3G Internet, Intimate Partner Violence, and Women's Empowerment: Evidence from Nigeria

Ridhi Kashyap* Prashant Poddar* Till Koebe† Valentina Rotondi‡

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Abstract

A growing body of research has highlighted the impacts of mobile phones on women's status in low- and middle-income countries (LMICs), through improved labour market opportunities, contraceptive knowledge and access, and decision-making power within the household. However, this literature relies on cross-sectional designs using measures of individual technology adoption that are endogenous, and does not distinguish between type of mobile technology (2G v 3G). This distinction is important because the spread of the internet can have theoretically ambiguous and complex effects, ranging from exposure to globalized liberal ideas to reinforcing gender stereotypes and misogynistic views. In this paper, we examine how the rollout of 3G mobile networks over time in Africa's most populous country, Nigeria, affects women's status within the household looking at the experience of intimate partner violence. We draw on three waves of the Demographic and Health Survey's women's and men's modules, which we link with novel, high-resolution mobile coverage maps, and estimate the impact of 3G using a twoway fixed effects design. We find the 3G network expansion results in reductions in the experience of emotional, sexual and physical intimate partner violence among women, with support for ideational and empowerment mechanisms in explaining these reductions. We find reductions in the acceptability of IPV among women, although less so among men. Among men and women, we find evidence for increases in women's decision-making power in the household. 3G exposure also brings shifts in demographic behaviour, linked to delayed marriage and first births for women. Our results highlight the potential of technological expansion to influence gender dynamics within households.

*Department of Sociology, Leverhulme Centre for Demographic Science, Nuffield College, University of Oxford
†Saarland University
‡Department of Business Economics, Health and Social Care, University of Applied Sciences and Arts of Italian Switzerland
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1 Introduction

The widespread diffusion of mobile phones has been the defining technological transformation of the new millennium. Since the mid-2000s, the spread of 3G+ networks have accelerated the spread of the internet through mobile phones, especially for the African continent, where fixed internet infrastructure remains limited (International Telecommunication Union, 2024). Beyond the communication capabilities offered by 2G-enabled mobile technology, the spread of mobile internet via 3G has the potential to improve access to a more advanced array of information and services, and enable exposure to globalized media content. These impacts of technologies may be especially salient for marginalised populations, such as women, who face disadvantaged access to economic resources and social networks through traditional channels. Recognising this potential, global sustainable development goal number 5 (SDG 5) on gender equality calls to "enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women" (United Nations, 2016).

A growing body of empirical research has explored these ideas and highlighted the positive impact of mobile phones on women's status in low- and middle-income countries (LMICs) through improved labour market outcomes (Suri and Jack, 2016; Chiplunkar and Goldberg, 2022; Viollaz and Winkler, 2022; Amber and Chichaibelu, 2023), decision-making power within the household (Rotondi et al., 2020; Pesando, 2022), contraceptive knowledge and access (Vahdat et al., 2013; Smith et al., 2015; Rotondi et al., 2020), and reductions in experiences of intimate partner violence (Pesando, 2022). Much of this research has relied on cross-sectional designs where mobile ownership is measured at the individual-level at one point in time, often drawing on the individual-level measures of mobile ownership collected in the Demographic and Health Surveys. This approach is limited being able to address the endogeneity of individual-level technology adoption, as mobile ownership at the individual-level is correlated with socioeconomic characteristics (Sánchez-Páez et al., 2023), and significant gender gaps in mobile adoption persist (Fatehkia, Kashyap and Weber, 2018). Moreover, this literature has, by and large, not distinguished between between type of technology enabled by mobile phones (2G v 3G), even though these technologies may plausibly result in differential impacts, given the distinct functionalities they offer (simple calling and messaging versus more advanced internet capabilities). This distinction is important because exposure to the internet can generate more theoretically complex and ambiguous effects. On the one hand, the internet may help promote access to information, bolster social connectivity, spread liberalised ideas of gender equality, but also reinforce misognyistic and traditional views of women in the household. Real or perceived improvements in social or financial autonomy among women generated by internet technologies may also threaten traditional patriarchal structures and trigger more violent behaviours by male partners within households.

This paper re-visits the question of mobile technology and women's empowerment by investigating the impacts of 3G expansion on women's experience of intimate partner violence, a key marker of women's status, and decision-making power within the household in the context of Africa's most populous country, Nigeria. In contrast to previous work, we study the *rollout* of mobile internet via 3G networks by linking the Demographic and Health Surveys (DHS) with geospatial data on mobile coverage maps exploiting geographic and temporal variations of the expansion. This design enables us to estimate the causal impacts of mobile internet rollout to explore how 3G expansion affects attitudes and behaviours linked to women's status in the household.

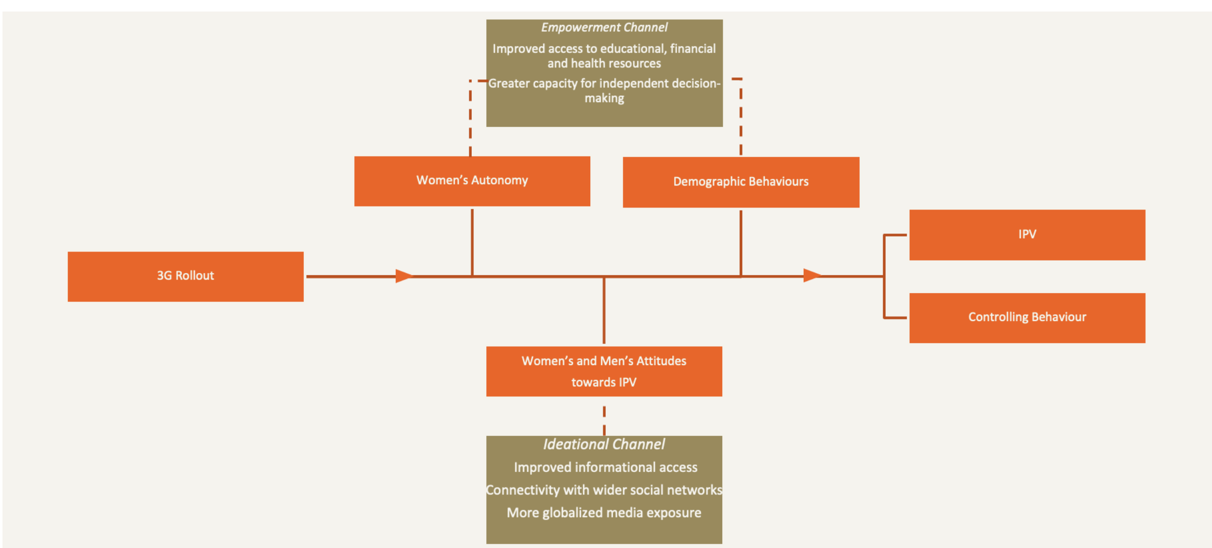
2 Background

Diffusion theories of fertility transitions have long acknowledged the role that mass media technologies can play in the spread of new ideas and norms, and in turn influence gender and demographic outcomes (Barber and Axinn, 2004). Consistent with these ideas, studies have shown how TV and radio have impacted on fertility ideals, son preference, and women's status within the household (Jensen and Oster, 2009; Ferrara, Chong and Duryea, 2012). While mass media technologies may help promote liberal and more 'modern' ideas of family and gender equality, spreading cultural norms associated with global elites (Pierotti, 2013), they may also reinforce gender stereotypes (Wood, 1994; Swindle, 2023). The digital revolution, generated by the spread of mobile phones and the internet, have re-invigorated interest in the impacts of technological change on gender and demographic dynamics. Burgeoning research has shown how the spread of mobile phones has impacted on improved access to labour market opportunities for women (Suri and Jack, 2016; Chiplunkar and Goldberg, 2022; Viollaz and Winkler, 2022; Amber and Chichaibelu, 2023), access to contraception and antenatal care (Rotondi et al., 2020), and women's empowerment, as measured through reductions in the experience of IPV (Pesando, 2022) and decision-making within the household (Rotondi et al., 2020).

