simultaneously, and thus will not privilege any particular geographic scale when estimating covariate effects.

To conduct this analysis, I first define spatio-temporal observation windows for each model. The spatial dimension of each window is constrained to locations within 40 kilometers of a survey cluster, which represents the approximate reach of a medium-powered transmitter. Robustness checks with alternative radii of 30 kilometers and 50 kilometers generated substantively equivalent results, and so are omitted here in the interest of space. Because the surveys underlying our key independent variables were collected in different years, I adopt two different approaches to the temporal dimension of the observation windows. The goal in each case is to use information from the GED database to estimate covariate effects on the locations of violent events which follow the entry of survey collectors into an area, while simultaneously controlling for the effects of violent events which preceded their entry, in order to guard against the possibility of spurious results arising from reverse causation between violence and infrastructure. In the first specification, I construct the windows using a common set of years, with the dependent variable measured for the years 2005-2010, and the control variable measured for the years 2000-2004. In the second specification, I construct windows which vary by country based on the year of each survey wave, with the dependent variable measured for the period following each survey's entry, and the control variable measured for the five years preceding each survey. In each case, the dependent portion of the window is characterized by point-like events, while the control portion is characterized by a continuous density surface, generated by Gaussian kernel smoothing (see the online appendix for details).

To guard against spurious correlations, the models reported below also include a number of additional control variables, each treated as a separate continuous surface, and recorded at a grid resolution of 5 kilometer square cells. To capture the effect of urban

environments, I include *Urban extent* as a dichotomous indicator, based on data from Global Rural-Urban Mapping Project (GRUMP) which measures the location of 'built environments' through satellite imagery (CIESIN, 2011). To capture the effects of cleavages between politically charged ethnic settlements, I rely on a newly geo-coded version of the Ethnic Power Relations dataset (Geo-EPR), which records the settlement locations and political status of all politically relevant ethnic groups living in geographically circumscribed regions (Wucherpfennig et al., 2011). I code *Ethnic inclusion* as a dichotomous indicator, which equals 1 for all settlement locations of ethnic groups with representation in the executive branch of multi-ethnic governments. *Population density* is measured using the UN's Gridded Population of the World (GPW) database (CIESIN, 2005) and *Elevation* data is taken from the USGS GTOPO30 database (1996). Lastly, *Local wealth* is measured using the purchasing power parity adjustment of gross cell product, from the G-Econ data set, which records gridded economic production data on global basis at a resolution of 1-degree latitude/longitude (Nordhaus, 2006; Nordhaus et al., 2006).

In addition, because our hypotheses are primarily concerned with sub-national variation in the reach of communications infrastructures, and because a number of country-level variables could conceivably be influencing our outcomes in unmeasured ways, all models are estimated with country-level fixed effects. This approach ensures that the results reported below are driven entirely by within-country variation in the production of collective violence, while also ensuring that the results are not due to spurious correlations between communication infrastructures and any state-level factors.

The point process modeling framework also provides a convenient means for parameterizing the spatial interdependence between events. Failure to account for such interdependence in the causal processes generating our observed events can result in severely biased statistical estimates, as spatial correlations which arose due to influences between

neighboring events can instead be spuriously attributed to spatial covariates. In the present specification, I account for this possible non-independence of events by specifying a pairwise Strauss interaction function between points as a component of the simulated point process, which provides a flexible means of accounting for the possibility that events are more likely to arise in proximity to other events, within a specified interaction radius (Diggle et al., 1994; Waagepetersen, 2007; Strauss, 1975).⁸ Optimized coefficients and standard errors for the parameters governing the strength of the inter-point influences and the influence of each additional independent variable are then jointly estimated from the data using maximum pseudolikelihood (Besag, 1975), selecting parameter values which allow the simulated point process events to most closely match the distribution of covariate values observed for the actual events.

Results

Coefficients and standard errors derived from these models are reported in Table I. Model 1 is a baseline specification which includes only the control variables, using the ‘common years’ approach to constructing the spatio-temporal observation window. Model 2 adds the two media penetration variables to the baseline specification, and Model 3 then adds a multiplicative interaction term between the media penetration variables. Model 4 repeats the specification of Mode 3, instead using the ‘survey years’ approach to construct the spatio-temporal observation window.

