Mobile Divides: Gender, Socioeconomic Status, and Mobile Phone Use in Rwanda

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***Abstract*—We combine data from a field survey with transaction log data from a mobile phone operator to provide new insight into daily patterns of mobile phone use in Rwanda. The analysis is divided into three parts. First, we present a statistical comparison of the general Rwandan population to the population of mobile phone owners in Rwanda. We find that phone owners are considerably wealthier, better educated, and more predominantly male than the general population. Second, we analyze patterns of phone use and access, based on self-reported survey data. We note statistically significant differences by gender; for instance, women are more likely to use shared phones than men. Third, we perform a quantitative analysis of calling patterns and social network structure using mobile operator billing logs. By these measures, the differences between men and women are more modest, but we observe vast differences in utilization between the relatively rich and the relatively poor. Taken together, the evidence in this paper suggests that phones are disproportionately owned and used by the privileged strata of Rwandan society.**

***Index Terms*—ICTD, mobile phones, CDR, call detail records, phone survey, Rwanda**

I. Introduction

> "Once the toys of rich yuppies, mobile phones have evolved in a few short years to become tools of economic empowerment for the world's poorest people. These phones compensate for inadequate infrastructure... making markets more efficient and unleashing entrepreneurship."
>
> *–The Economist, September 2009*

In the popular media and in the development community, observers are optimistic about the potential uses of the mobile phone in the developing world. Called a "lifeline for the world's poor" by the BBC, mobile phones are reaching the world's poor at an amazing rate.[1] Already, over two thirds of the world's mobile phones are in developing countries, and Nokia estimates that by 2012 over 90 percent of sub-Saharan Africa will have mobile coverage[1].

The potential impact of the mobile phone has not been lost on the research community. A wealth of recent ethnographic research has sought to characterize mobile phone use in the developing world, while a growing body of quantitative work attempts to estimate the impacts of these technologies on local and national economies [2][3]. A separate strain of research seeks to leverage this knowledge by building mobile-based technologies for deployment in developing countries [4][5].

Given this heightened interest in mobile phone use in developing countries, it is surprising how many basic gaps exist in our understanding of how phones are being used on a day-to-day basis by the average person. For instance, it is no secret that many phones in East Africa are shared by multiple individuals, but there are few reliable estimates regarding the overall prevalence of phone sharing. For this and for other phenomena, even less is known about the subtler dynamics *within* the population: Do women share phones more than men? Do they call a more diverse network of contacts? Do poor people use their phones differently from rich people?

This paper seeks to fill a number of these gaps in our understanding through a detailed quantitative

[1] *BBC News, February 19, 2007*

analysis of phone use in Rwanda. The analysis is divided into three sections. First, we compare the overall demographic composition of Rwanda with the demographic composition of a representative sample of mobile phone users, exposing systematic differences between those who own phones and those who do not. Second, we examine new survey data on phone use, paying particular attention to reported behaviors of phone ownership and sharing. Third, we analyze the call histories of our survey respondents, as recorded by the mobile operator, to better understand normal patterns of utilization. Some representative findings include:

- *Section IV:* Phone users are disproportionately male, better educated, older, and come from larger households than normal Rwandans. Using an econometric model, we estimate the annual expenditures of phone users to be over twice that of ordinary citizens.
- *Section V:* The vast majority of those surveyed report owning the phone they are using, and roughly one third say they share their mobile phone with friends and family. We note statistically significant differences between men and women in patterns of sharing and in types of calls made.
- *Section VI:* Average call length in Rwanda is extremely short, at roughly 32 seconds. While men and women spend approximately the same amount of time per day on the phone, there are subtle differences in use by gender. We also observe vastly different patterns of use between the upper and lower income quartiles.

While the primary focus of this paper is to provide a quantitative perspective on mobile phone use in Rwanda, we also contribute to the literature by describing a methodological innovation that may be useful to other researchers interested in studying information and communication technologies in developing countries. This innovation is to combine data collected in structured phone interviews with call detail records on network usage obtained from the dominant mobile phone operator. Thus, for a geographically stratified random sample of roughly 900 mobile phone users, we obtain not only basic demographic and socioeconomic information, but also a detailed history of all phone calls made and received. Our analysis leverages this novel source of data, and points to many possible extensions for future work.