While this literature points to associations between mobile phones and women's status, the technological measure of interest across many of these studies is the ownership of mobile phones at the individual level, often within a cross-sectional design that does not distinguish between 3G v 2G technologies, or between feature and smartphone use. Individual-level digital adoption is endogenous to socioeconomic factors (Fatehkia, Kashyap and Weber, 2018; Sánchez-Páez et al., 2023), which makes it challenging to distinguish causal impacts of technologies versus selection into technology access. Furthermore, the maturation of mobile technologies, and in particular, the spread of mobile internet with 3G may plausibly generate more complex, theoretically ambiguous effects, especially in relation to household dynamics and women's status.

In contrast to 2G technologies, which allow for calling or messaging within existing social networks, internet technologies via 3G enable improved access to more advanced informational, educational, and health resources, as well as access to broader social networks, e.g. through social media, where information sharing is interactive and amplified. The internet also enables globalized media exposure and exposure to liberalized cultural norms of global elites (Charles, 2020; Pesando, 2022; Varriale et al., 2022). These channels of increased informational access, connectivity to wider networks and globalized media exposure can activate new paths for social learning, which have the potential to shift gender roles and demographic behaviours (Montgomery and Casterline, 1996). We conceptualize this as an *ideational channel* through which 3G internet could affect the acceptability of IPV and attitudes around women's status in the household among both women and men. Exposure to informational and educational content, as well as financial and health resources afforded by internet technologies can also help empower women by enabling them to become more self-reliant decision-makers in the household. Exposure to the internet can also affect individual aspirations and behaviours around for instance, education and later marriage, factors which the literature suggests are linked to women's bargaining power in the household and experiences of IPV (Sara and Priyanka, 2023; Chatterjee and Poddar, 2024; Roychowdhury and Dhamija, 2021). We conceptualize this in terms of a *empowerment* channel. Empowerment here relates to both material improvements in women's lives in terms of economic, health and educational resources, but also in relation to their demographic behaviours, such as through later marriage or childbearing. 3G could also enable men to be less controlling of wife's behaviours if there are tangible benefits associated with 3G connectivity, such as more frequent connectivity. Figure 1 summarizes the theoretical framework linking 3G expansion to IPV exposure via the two channels (ideational and empowerment).

Figure 1: Theoretical framework linking 3G expansion to IPV exposure



Consistent with the ideational channel, in a multi-country analysis in Africa Charles (2020) finds that men and women who use the internet frequently report greater support for gender equality. As evidence for empowerment channel, in a qualitative study in Nigeria, Abubakar and Dasuki (2018) find that participation in Whatsapp groups provides women opportunities for greater social, economic and political engagement in their communities, thereby enhancing their sense of empowerment. Chiplunkar and Goldberg (2022) find that 3G internet expansion is linked to improved labour force participation for women across a range of low- and lower-middle income countries. Aker, Ksoll and Lybbert (2012) find mobile technologies to be linked to improved learning outcomes among adults in Niger.

While the internet can enable information exposure, the greater potential for unregulated content can also amplify the spread of dis- and mis-information. Media content that reinforces gender stereotypes and misogynistic views can also be accessed and shared at scale via the internet (Faith, 2022; Lisnek et al., 2022). The internet can also provide a new outlet to perpetuate gender-based violence against women (Dunn, 2020). Existing literature shows how improving women's relative status in terms of education may generate gender backlash effects in terms of increased IPV (Weitzman, 2014; Behrman, 2019). Similarly, increases in economic or social autonomy among women, or perceptions of increased autonomy, enabled by internet technologies may threaten male dominance within households and trigger backlash effects through increases in IPV by male partners.

The existing literature between media exposure and IPV and gender attitudes is suggestive of conflicting associations. While some studies show reduced tolerance for IPV only for men (Banerjee, La Ferrara and Orozco, 2019; Okenwa, Lawoko and Jansson, 2009), others show similar patterns only for women (Uthman, Lawoko and Moradi, 2009). Others find increases in tolerance for IPV among women with higher media exposure (Okenwa, Lawoko and Jansson, 2009), as well as among men when exposed to mainstream media (Swindle, 2023). Much of this literature, however, has focused on TV and radio exposure, and less is known about how these translate to media exposures via internet technologies. In light of these, we hypothesize that the net effect of 3G expansion on women's experiences of and attitudes towards intimate partner violence, and their decision-making power within the household could either be negative or positive. We expect similarly theoretically ambiguous effects for men in relation to their gender attitudes surrounding women's status in the household and attitudes to IPV.

3 Data

We rely on three waves of geo-referenced, nationally-representative Demographic and Health Survey (DHS) data from Nigeria for the period 2008, 2013 and 2018 for our analysis. We use both the women's and men's survey questionnaire files of the DHS, which sample women aged 15–49 and men aged 15–60 years. We use the domestic violence (DV) module of the DHS that collects information on women's experience of IPV within the household and focus on the sample of currently married or partnered women[1]. In addition to the experiences of IPV, the DHS also collects a broad set of questions around women's and men's attitudes towards wife beating, as well as questions around women's empowerment as defined by decision-making power in the household surrounding different domains. The DHS program uses a multi-step process for sampling. For the Nigerian DHS, the sampling frame is from the 2006 Population and Housing Census of the Federal Republic of Nigeria (NPHC). The sample is selected using a stratified, two-stage cluster survey design within primary sampling units ("clusters"). Each cluster contains approximately 100-300 households; each household in the cluster is enumerated and a random set of households are selected.

Each DHS cluster is geo-referenced using GPS receivers. The clusters are randomly displaced to preserve privacy by up to 2 kilometers for urban clusters and 5 kilometers for rural clusters, with an additional 1% of rural clusters displaced to a maximum of 10 kilometers. We supplement the data from DHS with information on 2G and 3G mobile coverage expansion from GSMA, the global business association of mobile network operators. Our principal mobile network coverage source is the GSMA Connectivity Maps (GSMA-

[1] In the Appendix Table 17, we show that 3G does not impact the probability of getting divorced or separated to account for potential selection issue.

CM), which provides a time series of maps from 2010–2019 for Nigeria, and were shared with us by GSMA via a data sharing agreement. These maps differ from the maps available via GSMA's *Mobile Coverage Explorer*, a collection of mobile coverage maps with unified reporting since 2009, via its official mapping partner Collins-Bartholomew (GSMA-CB). Although the GSMA-CB maps have been used in other studies examining the impacts of mobile coverage rollout on social and political outcomes (Chiplunkar and Goldberg, 2022; Flückiger and Ludwig, 2023; Manacorda and Tesei, 2020; Donati, 2023; Guriev, Melnikov and Zhuravskaya, 2021), through a systematic comparison between the GSMA-CB and GSMA-CM maps, we identify two major advantages of the GSMA-CM maps. First, the reporting methodology in GSMA-CM is the same across years and we find, after close inspection, the time-series data to be more reliable. Although GSMA-CB maps are published on an annual basis, mobile operators may not update the underlying maps over time, not all (or only minor operators) may report these maps to GSMA-CB, and the reporting methodologies may vary across operators. Consequently, when we define GSMA-CB maps as *recent* and *reliable*, that is if a major mobile network operator has reported coverage maps for within the two years prior to DHS data collection, the time-series of coverage maps for Nigeria becomes patchy. This is shown in Appendix Figure 5 that compares 3G rollout in Nigeria as revealed by the GSMA-CM and GSMA-CB maps. The GSMA-CB maps significantly underestimate 3G coverage rollout.