The results from Models 2-4 are all strongly supportive of Hypotheses 1 and 2. The negative and statistically significant coefficient for *Radio penetration* ($p < 0.001$) indicates that geographic regions with greater levels of penetration by radio infrastructure, as captured by greater rates of household radio ownership, experience systematically fewer events of

⁸ All results reported below utilize an interaction radius of 900 kilometers. Robustness checks with radii of 800 kilometers and 1,000 kilometers generated substantively equivalent results, with slight decreases in overall model fit.

collective violence. In contrast, the positive and statistically significant coefficient for *Cellular penetration* ($p < 0.001$) indicates that geographic regions with greater levels of penetration by cellular infrastructure experience systematically higher rates of collective violence. In addition we can see that these effects are robust to the inclusion of controls for electrification, urbanization, local wealth, ethnic inclusion, and state-level fixed effects, indicating that they cannot be dismissed as mere artifacts of modernization or development.

Examining the results reported in Models 3 and 4, we also find strong support for Hypotheses 3. The negative and statistically significant coefficient for *Radio x Cell* ($p < 0.001$) indicates that the violence inducing effects of *Cellular penetration* are greatest in regions characterized by low levels of *Radio penetration*. This relationship can be more easily visualized by the plotting predicted intensity of violent events as a function of our two key independent variables, while holding all other variables constant at their means, as shown in Figure 3. The central panel shows the predicted intensity of violent events – that is, the expected number of events per square kilometer – at different combinations of values of *Radio penetration* and *Cellular penetration*, with darker red colors indicating greater expected levels of collective violence. The purple plot above the central panel shows a kernel density estimate (a smoothed histogram) of the values of *Radio penetration* observed within our estimation sample, while the green plot to the right of the central panel shows the observed values of *Cellular penetration*. The plot makes clear that while *Radio penetration* generates pacifying effects under nearly all observed conditions, the effects of *Cellular penetration* are strongly conditioned by the local density of *Radio penetration*, with the greatest levels of violence observed in regions where the arrival of cellular technologies has occurred in the absence of prior penetration by radio infrastructure. In contrast, in areas with strong penetration by radio infrastructure, the marginal effect of cellular technologies goes nearly to zero.

Taken as a whole, these results thus lend strong credence to the predictions laid out in Hypotheses 1-3. Moreover, it seems that this pattern of effects could also provide a partial explanation for the apparent divergence between existing empirical findings in the literature, which point to a positive association between cell phone coverage and violence in the African context (Pierskalla & Hollenbach, 2013), but to a negative association between cell phone coverage and violence in the context of the counterinsurgency campaign in Iraq (Shapiro & Weidmann, 2014). While both sets of authors argue that the observed effects are due to reductions in the ‘transaction costs’ of communication, the results presented here indicate that the key difference may lie in divergent historical legacies, which left much of Africa with weak penetration of mass media infrastructure (Livingston, 2011), but granted the denizens of Iraq nearly universal access to mass media technologies (Awad & Eaton, 2013). If the theory presented above is correct, then the ideational forces generated by these divergent historical trajectories may help to explain how the same fundamental reduction in the costs of interpersonal communication could in one context facilitate divisive mobilization, but in the other facilitate collaboration with central authorities. Such patterns thus highlight the complexity and context-dependence of technological effects, and hence the clear need for approaches which allow comparisons within countries, across countries, and across technologies. They also further imply that the observed effects of new communication technologies are driven, not simply by their ability to solve ‘freeriding’ problems amongst would-be insurgents, but rather by their capacity to facilitate new lines of ideational cohesion and division.

Nevertheless, it could be objected that because the measurement of our dependent variable draws heavily on mass media reports, the observed correlation between social media and collective violence might have resulted from increases in the reporting of violence, rather than actual increases in violence. However, it is important to note that the coding procedures

used in the GED project were designed to make extensive use of NGO reports, local newswires, and other secondary sources, in an attempt to mitigate such biases (Sundberg, Lindgren & Pads kocimaite, 2010; Sundberg & Melander, 2013). In addition, comparative evidence indicates that the GED database leads the field in providing coverage of events which occur even in remote, peripheral locations (Eck, 2012). This potential criticism also is greatly weakened by the fact that the effects reported here have been shown to be robust to wide variety of controls for development and urbanization, which should be strongly correlated with the conditions under which such reporting biases would be observed. Moreover, it seems difficult for such an account to explain the observed negative association between mass media and collective violence, as it seems unlikely that those infrastructures were associated with a reduction in the reporting of violent events.