The remainder of the paper is organized as follows: Section II discusses related work, and Section III describes the principal datasets used in the analysis. Section IV presents a quantitative comparison of the population of mobile phone users to the larger population of Rwandans. Sections V and VI analyze reported and observed patterns of mobile phone use, first using data collected in phone interviews and later incorporating the data obtained from the phone company. Section VII concludes.

II. Related Work

To our knowledge, this is the first paper to study phone use through a joint analysis of direct demographic surveys and call detail records (CDR) obtained from the phone company. However, in addition to the review articles mentioned in the introduction, we highlight the results of three separate strands of research that are directly relevant to the analysis that follows.

First, a small group of studies have previously attempted to quantify patterns of phone use in the developing world at a level of detail exceeding the cross-country statistics provided by organizations such as the International Telecommunication Union. In particular, [6] conducted household surveys in ten African nations, in an effort to measure how individuals and households use different types of information and communication technologies (ICTs). Using data collected in 2004 and 2005, the authors provide reference statistics that provide a useful context for some of the numbers reported in this paper. Separately, [7] conducted 1,800 household surveys in Uganda, Botswana, and Ghana, focusing on gender-disaggregated access to ICTs. They found that men and women had remarkably similar patterns of use. In similar work, [8] draws on gender-disaggregated data from various sources to characterize the "gender divide" in access to and use of ICTs. While the majority of our findings are consistent with these results, we describe a number of gender-specific differences which, due to a lack

of suitable data, were not tested in prior work.

Second, a nascent body of literature has begun to use CDR to understand underlying dynamics of human behavior. For instance, [9] use CDR to analyze the trajectories of 100,000 people in a European country to study patterns of human mobility, and [10] examine the structure of friend networks using data from 100 specially programmed smartphones. There are only a few examples of this type of analysis in the context of the developing world [11][12][13], but the number of studies is rapidly increasing as data becomes more readily available.

Finally, there exist a handful of studies which provide excellent descriptions of different patterns of mobile phone use in specific communities throughout the developing world [14][15], with a few focused specifically on Rwanda [16][17]. We will draw on these insights in interpreting our quantitative results in the sections that follow. In particular, in the discussion and conclusion, we will try to situate the quantitative results of this paper within the qualitative findings of researchers working on similar questions.

III. Data & Survey Methodology

The analysis relies on three different sources of data: a phone survey of a representative sample of Rwandan mobile phone users, a detailed log of all phone activity by those individuals in the period from January 2005 to December 2008, and a household-level demographic survey conducted by the Rwandan government. Further details on each dataset is provided in the following subsections.

A. Phone survey

In Summer 2009 we administered a short, structured interview to a geographically stratified group of mobile phone users using a trained group of enumerators from the Kigali Institute of Science and Technology (KIST). The survey instrument contained roughly 80 questions and took between 10 and 20 minutes to administer. We queried basic demographic and socioeconomic information, but did not collect identifying information such as the respondent's name, address, or identification numbers. The anonymized phone numbers were obtained from Rwanda's primary mobile phone operator, which had over 90 percent market share at the time of the survey.

The survey population was intended to be a representative sample of all active phone users. Thus, from the full database of 1.5 million registered phone numbers, we eliminated numbers which had not been used at least once in each of the three most recent months for which we had data (October through December 2008). Then, each of the remaining 800,000 numbers was assigned to a geographic district based on the location of the phone for the majority of calls made. From each of the 30 districts, 300 numbers were then selected randomly, creating a base survey population of 9,000 candidate respondents. Finally, sampling weights for each district were determined based on the distribution of districts in the set of 800,000 active numbers.

Given available resources, the team of surveyors was able to call 1,529 unique respondents; these were selected randomly from the original 9,000. Of the numbers dialed, 588 (38%) never picked up the phone. However, of those who answered their phones, only 16 (2%) refused to participate in the survey. After discarding a handful of surveys that had imperfect data, we were left with a total of 901 valid surveys. The full breakdown of survey responses is given in Figure 1.