Second, the GSMA-CM data for Nigeria are reconstructed from metadata on the recent mobile network infrastructure. This metadata includes technical specifications used to estimate coverage ranges for each tower, but also the construction date of a respective tower. By filtering on the construction date, it is possible to model network rollout across time, thus overcoming reporting gaps. Nevertheless, the GSMA-CM data also come with shortcomings: First, metadata processing was done for GSMA by a third-party contractor. Thus, in contrast to the GSMA-CB maps, we do not know which operator provided the data. Comparing GSMA-CB maps with GSMA-CM, we are certain that it must be one of the major operators in the case of Nigeria, given the wider extent of coverage revealed in Appendix Figure

5. Second, although the same coverage modeling approach has been applied, details about the approach are unknown to us. Third, we reconstructed the GSMA-CM maps from a 1% sample of pixels, but at a finer geographical resolution than that available for the CB maps. Since the native resolution of the connectivity maps are $30 \times 30m$ versus roughly $260 \times 260m$ for the CB maps, this represents a 75% sample at CB resolution, with virtually no missing pixels as interpolation of missing pixels is done at $30m$ pixel resolution. Fourth, we have GSMA-CM maps for Nigeria for the years 2010 to 2019. Although 3G was piloted in parts of three major Nigerian cities in 2007, we assume that 3G was generally not available at the time of DHS 2008 data collection. For the DHS 2013 and 2018, we consequently use coverage information from the GSMA-CM maps. Since we also use 2G coverage as a control variable in our analysis, we use recent and reliable CB maps on 2G for the DHS 2008 and data from the connectivity maps for the DHS 2013 and 2018.

To process the coverage maps, we first construct buffers around the displaced coordinates of each DHS cluster. These buffers are 2km for urban areas or 10km for rural areas, corresponding to the maximum amount of displacement. Since DHS clusters are just displaced within given admin-level 1 boundaries (since 2009 even admin-level 2), we crop these buffers to the admin-level 1 areas of the respective country using the survey boundaries provided by the spatial data repository of the DHS [2]. This way, we try to narrow down the coverage status at potentially the true cluster location without actually re-identifying it. We then overlay these buffers with 2G and 3G coverage maps and calculate the area within each cluster with and without coverage, respectively. In addition, we further overlay $100 \times 100m$ UN-adjusted population counts from Worldpop (WorldPop, 2023), and use these population estimates to calculate the proportion of people living in each cluster covered by a 2G and a 3G network. We interpret these proportions (area-weighted v population-weighted) as probabilities of the surveyed population within a cluster being covered by a given technology.

[2] https://spatialdata.dhsprogram.com/data

4 Methodology

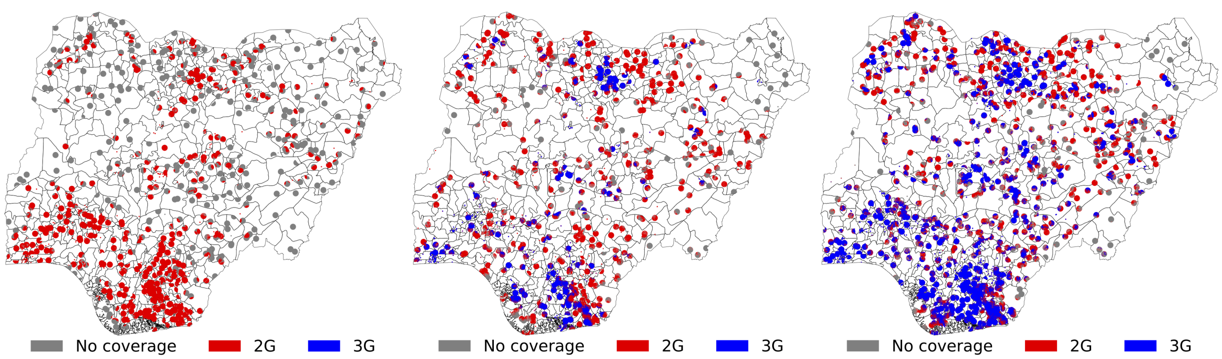
To examine the causal impact of 3G internet on intimate partner violence and women's empowerment, we exploit plausibly exogenous variation generated by the 3G coverage expansion in Nigeria over the period 2008-2018. In Nigeria, mobile phone coverage has expanded rapidly over the course of the past two decades (Forenbacher et al., 2019). As shown in Figure 2, in 2008, the year of our first DHS survey round, no DHS cluster in our sample had 3G coverage. In 2013 DHS, we find that around 59% of DHS clusters had some 3G coverage which further increased to 88% of clusters in 2018.

Our quasi-experimental setup, therefore, exploits cluster level variation (geographic) in 3G coverage in Nigeria over the period 2008 to 2018 (time) using DHS waves from the years 2008, 2013, and 2018. We essentially compare clusters that were covered by 3G technology with those that were not over the period 2008 to 2018. To ensure that our results are on account of access to 3G internet and not due to availability of basic cellular mobile network infrastructure, we control for the share of population covered by 2G network in a cluster, in all our regressions, similarly to Chiplunkar and Goldberg (2022). We also include controls for age, gender of the household head, age of the household head, number of members and children in the household, religion, ethnicity, drinking status of the husband, wealth status of the household, household ownership of television and radio, place of residence (rural vs urban) along with time fixed effects in our regressions. In order to account for potential selection issues where network providers may choose to provide 3G coverage in regions with favorable socio-economic and geographic characteristics, we control for several economic and geo-spatial characteristics at the cluster level including elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, GDP per capita, education, and area in our regressions.

While we control for a large number of observable characteristics at the cluster-level, there may still be unobservables that might affect the rollout of 3G coverage. To account for this, we create *pseudo-clusters* by matching DHS clusters that are geographically as close as possible across waves and use pseudo-cluster fixed effects in our regressions. This helps us to account for time invariant unobservable characteristics at the pseudo-cluster level. This becomes important considering that the DHS is not a longitudinal survey and that DHS clusters change across waves, which in turn does not allow us to use cluster fixed effects. We validate the quality of the match by comparing the correlation on key control variables between matched clusters vs randomly matched clusters. Our estimation equation for individual i residing in cluster c at time t is given below:

$$Y_{i,c,t} = \alpha_p + \beta_t + \theta \cdot 3G_{c,t} + \gamma \cdot X_{i,c,t} + \epsilon_{i,c,t} \quad (1)$$

where, $3G$ is a continuous measure which captures the proportion of population of a given cluster that is covered by 3G network at given time t. θ captures the effect of 3G on our outcomes of interest Y. X accounts for time varying controls at the individual, household, and cluster level. α_p and β_t represent pseudo-cluster and time fixed effects, respectively. We cluster our standard errors at the geographic pseudo-cluster level.



(a) 2008 (b) 2013 (c) 2018

Figure 2: Expansion of 3G in Nigeria between 2008, 2013 and 2018. Only areas with DHS clusters are shown in the figure and 2G and 3G coverage is calculated in areas that correspond to the clusters. Black boundaries indicate administrative level-2 identifiers.