A more serious objection is raised by the possibility of reverse causation between violence and the presence of ICT infrastructure. While the results were shown to be robust to the inclusion of controls for prior violence in the vicinity, in principle it is always possible that these controls have missed some historical process by which broader patterns of violence have conditioned the spread of ICT infrastructure, rather than ICT infrastructure conditioning the spread of violence. To address this possibility, I make use of data derived from longitudinal surveys to capture variation over time in the spread of ICTs. For most of the countries in our sample, surveys recording both forms of communication technology have only been conducted for a single year. However, in Uganda we have access to repeated surveys, conducted in 2006 and 2011. Utilizing the kriging approach described above, I estimate separate interpolated surfaces for each form of communication technology and for each year of survey collection. I then define two new variables, *Radio growth* and *Cellular growth*, as the difference between the values observed in 2006 and the values observed in 2011, for each form of communication technology. Positive values on these variables thus

indicate increases in ICT penetration over time at a given location, while negative values indicate the destruction of existing ICT infrastructure.

To assess whether a relationship exists between the location of violent events and rates of ICT expansion, I then specify two separate point process models, using the same procedures described, with reduced observation windows that include only locations in Uganda within 30 kilometers of survey clusters in both years. The first model seeks to predict the location of violent events observed in the years between the two surveys, using the initial values of *Radio penetration* and *Cellular penetration*. The second model seeks to predict the same events using these variables in addition to *Radio growth* and *Cellular growth*. The results are presented in Table II. If the violent events which occurred within this temporal window did in fact condition the rates of change in ICT infrastructure, then the addition of these variables to the model should increase its ability to retrospectively predict the locations at which those events occurred. In fact, coefficients for the growth variables are both far from statistical significance ($p = 0.481$ and $p = 0.399$), and the results show no improvement in predictive capacity across the two models (actually a small decrease), as measured by the Akaike information criterion (AIC). In other words, I find no evidence that the locations of contemporaneous violent events are systematically associated with subsequent increases or decreases in the strength of ICT infrastructure, indicating that the results reported in Table I are not likely to have been driven by reverse causation.

Conclusion

The results presented here thus represent strong evidence that patterns of collective violence are powerfully influenced by technologies of communication. Moreover, the results also indicate that different forms of communication technology can generate starkly divergent effects. Mass communication technologies facilitate vertical linkages between state and

society, by increasing the ease with which centralized authorities can disseminate broad symbolic appeals to national unity. That is, such technologies tend to increase the strength of *economies of scale in the marketplace of ideas*. In contrast, social communication technologies facilitate horizontal linkages between the members of a society, which serve to heighten the relevance of socially-segregated communications, thereby decreasing the strength of economies of scale in the marketplace of ideas, and rendering easier the production of divisive mobilizational appeals and sectarian attachments. As a result, radio infrastructures function to reduce the occurrence of collective violence, while cell phone infrastructures function to increase the occurrence of collective violence, especially in peripheral areas lacking prior access to mass media technologies.

Moreover, I have shown that these inferences are robust to controls for electrification, urbanization, wealth, and state-level fixed effects, and thus cannot be easily attributed to the broader effects of economic development or modernization. In addition, analysis of longitudinal surveys from Uganda has indicated these results are not likely to have been driven by reverse causation, as there is no evidence that rates of ICT expansion are associated with the locations of contemporaneous violent events. Rather, the evidence indicates that spatial differences in the reach of communication infrastructures have powerfully influenced processes of nation-state formation, by altering the dynamics of ideational competition, and thereby altering the opportunities for the production of collective violence and collective peace. In other words, the evidence demonstrates that the geography of collective violence is strongly conditioned by the geography of collective ideas.

Consequently, attempts to understand and predict the emergence of collective violence will require careful attention, not only to the forces generated by physical coercion, but also to the forces generated by normative communication.