The large number of unanswered calls is somewhat striking, but not surprising. As has been noted by other researchers [18], a large number of people own a SIM card (which costs roughly USD$1) without actually owning a mobile phone (which

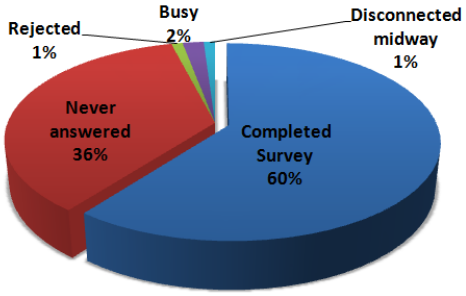


Fig. 1. Survey population

costs closer to USD$30). Moreover, SIM cards are commonly lost or stolen, and many people leave their phone off due to the lack of reliable power in the country. Also noteworthy was the high response rate of those who did pick up the phone. We believe this was due to several factors: first, incoming calls cost nothing to receive, and respondents were paid USD$1 in airtime as compensation - a significant amount given that GDP per capita is roughly USD$1,000. Second, most Rwandans are unaccustomed to receiving a call lasting up to 20 minutes (40 times the length of the average phone call), and many seemed quite flattered to receive the extended attention of university researchers. Finally, respondents were generally much more receptive than would be expected in most developed countries, where privacy concerns are rife.[2]

B. Phone company records (CDR)

For each of the users whom we attempted to contact in the phone survey, we have obtained from the phone company an exhaustive log of all phone-based activity that occurred from the beginning of 2005 through the end of 2008. Thus, for every phone call made or received by one of the survey respondents, we know the time and date of the call, as well as the proximate location (based on the cell towers through which the call was routed) of both the caller and the receiver.

Table I presents simple summary statistics computed from these call detail records for the sample of 1,529 users whom we attempted to contact. Most of the metrics are intuitive, but a few require explanation:

- *Activation date*: The date on which the phone first appears in the transaction logs.
- *Days of activity*: The number of different days on which the phone was used.
- *Net calls*: The number of outgoing calls minus the number of incoming calls.
- *Degree*: The number of unique contacts with whom the person communicated (called or received a call).
- *Daily degree*: The average number of unique people contacted on any given day that the phone was used.
- *Recharge*: Monetary value deposited on SIM card.

In Table I, average values are computed separately for the set of numbers dialed (column 1), for survey respondents (column 2), for non-respondents (column 3), and by response to the question, "Does anyone else use this phone regularly?" (columns 4 and 5). The final two columns present the p-values obtained by running two-sample t-tests comparing all respondents with all non-respondents (column 6), and by comparing respondents who share their phones with those who do not (column 7).

In general, we observe only modest differences between the group of individuals who participated in the phone survey and those who did not. This is important, as we will later assume that the sample of survey respondents is representative of the larger population of mobile phone users in Rwanda. However, the two groups are not identical. Namely, there is a significant difference in the number of days during which the phone is used. This difference may be indicative of the fact that on any given day a non-respondent is more likely to have his phone off or unavailable, and therefore is less likely to answer his phone on the day of the survey. However, on the days during which the phone is used, behavior of respondents and non-respondents appears quite similar.

Also worth noting is the fact that aggregate usage on shared phones does not appear to be significantly different from aggregate usage on unshared phones (Table I, column 7). This is useful, as it allows us to increase our statistical power by including shared phones in most of the later analysis. More generally, however, the result is surprising, as our ex ante expectation was that shared phones would show a higher level of utilization and a wider network of contacts. The fact that shared phones appear so similar to unshared phones could be due to a variety of factors: non-owners might be using their own SIM cards; the owner of the shared phone might be the dominant user; non-owners may use the phone in exactly the same way as the owner. These and other dynamics of phone sharing are discussed further in Section V-A.

[2]We had multiple respondents call us back at the call center, at their own expense, to thank us for taking an interest in their affairs, and to request that we call their friends and family as well (such requests were politely declined).

TABLE I
SUMMARY STATISTICS: SURVEY RESPONDENTS, SURVEY NON-RESPONDENTS, AND SHARED PHONES.