We estimate how expansion in 3G coverage over time affects intimate partner violence faced by women. Our primary outcome of interest is a dummy variable that captures if a woman experienced (or faced) a particular kind of intimate partner violence including emotional violence, sexual violence, and physical violence, in last 12 months. We also create

Table 1: Descriptive Statistics

Variable	Description	Mean	Minimum	Maximum	Observations
Faced IPV in last 12 months	No=0 Yes=1	0.242 (0.428)	0	1	46952
Faced EV in last 12 months	No=0 Yes=1	0.194 (0.395)	0	1	47029
Faced SV in last 12 months	No=0 Yes=1	0.037 (0.190)	0	1	47180
Faced PV in last 12 months	No=0 Yes=1	0.118 (0.323)	0	1	47104
Prop. of pop. covered by 3G in a cluster	Continuous Variable	0.343 (0.424)	0	1	78951
Prop. of pop. covered by 2G in a cluster	Continuous Variable	0.770 (0.344)	0	1	78951
Age	Continuous Variable	31.556 (8.775)	15	49	79329
Household size	Continuous Variable	6.517 (3.671)	1	43	79,329
Children below 5 years in household	Continuous Variable	1.591 (1.330)	0	9	79329
Sex of household head	Male=0 Female=1	0.086 (0.281)	0	1	79329
Age of household head	Continuous Variable	42.767 (12.571)	15	95	79187
Wealth Index	1=Poorest, 2=Poorer 3=Middle, 4=Richer 6=Richest	2.832 (1.408)	1	5	79329
Place of residence	Urban=0 Rural=1	0.670 (0.470)	0	1	79,329
Ethnicity	Hausa=1 Others=0	0.291 (0.454)	0	1	79,329
Religion	Islam=1 Others=0	0.567 (0.495)	0	1	79329
Husband drinks Alcohol	No=0 Yes=1	0.193 (0.395)	0	1	47257
Mean Education years at cluster level	Continuous Variable	5.346 (4.270)	0	15.9	79,329
Household owns Television	No=0 Yes=1	0.413 (0.492)	0	1	79198
Household owns Radio	No=0 Yes=1	0.679 (0.466)	0	1	79242

Table 2: Descriptive Statistics: Geospatial Controls at Cluster level

Variable	Description	Mean	Minimum	Maximum	Observations
Elevation	Continuous Variable	311.641 (229.324)	0.939	1559.57	78,951
Distance to Coast	Continuous Variable	435.895 (296.89)	0.262	1105.559	78,951
Rainfall	Continuous Variable	3.655 (1.406)	0.818	7.280	78,951
Forest Share	Continuous Variable	0.149 (0.211)	0	1	78,951
Roads	Continuous Variable	2.015 (2.792)	0	25.394	78,951
Mines	No=0 Yes=1	0.003 (0.062)	0	1	78,951
Temperature	Continuous Variable	300.341 (1.475)	291.508	303.455	78,951
Desert Share	Continuous Variable	0.012 (0.106)	0	1	78,951
GDP	Continuous Variable	5604117717 (27109809549.87)	11922900.00	224194002944.00	78,951
Area	Continuous Variable	210076801.94 (140307262.24)	5945045.51	315270103.29	78,951

an aggregate measure - faced IPV in last 12 months - that captures if a woman faced any type of intimate partner violence - emotional, sexual or physical, during last 12 months. The summary statistics for our primary outcome and control variables are given in Table 1 and Table 2. We also examine the impact of 3G on several intermediary channels, including attitudes to IPV, women's empowerment as measured by decision-making power, husband's controlling behavior, and women's education and marriage.

5 Results

Table 3: Impact of 3G on Intimate Partner Violence in Nigeria

	Intimate Partner Violence (1)	Emotional Violence (2)	Sexual Violence (3)	Physical Violence (4)
3G Effect	-0.049***	-0.037**	-0.021***	-0.031***
	(0.018)	(0.018)	(0.006)	(0.010)
R^2	0.17	0.16	0.10	0.14
Observations	46,435	46,507	46,662	46,586
Mean	0.242	0.194	0.037	0.118

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, television and radio ownership of the household, religion, ethnicity, drinking status of the husband, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education, and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Table 3 reports the results for the effect of 3G internet on intimate partner violence faced by women in Nigeria. We find that women residing in regions exposed to 3G expansion were likely to face lower levels of intimate partner violence. Specifically, we find that women were significantly less likely to experience an instance of emotional violence, sexual violence, and physical violence in the last 12 months preceding the survey on account of 3G exposure. Women faced 3.7pp lower emotional violence (19% reduction from the mean level), 2.1pp lower sexual violence (56% reduction from the mean level), and 3.1pp lower physical violence

Table 4: Impact of 3G on husband's controlling behavior in Nigeria

	Husband:					
	jealous if talks with other men (1)	accuses of unfaithfulness (2)	doesn't permit to meet female friends (3)	limits wife's contact with family (4)	insists on knowing location (5)	Control Index (6)
3G Effect	-0.006	0.023*	-0.027**	-0.031***	0.046*	0.007
	(0.025)	(0.013)	(0.013)	(0.009)	(0.024)	(0.059)
R^2	0.14	0.09	0.09	0.09	0.13	0.12
Observations	46,493	46,577	46,625	46,607	46,611	46,079

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, religion, ethnicity, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

(26% reduction from the mean level) for a unitary increase in 3G coverage in a cluster i.e. moving from 0% of population covered to 100% population covered by 3G. For an average size increase in 3G (66% in 2018), this effect corresponds to 2.4pp lesser emotional violence, 1.38pp lesser sexual violence, and 2.04pp lower physical violence for women exposed to 3G.

We further assess if husband's controlling behavior (as reported by women) changes on account of exposure to 3G network and present the results for this exercise in Table 4. On some measures, we find that 3G exposure results in reductions in husband's controlling behaviours – for example, around wife's contacts with female friends or contacts with family. These results are suggestive of less control over women's connectivity with others, which can be facilitated by better communication afforded by internet technologies. On the other hand, we also see husbands were significantly more likely to accuse partners of unfaithfulness and insist on knowing their location. These results taken together show some of the mixed effects that can result from technologies – while they may facilitate improved communication, they can also generate opportunities for more control or monitoring of others. Increased opportunities for wider social contacts beyond family and friend networks may also trigger jealousy or accusations of unfaithfulness.

6 Potential Channels

We investigate potential channels through which access to 3G internet can impact IPV. Exposure to informational, and educational content on the internet in the form of videos, blogs, or social media can potentially empower women by assisting them in decision-making and enabling them to become self-reliant (*empowerment channel*), and also promote men's views around women's decision-making in the household. Second, exposure to internet could also affect women's ideals and aspirations, for instance, around education of women and marriage, which are factors that the literature shows could affect intimate partner violence faced in later life (Sara and Priyanka, 2023; Chatterjee and Poddar, 2024; Roychowdhury and Dhamija, 2021). Furthermore, 3G can also affect attitudes around the acceptability of IPV for both men and women (*ideational channel*). Third, 3G could also enable men to be less controlling of wife's behaviours, especially if there are tangible benefits associated with 3G (e.g. more frequent communication or connectivity).