Table I. Point process models of collective violence events

	<u>Model 1</u> (post-2005)	<u>Model 2</u> (post-2005)	<u>Model 3</u> (post-2005)	<u>Model 4</u> (post-survey)
Radio penetration		-5.260*** (0.386)	-4.555*** (0.403)	-4.204*** (0.485)
Cellular penetration		2.326*** (0.440)	6.716*** (0.794)	7.130*** (1.124)
Radio x Cellular			-6.973*** (1.049)	-7.660*** (1.394)
Electrification	1.238*** (0.233)	1.369*** (0.351)	2.477*** (0.385)	2.076*** (0.518)
Elevation	1.303*** (0.106)	1.231*** (0.108)	1.335*** (0.108)	1.519*** (0.153)
Local wealth	0.186*** (0.030)	0.242*** (0.031)	0.194*** (0.031)	0.067 (0.041)
Population density	0.046*** (0.011)	0.094*** (0.011)	0.111*** (0.011)	0.279*** (0.017)
Urban extent	0.865*** (0.122)	0.794*** (0.125)	0.893*** (0.126)	0.595*** (0.164)
Ethnic inclusion	0.011 (0.090)	0.064 (0.091)	0.040 (0.091)	0.554*** (0.121)
Local violence density (2000-2004)	0.809*** (0.115)	0.922*** (0.122)	0.794*** (0.126)	
Local violence density (pre-survey)				1.008*** (0.1476)
Interpoint interaction	0.0030*** (0.0004)	0.0032*** (0.0004)	0.0036*** (0.0004)	0.0036*** (0.0008)
Intercept	-20.154*** (2.846)	-15.495*** (2.976)	-20.161*** (3.130)	-18.277*** (3.833)
Country-level fixed effects	Included	Included	Included	Included
AIC	57891.86	57587.33	57543.86	35445.77

Coefficients and standard errors derived from non-stationary, inhomogeneous point process models with pairwise inter-point interactions. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table II. Point process models of collective violence events in Uganda

	Model 5 (Uganda)	Model 6 (Uganda)
Radio penetration	-3.769*** (0.688)	-2.678* (1.359)
Radio growth		1.852 (2.6294)
Cellular penetration	4.497*** (0.985)	3.954** (1.255)
Cellular growth		-1.751 (2.079)
Interpoint interaction	0.079*** (0.015)	0.077** (0.025)
Intercept	-21.432*** (0.304)	-21.346*** (0.313)
AIC	2432.59	2435.92

Coefficients and standard errors derived from non-stationary, inhomogeneous point process models with pairwise inter-point interactions. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