	(1) Dialed	(2) Respondents	(3) No Answer	(4) Shared	(5) Unshared	(6) RvN	(7) SvNS
Activation Date	2/9/08	1/12/08	4/5/08	1/2/08	1/12/08	-	-
Days of activity	672.2	770.3	540.3	702.3	799	0.0002	0.31
Avg. call length	32.3	31.7	33	31.5	31.8	0.49	0.9
Calls per day	6.24	6.25	6.23	6.32	6.22	0.98	0.94
Net calls per day (out-in)	0.4	0.087	0.82	0.54	-0.1	0.19	0.46
Degree	797.8	734.0	883.6	882.9	671.3	0.67	0.55
Daily degree	3.81	3.78	3.86	3.98	3.7	0.91	0.72
Int'l calls per day	0.09	0.084	0.099	0.083	0.084	0.53	0.97
Credit used per day	184.6	163.5	212.9	151	168.8	0.3	0.62
Max. recharge value	3391.6	2756.3	4246.4	2609.8	2818.3	0.28	0.62
Calls per day (out)	3.32	3.17	3.52	3.43	3.06	0.63	0.69
Calls per day (in)	2.92	3.08	2.71	2.89	3.16	0.28	0.58
N	1,529	901	628	239	661	-	-

Notes: Mean values, weighted by sampling strata, are reported for all statistics except activation date, where the median is reported. Columns (6) and (7) report p-values from adjusted wald test for difference in means between columns (2) and (3), and (4) and (5), respectively.

C. Rwanda Demographic and Health Survey (DHS)

The final dataset we utilize is a large, representative household survey conducted by the Rwandan government in 2005. In the Demographic and Health Survey (DHS) of 10,272 households, detailed data was collected on demographic composition, asset and durable ownership, and a wealth of other socioeconomic indicators [19]. We use this data to compare the general Rwandan population to the population of phone users contacted in our phone survey.

IV. COMPARISON OF PHONE USERS TO THE AT-LARGE POPULATION

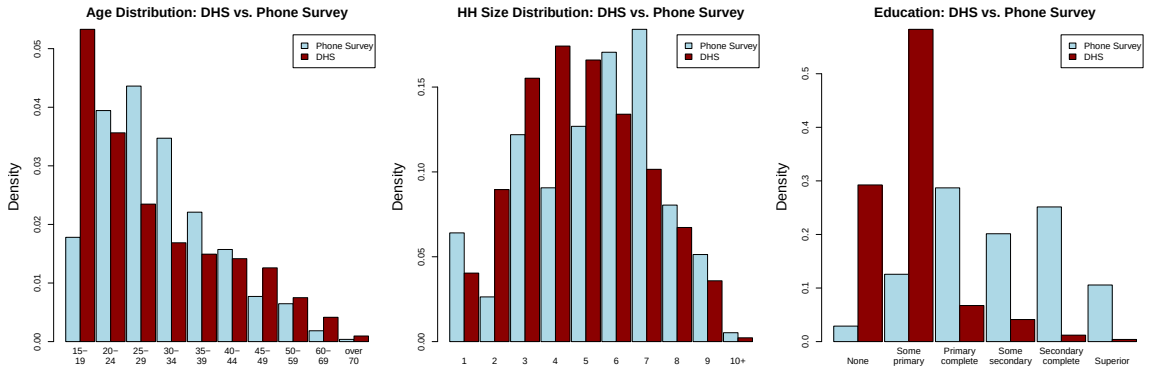
Though mobile phone penetration has risen rapidly in Rwanda over the past decade, still less than a quarter of the population currently owns a mobile phone.[3] While it is generally assumed that these phone owners are *not* representative of the population at large, the nature and extent of these differences is not well understood. Here, we present a quantitative comparison of the representative population of mobile phone owners, as captured in the phone survey, with the representative sample of the at-large population, as recorded in the 2005 household survey. For both samples, reported statistics are weighted by sampling strata.

A. Demographic composition

We begin by analyzing the demographic composition of the two populations. The most striking demographic difference is in gender composition. While 47 percent of Rwandans are male, males account for 67 percent of phone owners (Panel A of Table II). Beyond gender, there are also significant differences in age, household size, and educational attainment. As is evident in Figure 2, the differences between phone users and the at-large population are systematic and occur throughout the demographic distribution.[4]

[3] http://www.itu.int/ITU-D/icteye/, accessed March 2010

[4] In Figure 2a we exclude persons under 15 years to highlight the fact that the difference in mean is not caused solely by the fact that children do not own phones.