6.1 Women's Autonomy

Table 5: Impact of 3G on autonomy of women (say in decision-making) in Nigeria

	Say in decision making for:					
	own healthcare (1)	large hh purchases (2)	visit to family/relatives (3)	husband earnings (4)	own earnings (5)	Autonomy Index (6)
3G Effect	0.016 (0.017)	0.028* (0.016)	0.002 (0.018)	0.026* (0.016)	0.006 (0.017)	0.074 (0.057)
R^2	0.31	0.30	0.28	0.20	0.13	0.36
Observations	78,535	78,511	78,523	77,466	47,731	77,391

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, television and radio ownership of the household, religion, ethnicity, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

We first assess if 3G network expansion affected women's autonomy in the household as expressed in terms of higher decision-making power and present these results in Table 5. We find that all the dimensions related to autonomy in different domains were positively associated with 3G expansion, with decision-making in two domains – regarding household purchases and husband's earnings – reaching statistical significance at 10% levels.

Table 6: Impact of 3G on women's say in decision making (as reported by men) in Nigeria

	Say in decision making for:	
	large hh purchases (1)	husband's earnings (2)
3G Effect	0.062**	0.019
	(0.026)	(0.025)
R^2	0.29	0.27
Observations	25,000	20,021

Notes: All columns represent different regressions for currently married (or partnered) men from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members in the household, religion, ethnicity, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** $p<0.01$ **$p<0.05$ *$p<0.1$

We further examine if this improved decision-making power for women in the household is reflected also in the responses of men. These results are presented in Table 6. Men were also more likely to say that women had higher autonomy in decisions, with say in decision-making surrounding large household purchases statistically significant at p ¡ 0.05. While we would like to test this impact across a larger set of questions, the DHS only covers the dimensions of household purchases and husband's earnings to look at women's say in decision making on these issues as reported by men. The results, however, provide support for the idea that exposure to 3G led to increases in women's decision-making power in the household.

6.2 Change in Views around IPV

We next examine how 3G expansion affected views around the acceptability of intimate partner violence against women. This is crucial considering that attitudes can be important drivers of intimate partner violence against women (González and Rodríguez-Planas, 2020; Mookerjee, Ojha and Roy, 2021). The results for this exercise are reported in Table 7 and Table 8. As we can observe, women exposed to 3G were now less likely to justify intimate partner violence across different dimensions – they were 3.3 pp less likely to justify violence caused on account of arguing with the husband or on account of wife burning food. While we observe that husband's acceptability of violence was negatively associated with 3G availability across the different measures, we do not pick any significant effects here at the conventional levels.

Table 7: Impact of 3G on women's views on IPV in Nigeria

	Beating justified if wife:					
	goes out without telling husband (1)	neglects children (2)	argues with husband (3)	refuses sex with husband (4)	burns food (5)	IPV Views Index (6)
3G Effect	-0.014 (0.021)	-0.026 (0.021)	-0.033* (0.019)	-0.004 (0.022)	-0.033* (0.019)	-0.105 (0.097)
R^2	0.21	0.19	0.18	0.24	0.17	0.25
Observations	77,922	77,902	77,738	77,552	77,784	76,834

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, television and radio ownership of the household, religion, ethnicity, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

6.3 Changes in Education, Marriage and Fertility

We examine if availability of 3G internet changes women's education, as well as demographic behaviours such as age at marriage and first birth, which can contribute to reduction in the

Table 8: Impact of 3G on men's views on IPV in Nigeria

	Beating justified if wife:					
	goes out without telling husband (1)	neglects children (2)	argues with husband (3)	refuses sex with husband (4)	burns food (5)	IPV Views Index (6)
3G Effect	-0.00003	-0.027	-0.0005	-0.001	-0.012	-0.025
	(0.018)	(0.017)	(0.015)	(0.014)	(0.012)	(0.064)
R^2	0.17	0.15	0.13	0.17	0.16	0.19
Observations	24,687	24,772	24,755	24,812	24,848	24,337

Notes: All columns represent different regressions for currently married (or partnered) men from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members in the household, religion, ethnicity, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

experiences of intimate partner violence. Women who are educated are more likely to have higher bargaining power in the household (Chatterjee and Poddar, 2024), which may in turn reduce their risk of IPV (Weitzman, 2014; Roychowdhury and Dhamija, 2021). Furthermore, higher education is also linked to higher age at marriage, and higher ages at marriage can increase women's bargaining power within unions and reduce risks of IPV (Roychowdhury and Dhamija, 2021). Higher education together with higher age at marriage for women is also likely to have positive effects for partner quality (Sara and Priyanka, 2023). Changes in women's marriage and fertility behaviours on account of 3G could also emerge from ideational changes from the exposure to more liberalized ideas about women's roles.

As shown in Table 9, we observe that women exposed to 3G were significantly more likely to have a higher age of marriage and first birth when compared to women residing in non-3G regions. We do not observe statistically significant effects for women's education at the individual level (all models control for cluster-level community education). These results point to the potential greater importance of the demographic pathways through which IPV reductions could occur. When looking at the same outcomes for men, we do not observe

Table 9: Impact of 3G on women's education, age at marriage and age at first birth

	Years of Education (1)	Age at Marriage (2)	Age at First Birth (3)
3G Effect	0.089	0.189*	0.286***
	(0.068)	(0.104)	(0.100)
R^2	0.68	0.37	0.28
Observations	78,617	78,654	72,470

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, television and radio ownership of the household, religion, ethnicity, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

statistically significant effects across the three outcomes as highlighted in Table 10.

6.4 Labour Market Outcomes

We also test an empowerment channel linked to labour market outcomes that can potentially reduce intimate partner violence. This can happen as improved labor market outcomes can potentially provide women higher bargaining power within the household (Aizer, 2010). We report the results for this exercise in Table 11. As we can observe, we do not find consistent effects of 3G exposure on labor market outcomes of women in Nigeria.

7 Heterogeneity

We perform heterogeneity analysis to gain a more nuanced understanding of the impacts of 3G on IPV. Here, we assess if the impacts of 3G varied based on rural-urban residence of a woman respondent. The impact of 3G may be different for rural versus urban areas. Incentives to adopt 3G may be higher in urban areas, but pre-existing views on IPV may

Table 10: Impact of 3G on men's education, age at marriage and age at first birth

	Years of Education (1)	Age at Marriage (2)	Age at First Birth (3)
3G Effect	-0.00002	0.210	0.090
	(0.112)	(0.201)	(0.203)
R^2	0.59	0.33	0.31
Observations	25,046	25,053	23,060