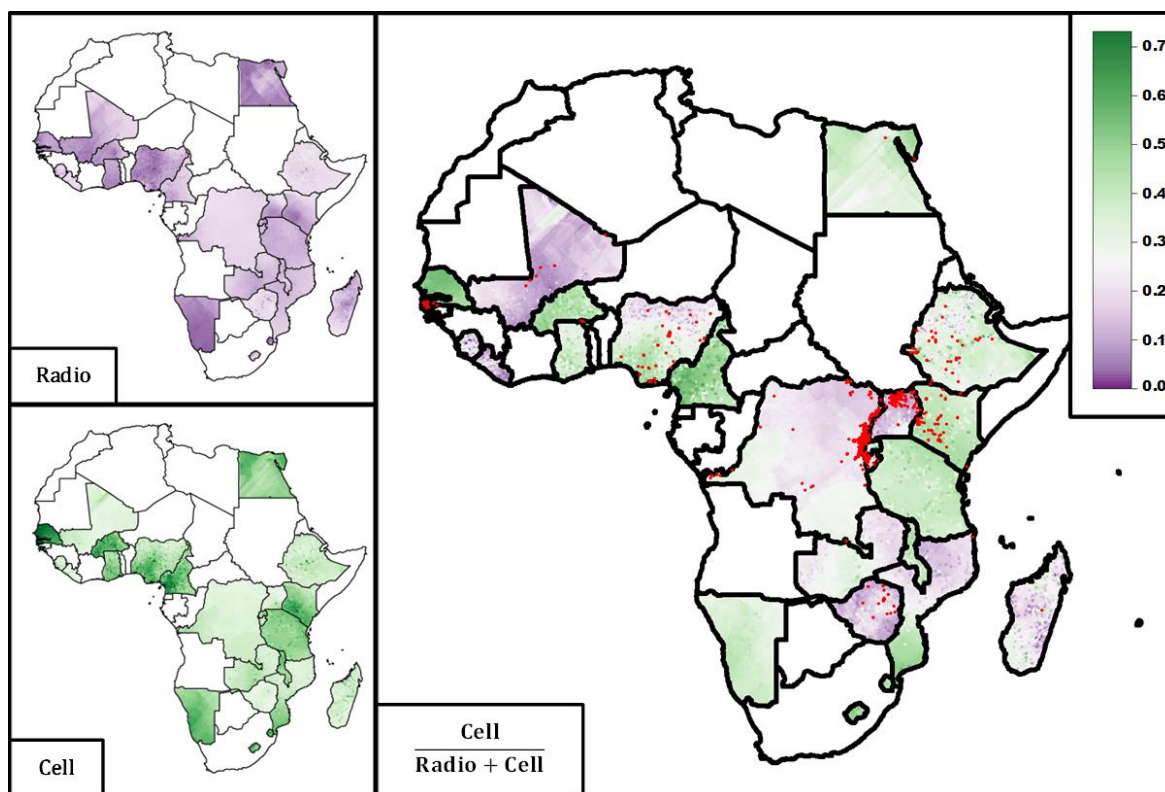


Figure 1. Radio and cellular penetration in Africa, c. 2005

Interpolated values derived from kriging across 11,556 survey clusters. The upper left panel shows radio ownership rates, with darker values of purple indicating greater levels of radio penetration. The lower left panel shows cell phone ownership rates, with darker values of green indicating greater levels of cellular penetration. The right panel shows the proportion of the local density represented by cell phones, relative to radios, with darker purple indicating greater dominance of radio, and darker green indicating greater dominance of cell phones. Red dots show the locations of violent events within the surveyed countries, 2005-2010.