(a) Age (b) Household Size (c) Education

Fig. 2. Demographic comparison of the population of mobile phone users to the population at large.

TABLE II
COMPARISON OF PHONE USERS TO GENERAL POPULACE

	(1) Phone Users	(2) All Rwandans	(3) T-statistic
Panel A: Demographic indicators			
Age	32.03	21.37	32.03
Household size	5.87	4.98	11.56
Percent male	66.6%	47.4%	15.76
Completed sec. school	35.71%	1.60%	21.30
Panel B: Socioeconomic Status			
Owns a car	19.1%	0.1%	6.35
Owns a bicycle	38.6%	12.9%	19.51
Owns a fridge	16.7%	1.2%	4.33
Owns a landline	2.8%	6.2%	-17.33
Owns a radio	94.3%	52.9%	82.78
Owns a TV	39.4%	2.4%	12.53
Panel C: Expenditures			
Predicted Expenditures	$1,725	$753	24.05

Notes: Mean values reported, weighted by sampling strata. Column (3) reports t-statistics testing for a difference in means between columns (1) and (2). All differences are significant with at least 99.99% confidence. Predicted expenditures computed using a conversion rate of RWF550=USD$1.

B. Socioeconomic Status

The demographic evidence seems to indicate that phones in Rwanda are owned primarily by the economically privileged. We now test this hypothesis directly. This test is not entirely straightforward, since in practice it is quite difficult to measure the socioeconomic status of a respondent, particularly in a short telephone interview. This difficulty arises because most Rwandans do not earn a fixed wage, and a large percentage of "income" is derived from home-produced goods and other informal channels. Thus, we employ two separate means of measuring socioeconomic status: asset ownership and predicted expenditures.

Asset ownership: In the Demographic and Health Survey (DHS), the Rwandan government collected data on a large number of indicators of wealth such as housing characteristics and ownership of assets and durables. We obtained the data and questionnaires used in the DHS, and asked the respondents in our phone survey a subset of these questions verbatim. Panel B of Table II reports the average levels of asset ownership among phone survey respondents (column 1) and Rwandan households measured in the DHS (column 2). The differences in asset ownership are stark, with phone users possessing a disproportionately large number of expensive assets. For instance, while only 0.1% of Rwandan households possess a TV, nearly 40% of phone users report TV ownership.

Predicted expenditures: The difference in asset ownership provides compelling evidence that phone users are better off than the general population.

However, the underlying differences in wealth and well-being are still murky. For instance, it is hard to say whether a person with a TV and a bicycle is better off than someone with a radio and a fridge. Thus, we derive a second measure of socioeconomic status, *predicted expenditures*, that allows for a more direct comparison of well-being along a single dimension of wealth. While the precise method for computing predicted expenditures is the subject of a separate working paper [20], the basic idea is as follows: First, actual expenditures are captured in the Demographic and Health Survey through an exhaustive series of questions about household consumption. For the DHS sample, we can therefore compute total expenditures by simply aggregating expenditures across these subcategories in a manner following [21]. We then fit a model to the DHS data that relates total expenditures to asset ownership. The estimated coefficients of three different models are presented in Table III.[5] We observe a very strong relationship between asset ownership and total expenditures; using information on just eight attributes, the best model explains almost 60 percent of the variation in household expenditures. Finally, since each of these assets was also measured in the phone survey, we can then *predict* the level of expenditures that would be expected for each of the phone survey respondents, based on the assets owned by the respondent.

In Panel C of Table II, we report the predicted annual expenditures for both populations, estimated with the above technique. Using the asset-based formula, we find that phone users have over twice the predicted expenditures of ordinary Rwandans. As before, this difference is not idiosyncratic at the mean. As can be seen in Figure 3, the entire expenditure distribution is shifted to the right.