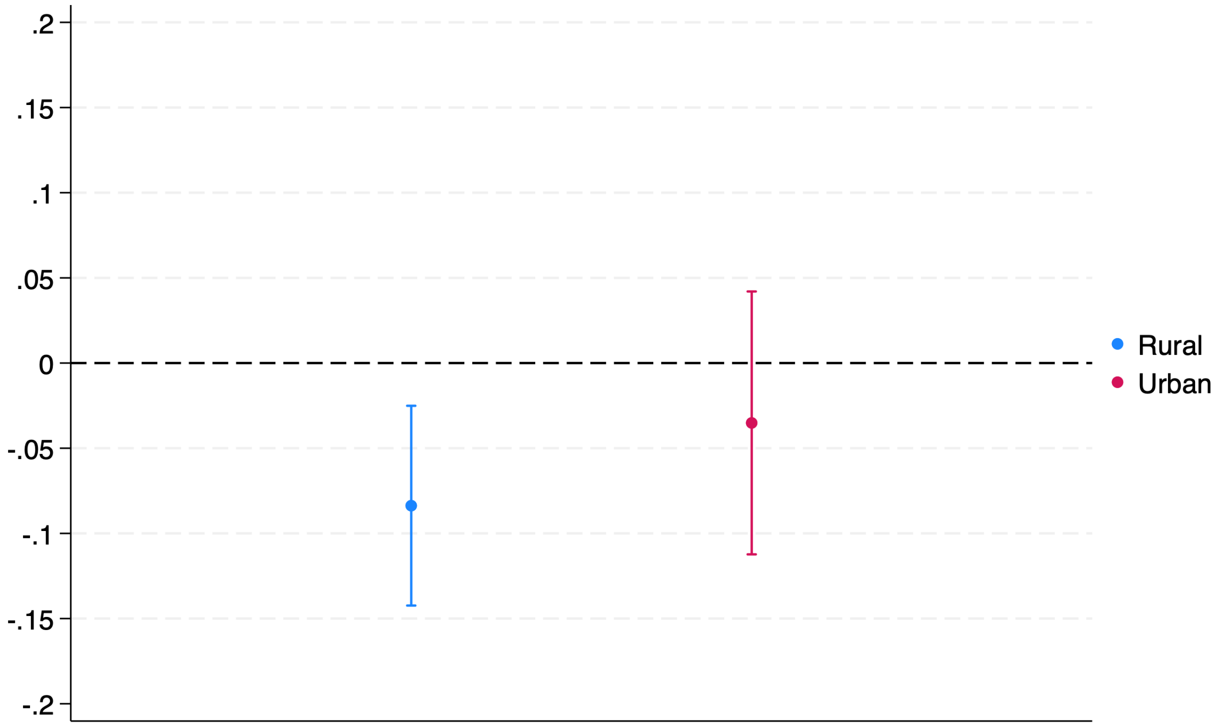
Notes: All columns represent different regressions for currently married (or partnered) men from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members in the household, religion, ethnicity, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Table 11: Impact of 3G on labour market outcomes of women in Nigeria

					if Earnings Received=1
	Currently Employed (1)	Work Frequency (2)	Work for an Employer (3)	Earnings Received (4)	Cash Earnings (5)
3G Effect	-0.007	-0.045**	-0.007	-0.003	-0.006
	(0.017)	(0.022)	(0.008)	(0.018)	(0.006)
R^2	0.21	0.22	0.14	0.26	0.13
Observations	78,387	56,523	56,472	56,541	48,531

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, television and radio ownership of the household, religion, ethnicity, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Figure 3: Subsample Estimates for IPV in last 12 months: Rural vs Urban



also be more liberal in urban areas. In rural areas, gender attitudes may be more patriarchal with a greater scope to be influenced by the ideas brought about by exposure to the extra-local influences through the internet. Consistent with this latter pathway, we find find larger impacts of 3G on IPV in rural areas (Figure 3).

We further assess differences in impacts of 3G by religion, comparing Christians and Muslims (Figure 4), and in areas affected by Boko Haram militias versus those that are not. The latter captures significant regional variations in Nigeria as Boko Haram affected area lie largely to the northeast of the country (Table 12). The impacts of 3G are more negative (larger) among Christians, and largely concentrated in non-Boko Haram areas.

Figure 4: Subsample Estimates for IPV in last 12 months: Muslims and Christians

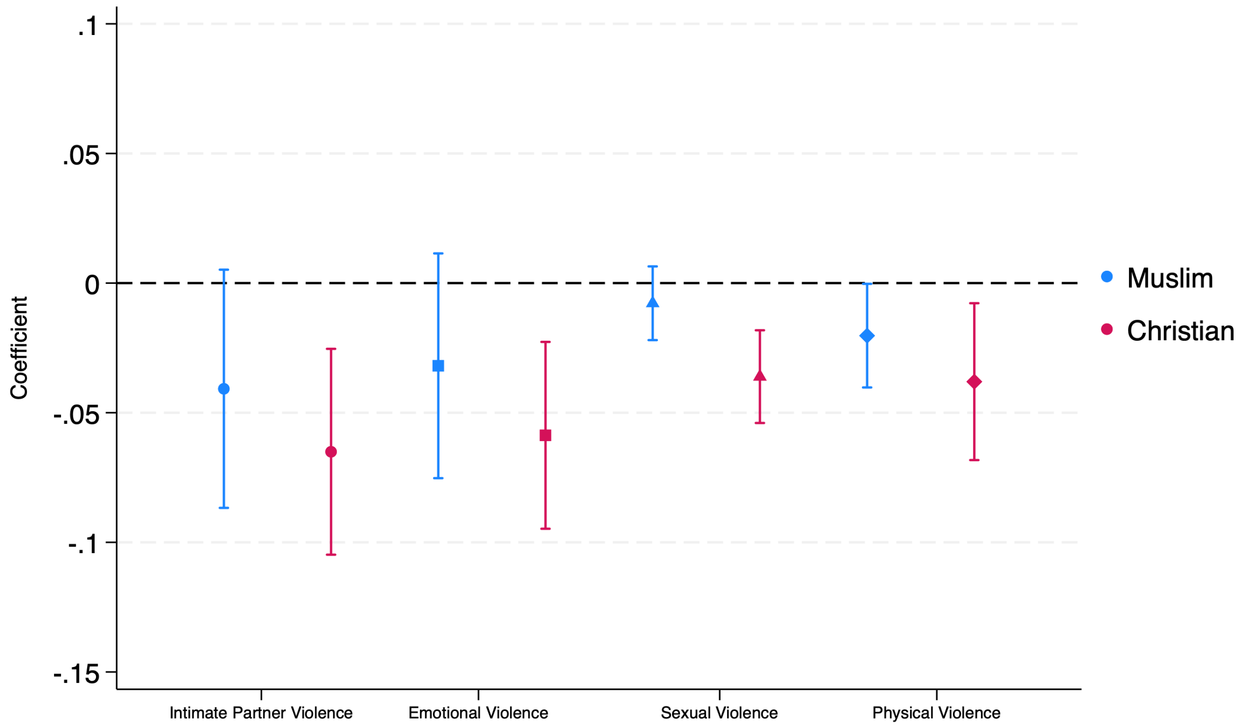


Table 12: Impact of 3G: Accounting for presence of Boko Haram

	Intimate Partner Violence (1)	Emotional Violence (2)	Sexual Violence (3)	Physical Violence (4)
3G × Non-Boko Haram Areas	-0.076**	-0.073**	-0.021	-0.039**
	(0.035)	(0.033)	(0.012)	(0.016)
R^2	0.18	0.16	0.09	0.14
Observations	46,435	46,507	46,662	46,586

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, religion, ethnicity, drinking status of the husband, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

8 Robustness Checks

In this section, we test the sensitivity of our estimates by running several robustness checks.

8.1 Alternative Identification Strategy

While our primary findings are based on the design that exploits variation in 3G coverage at the cluster level, we also try to devise an alternative identification strategy at a higher (or coarser) geographical resolution – the local government area (LGA) (administrative level 2) level to test the robustness of our estimates. While LGAs are larger than cluster, we are able to track LGAs across the three waves, which is not possible in the cluster design as the DHS does not provide a unique cluster identifier across different waves. This also helps to account for any potential issues originating on account of a cluster's spatial displacement as a given cluster would have a higher probability of being located within a fixed and larger LGA. However, these advantages of using an LGA based design come at the cost of precision as the 3G coverage in an LGA region comes up to be an average of coverage shares of the clusters located within that LGA unit. The LGA design still provides us a useful measure to understand the robustness of our effects. Currently, there are 774 administrative level 2 regions (local government areas) in Nigeria.[3]

Our identification strategy for the LGA design relies on a simple difference-in-difference framework. We run the following regression for individual i residing in local government area l at time t :

$$Y_{i,l,t} = \alpha_l + \beta_t + \theta \cdot 3G_{l,t} + \gamma \cdot X_{i,c,t} + \epsilon_{i,c,l,t} \tag{2}$$

where, α_c and β_t represent local government area and time fixed effects, respectively. $3G$ is a continuous measure which captures the proportion of population of a given local government area that is covered by 3G network at given time t. θ captures the effect of 3G on our outcomes of interest Y. X accounts for time varying controls at the individual,

[3] https://www.clgf.org.uk/default/assets/File/Country_profiles/Nigeria.pdf

household, and cluster level. We cluster our standard errors at the level of local government area. The results for this alternative identification strategy is reported in Table 13. As we can observe, the results for this alternative strategy are qualitatively similar to our primary estimates as we again find that exposure to 3G lead to lower instances of intimate partner violence. To some extent, we can also interpret these results as conservative estimates when compared to our primary cluster based identification design that has a higher degree of precision, as it captures the treatment at a more localized level.