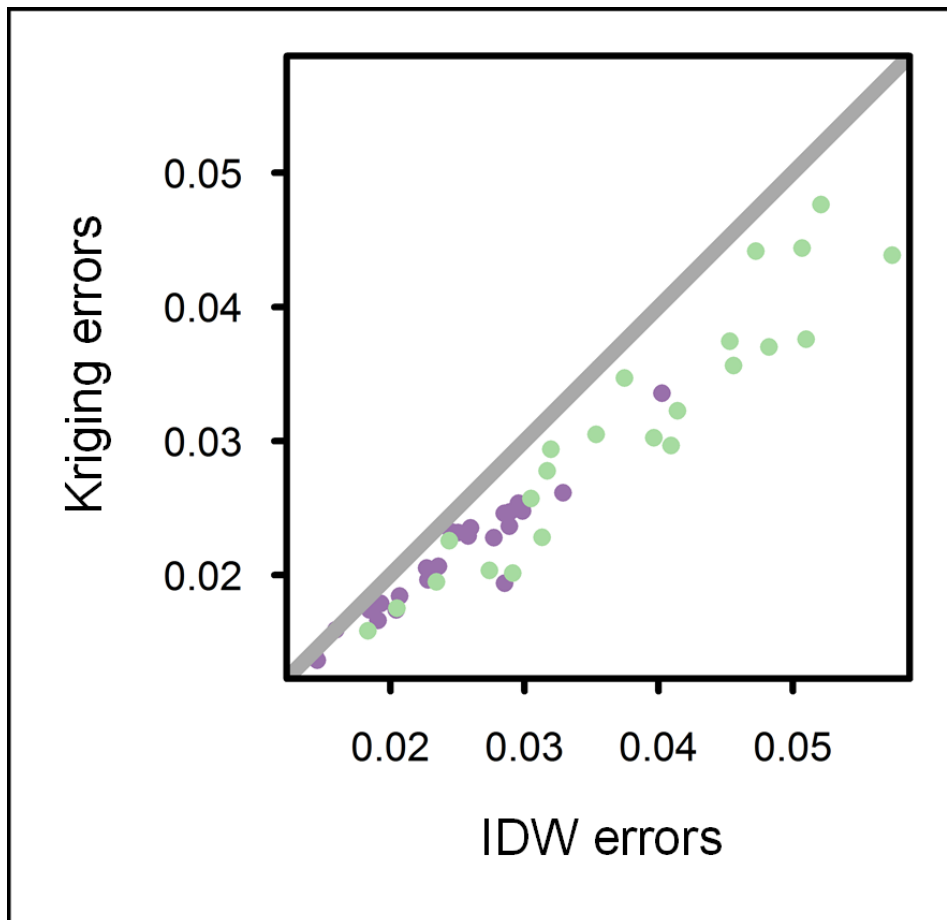
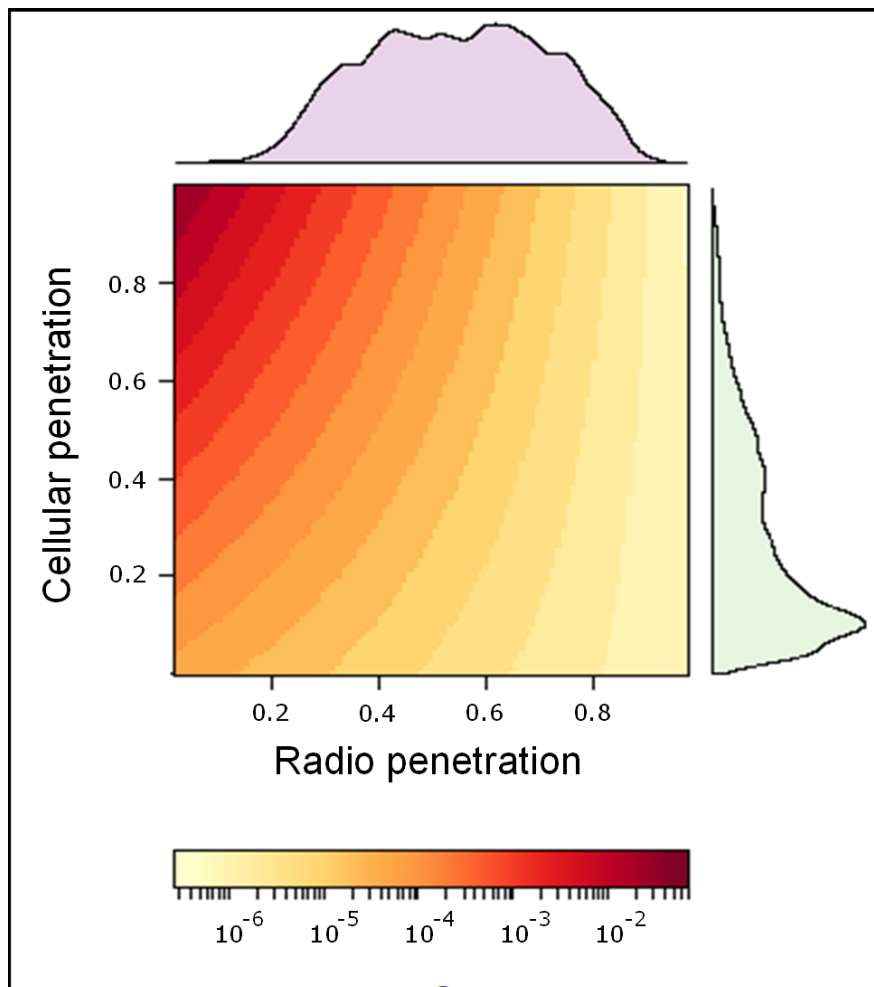


Figure 2. Cross-validation of interpolation estimates

Plot shows the MSPEs derived from cross-validation of surfaces estimated through optimized ordinary kriging and IDW interpolation. Each dot represents the errors associated with the surfaces derived for a particular technology in a particular country, with purple dots showing errors derived from estimates of *Radio penetration* and green dots showing the errors derived from estimates of *Cellular penetration*. The diagonal reference line shows where the points would fall if the errors were equal between the two interpolation approaches, while points below the diagonal indicate superior predictive performance of the kriging approach.



**Figure 3. Predicted intensity of violent events:
Radio penetration vs. Cellular penetration**

Estimates derived from coefficients and standard errors from Model 3. Central panel shows the predicted intensity of violent events (the expected number of violent events per square kilometer) at each combination of values of *Radio penetration* and *Cellular penetration*, with darker red colors indicating greater levels of collective violence, scaled logarithmically. Purple plot above the central panel shows a kernel density estimate of the values of *Radio penetration* observed within the estimation sample. Green plot to the right of the central panel shows the observed values of *Cellular penetration*.

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The online appendix with replication data and code is available at:
<<http://www.camberwarren.net>> and <<http://www.prio.org/jpr/datasets>>.

T Camber Warren, b. 1980, PhD in Political Science (Duke University, 2008); Assistant Professor, Department of Defense Analysis, Naval Postgraduate School.