With this measure of predicted expenditures, it is possible to further characterize economic stratification and inequality within the population of mobile phone users. For instance, we estimate that while

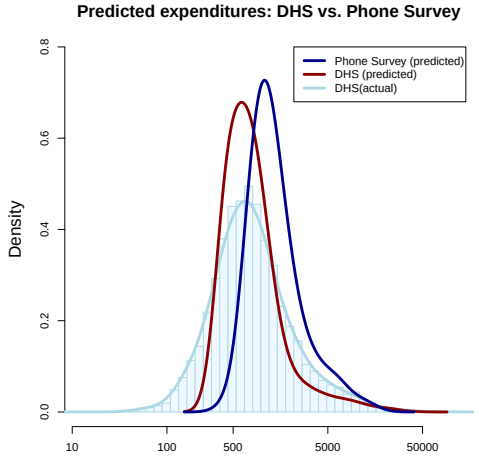


Fig. 3. Predicted expenditures: DHS vs. Phone Survey

77.8 percent of phone owners live on less than $2 per day and 51.8 percent live on less than $1 per day, only 6.9 percent live below the poverty line of $0.43 per day. In the at-large population, we compute the corresponding rates to be much higher at 94 percent (less than $2/day), 82.5 percent (less than $1/day), and 48.2 percent (below the poverty line). Just as poverty is reduced amongst mobile phone owners, inequality is considerably lower: the Gini coefficient for the mobile phone population is 0.495, as compared to the national Gini of 0.556.[6]

The aggregate socioeconomic differences between the two populations are notable, but should be taken in context of the limitations of the data. First, there was a three year interval between when the government data was collected and when the phone survey was conducted, during which most Rwandans experienced substantial improvements in

[5]Predicted expenditures are estimated with a flexible polynomial regression of the logarithm of total expenditures on a variety of assets and durables. Column 1 reports estimates from ordinary least squares; column 2 adds district-level fixed effects, and column additionally controls for livestock possession.

[6]For the population at large, we compute these statistics directly from the DHS data, adjusting for household composition by counting each child as one half of an adult equivalent (we set α=.5 and θ=1 as recommended by [21]). The poverty rate we compute for the general population is considerably lower than the most recent (2001) CIA estimate of 60%. The Gini coefficient we compute is slightly higher than (2006) UNDP estimate of 0.51. However, these differences are in line with recent trends in the Rwandan economy.

socioeconomic status.[7] Second, the data for the two populations was collected with different methodologies, and the self-reporting bias in asset ownership could conceivably be exaggerated in the phone survey. Whereas the government data was collected by enumerators at the place of residence and could be verified visually, the data collected over the phone could not be similarly confirmed. Finally, our measure of predicted expenditures is crude and requires many problematic assumptions, particularly about the relationship between assets and expenditures. Despite these weaknesses, we believe the metric does provide a noisy indicator of socioeconomic status. In future work we hope to do in-person follow up interviews with a small subset of respondents, to gauge the magnitude of potential biases.

TABLE III
REGRESSION OF EXPENDITURES ON ASSET OWNERSHIP

	(1) Assets	(2) + District FE	(3) + Livestock
HH size	0.115	0.123	0.110
	(31.20)	(35.24)	(26.94)
Car/Truck	0.650	0.661	0.545
	(8.12)	(8.76)	(4.81)
Bicycle	0.329	0.350	0.327
	(12.64)	(13.65)	(12.06)
Fridge	0.404	0.293	0.351
	(5.70)	(4.40)	(3.61)
Landline	1.055	0.800	0.779
	(28.97)	(22.41)	(15.66)
Goats			0.024
			(6.42)
Pigs			0.027
			(2.66)
Rabbits			0.005
			(0.99)
District FE	NO	YES	YES
R^2	0.520	0.577	0.487
N	6900	6900	4739

Notes: Outcome is log of total household expenditures. T-statistics reported in parentheses. Regressions also included motorcycle, tv, radio, cattle, sheep, and chickens.

[7]The IMF estimates an increase in GDP from $789 to $1002 between 2005 and 2009 (roughly 27 percent).

V. REPORTED PATTERNS OF PHONE USE

The previous section highlights the differences between average Rwandans and Rwandans with mobile phones. For the remainder of the paper, we restrict our attention to the population of mobile phone users, and analyze reported and observed patterns of mobile phone use. Reported behaviors are based on data gathered through phone interviews; observed patterns are computed from the CDR records obtained from the phone company.