Table 13: Impact of 3G on Intimate Partner Violence in Nigeria

	Intimate Partner Violence (1)	Emotional Violence (2)	Sexual Violence (3)	Physical Violence
3G Effect	-0.051*	-0.035	-0.025***	-0.018
	(0.026)	(0.024)	(0.008)	(0.013)
R^2	0.15	0.14	0.08	0.12
Observations	46,355	46,427	46,582	46,506
Mean	0.242	0.194	0.037	0.118

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, television and radio ownership of the household, religion, ethnicity, drinking status of the husband, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education, and GDP. Robust standard errors clustered at the level of local government area are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

8.2 Alternative formulations of IPV variable

We test the robustness of our findings by looking at an alternative way of measuring intimate partner violence. We create a continuous measure to capture instances of violence faced by women under different violence categories including emotional violence, sexual violence, and physical violence. So if a women answers that she has been humiliated and threatened by husband then the emotional violence variable will take the value two. This is in contrast to our dummy variable indicator for 'facing a particular type of IPV' as it focuses more on the intensity of different violence types. The results for this alternative measure are reported in Table 14. As can be observed, our results remain qualitatively the same to our main estimates.

Table 14: Impact of 3G on Intimate Partner Violence in Nigeria

	Intimate Partner Violence Index (1)	Emotional Violence Index (2)	Sexual Violence Index (3)	Physical Violence Index (4)
3G Effect	-0.162***	-0.061**	-0.024***	-0.079***
	(0.049)	(0.028)	(0.009)	(0.025)
R^2	0.16	0.15	0.09	0.14
Observations	46,084	46,443	46,642	46,446

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, television and radio ownership of the household, religion, ethnicity, drinking status of the husband, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

8.3 Under-reporting of Intimate Partner Violence

With intimate partner violence being a sensitive issue, it is possible for our results to be confounded by potential self-reported bias where women might be inclined to give socially desirable responses (Chatterjee and Poddar, 2024; Ellsberg et al., 2001). This will result in potential under-reporting of intimate partner violence (Saunders, 1991; Hidrobo and Fernald, 2013). To account for this concern, we run our regressions on the sub-sample of women whose interviews were not interrupted by the presence of any adult household member with the rationale being that women would be more likely to under-report intimate partner violence in the presence of a household member rather than in private. We report the results of this exercise in Table 15. The results are very much in line with our main estimates and suggest that impact of potential under-reporting is likely to be minimal here.

Table 15: Uninterrupted Interviews: Impact of 3G on Intimate Partner Violence in Nigeria

	Intimate Partner Violence (1)	Emotional Violence (2)	Sexual Violence (3)	Physical Violence (4)
3G Effect	-0.048**	-0.038**	-0.019***	-0.035***
	(0.019)	(0.019)	(0.006)	(0.010)
R^2	0.18	0.16	0.10	0.15
Observations	42,991	43,050	43,196	43,126

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, religion, ethnicity, drinking status of the husband, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

9 Conclusion

We examine the impact of the rollout of 3G mobile networks on intimate partner violence – a key marker of women's status in the household – in Nigeria, as well as channels affecting IPV linked to attitudes to IPV, women's decision-making power and empowerment, as measured in educational and demographic outcomes. Using a two-way fixed-effect design that relies on geographic and time variation, and by accounting for a range of individual, household and geographic controls, we show that arrival of 3G internet results in lower reported IPV among women across physical, emotional and sexual violence. We provide support for ideational and empowerment mechanisms in explaining these reductions in IPV experience. We find reductions in the acceptability of IPV among women, although weaker evidence for this among men. Among men and women, we find clearer evidence for increases in women's decision-making power in the household. We find shifts in demographic behaviour, linked to delayed marriage and first births, among women exposed to 3G. We find more mixed effects for women's reports of husband's controlling behaviours – with reductions in controlling behaviours surrounding women's contacts with friends and families, but increased accusations of unfaithfulness.

Our paper contributes to a growing literature examining the impacts of digital technologies, particularly mobile phones, on gender and demographic outcomes. It is, to the best of our knowledge, the first to link detailed, high-resolution mobile coverage maps with the Demographic and Health Surveys. In contrast to the current state of the empirical evidence that has relied on cross-sectional designs with individual-level measures of mobile ownership and their links with IPV and women's empowerment outcomes (e.g. (Pesando, 2022; Rotondi et al., 2020)), our study uses a more rigorous design that exploits an exogenous measure of the expansion of technology infrastructure, leveraging the shift from 2G to 3G over time over 10 years. This allows us to identify effects of internet expansion, as distinct from communication technologies such as 2G. We also explore a broader range of mechanisms than past work, considering ideational and empowerment channels in our analysis.

A significant data contribution of our work lies in our systematic comparison of mobile coverage maps across different sources, including those that have been applied in other studies from GSMA-CB (e.g. (Chiplunkar and Goldberg, 2022; Manacorda and Tesei, 2020)), and highlight notable deficiencies in the GSMA-CB maps that are currently the ones most widely used in this emerging literature. The internet, we hypothesize, can give result to more complex and theoretically ambiguous effects, which can be both empowering and disempowering. Our results point to an empowering role for internet technologies on women's status. Yet, we also find more mixed effects in some outcomes, linked to husband's controlling behaviours as well as labour market outcomes for women.

While our design provides us with several strengths, we also acknowledge several limitations. First, while we use a measure of 3G expansion, we cannot distinguish between impacts of individual technology adoption and the broader spillovers of technological availability in communities that the arrival of 3G enables. Both mechanisms are plausible – 3G enables women and men to use the internet directly, but some social learning and feedback mechanisms could be activated also through exposure of others within a community to the internet or through other types of access like device sharing. We do not have individual-level measures of mobile and internet use over time across all three waves in the DHS to be able to test this, but in next steps, we plan to use the measures available in the 2018 wave. Second, our effect of interest seeks to capture the expansion of 3G, but does not assess how this varies with continued exposure. With greater exposure to technology, more complex effects, linked, for example, to excessive use or diversifying exposures to different channels may emerge with greater use and integration of the technology across multiple domains of life. In next steps, we intend to expand on other measures of technology rollout including lagged coverage measures and time since 3G availability. Third, our measures rely on self-reported measures of IPV experience, as well as reported measures on decision-making power and husband's controlling behaviours. While we conduct analysis to test the sensitivity of our results to underreporting based on presence of others, we cannot entirely exclude concerns around underrporting and/or social desirability bias. Fourth, the lack of a common cluster identifier across waves in the DHS implies that we control for time-invariant observables through pseudo-cluster fixed effects. These assume that geographically proximate areas are similar on time invariant unobservables. We test a complementary strategy with admin-2 fixed effects (that are stable over time), but are geographically coarser areas (and less conducive to more precise 3G measurement). The general directions of our results are consistent across the two strategies, which provides additional support for our findings.

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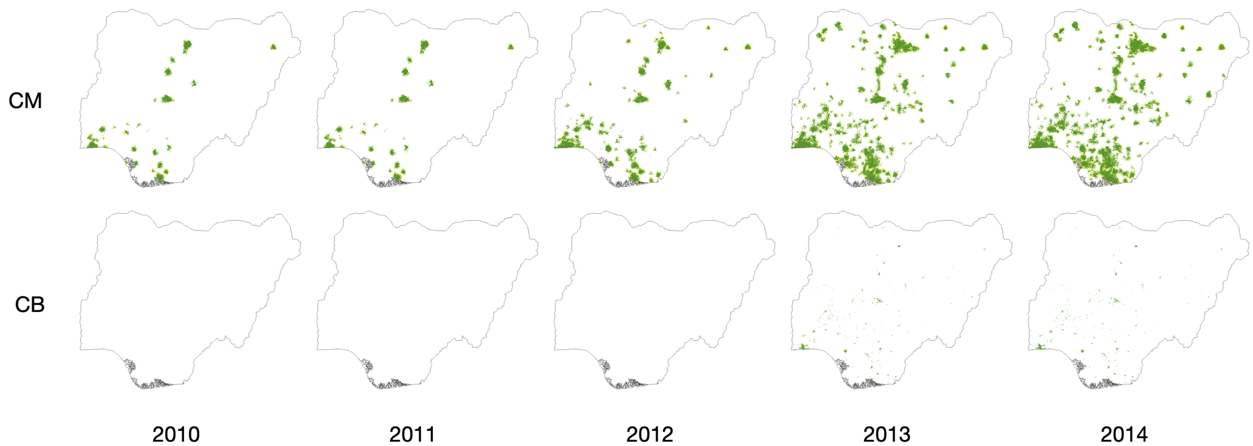
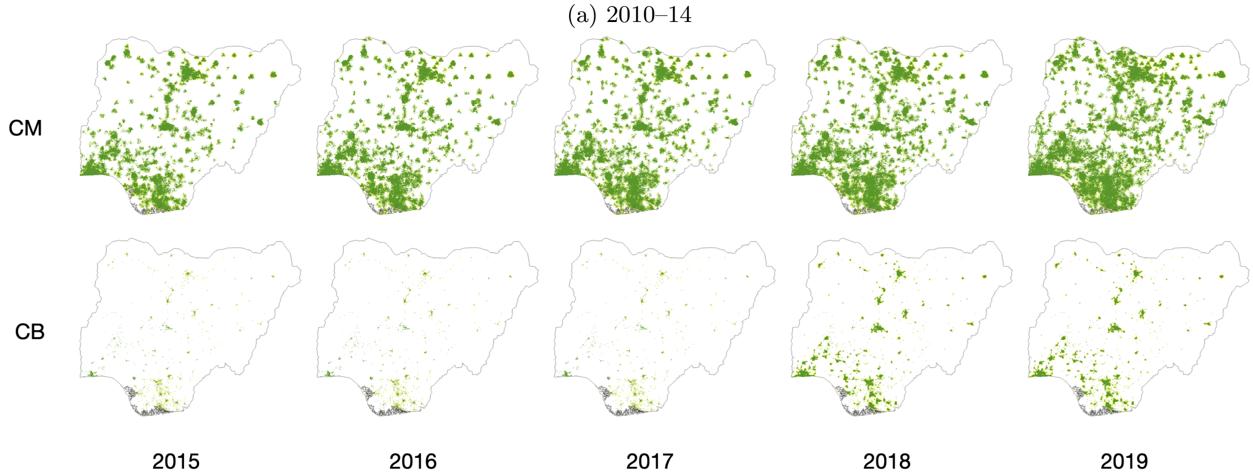
Table 16: Domestic Violence Module of DHS

	Response
Emotional Violence	
1) Spouse ever humiliated you?	No=0, Yes=1
2) Spouse ever threatened you with harm?	No=0, Yes=1
3) Spouse ever insulted you?	No=0, Yes=1
Sexual Violence	
1) Spouse ever physically forced sex when not wanted?	No=0, Yes=1
2) Spouse ever forced other unwanted sexual acts when not wanted?	No=0, Yes=1
Physical Violence	
1) Spouse ever pushed, shook or threw something?	No=0, Yes=1
2) Spouse ever slapped?	No=0, Yes=1
3) Spouse ever punched with fist or something harmful?	No=0, Yes=1
4) Spouse ever kicked or dragged?	No=0, Yes=1
5) Spouse ever tried to strangle or burn?	No=0, Yes=1
6) Spouse ever threatened with knife/gun or other weapon?	No=0, Yes=1
7) Spouse ever twisted her arm or pulled her hair?	No=0, Yes=1



(a) 2010–14



(b) 2015–19

Figure 5: Rollout of 3G coverage in Nigeria from 2010–19. CM are the GSMA Connectivity Maps, CB are the maps from the GSMA Mobile Coverage Explorer maps distributed through Collins-Bartholomew. The green-yellow colour represents mobile coverage.

Table 17: Impact of 3G in Nigeria on probability of getting divorced or separated

	Divorced or Separated (1)
3G Effect	0.004
	(0.004)
R^2	0.13
Observations	81,228

Notes: All columns represent different regressions for women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, religion, ethnicity, wealth status of the household, household ownership of television and radio, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, education, area, and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Table 18: Heterogeneity: Muslims and Christians

	Intimate Partner Violence		Emotional Violence		Sexual Violence		Physical Violence	
	Muslim	Christian	Muslim	Christian	Muslim	Christian	Muslim	Christian
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3G Effect	-0.040	-0.065***	-0.032	-0.058***	-0.008	-0.036***	-0.020*	-0.038**
	(0.028)	(0.024)	(0.026)	(0.021)	(0.009)	(0.010)	(0.012)	(0.018)
R^2	0.17	0.18	0.16	0.17	0.11	0.11	0.12	0.14
Observations	24,912	20,686	24,952	20,717	25,048	20,771	25,021	20,725

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, television and radio ownership of the household, ethnicity, drinking status of the husband, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, education and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1

Table 19: Impact of 3G: Heterogeneity based on Religion (Muslims=0 & Christians=1)

	Intimate Partner Violence (1)	Emotional Violence (2)	Sexual Violence (3)	Physical Violence (4)
3G × Christians	0.005	0.033*	-0.020***	-0.041***
	(0.018)	(0.017)	(0.006)	(0.010)
R^2	0.17	0.16	0.09	0.14
Observations	45,598	46,669	45,819	45,746

Notes: All columns represent different regressions for currently married (or partnered) women from the DHS 2008, 2013 and 2018 dataset for Nigeria. All regressions include geographic and time fixed effects. Additional variables in the model include individual and household level controls such as age, gender of the household head, age of the household head, number of members and children in the household, religion, ethnicity, drinking status of the husband, wealth status of the household, place of residence (rural vs urban). Model also includes cluster level controls such as population covered by 2G coverage, elevation, distance to coast, rainfall, temperature, forest share, share of desert, availability of mine, availability of roads, area, and GDP. Robust standard errors clustered at the level of pseudo-cluster are reported in parentheses. *** p<0.01 **p<0.05 *p<0.1