A. Ownership and Sharing

While most mobile phones in industrialized countries are owned and used by individuals, the situation in developing countries is quite different [22], and in East Africa phone sharing is common. In Uganda, for instance, ethnographers have noted intricate social norms of sharing that systematically exclude women and other subpopulations [14]. Using the data from the phone survey, we can provide a quantitative perspective on these dynamics.

Extrapolating from the representative survey to the larger population, we estimate that 30 percent of Rwandans share their phone, where sharing is defined as an affirmative response to the question, "Does anyone else use this phone regularly?" Of those who reported letting others use the phone, 42 percent reported that someone else had used their phone in the last day; 78 percent reported that someone had used the phone in the last week. These and other statistics are presented in column 1 of Table IV, Panel A. Also worth noting is the fact that nearly 98 percent of those surveyed reported that they owned the phone they were using. Taken in the context of the statistics on phone sharing, this leads us to believe that whether or not other people have access to a phone, it is the owner of the phone who typically answers incoming calls from unknown callers.

Do these numbers match the observations of other researchers in similar contexts? The only other statistics we have seen on phone sharing in Rwanda estimate that between 2% and 70% of people share their phones, but the survey sample was biased and not representative of the national population [23]. In other African nations, estimates of phone sharing

TABLE IV
REPORTED PHONE USE

	(1) All	(2) Men	(3) Women	(4) p-value
Panel A: Phone Ownership and sharing				
Do you own this phone?	97.87%	97.36%	98.87%	0.411
Do you own another SIM card?	34.72%	35.42%	33.31%	0.806
Does anyone else use this phone regularly?	29.67%	25.20%	38.55%	0.105
... How many different people used it in the last 24 hours?	0.73	0.74	0.71	0.925
... How many different people in the last 7 days?	2.15	2.37	1.87	0.362
Panel B: Regular contacts				
Roughly how many times per week do you talk to...				
... Friends (boy/girlfriend included)	20.85	25.42	11.76	0.002
... Family (spouse included)	11.02	9.99	13.06	0.323
... Business contacts	23.49	29.55	11.37	0.027
Total calls per day (computed from above)	8.05	9.44	5.27	0.014
Panel C: Types of calls made				
Have you ever used your phone to...				
... Seek help in an emergency?	26.82%	28.21%	24.06%	0.578
... Find a doctor?	31.07%	29.31%	34.57%	0.524
... Find a job?	45.22%	49.30%	36.83%	0.147
... Get advice on farming?	25.02%	27.21%	20.68%	0.308
N	901	645	256	-

Notes: Percentages correspond to percent of affirmative responses (Panels A and C) or mean values (Panel B). All values weighted by sampling strata to produce averages representative of entire phone population. Sharing within last 24 hours and 7 days is conditional on the phone being shared.

tend to be higher, typically in the range of 30% to 70%[6]. However, given the large differences in mobile access and ownership between nations, the numbers are hard to compare. Moreover, the data in [6] was gathered in 2004, when fees were higher and mobile penetration was lower.

Columns 2-4 of Table IV highlight differences between genders with respect to phone sharing. In our representative sample, female respondents disproportionately reported that the phone was shared. However, this difference is only marginally statistically significant. Also noteworthy is the fact that men and women report that a comparable number of different people have used their phones in the past 24 hours and 7 days. This is likely due to the fact that both genders report that their spouse is the main other person to use the phone (38% for women, 43% for men). Finally, we observe modest differences in the gender composition of owners (22% female) vs. non-owners (37% female), but due to the small sample size of non-owners (19 of 901 respondents), the difference is not statistically significant.[8] We discuss the implications of this gender divide in section VII.

More generally, we checked a variety of other socioeconomic and demographic factors to see whether any particular subpopulation was unusually likely to report using a shared phone. However, phone sharing appeared to be evenly distributed across the population. For instance, we observed only modest differences by geographic location. Similarly, a probit regression of phone sharing on

[8]It is possible that the observed differences in ownership are driven by a disinclination among women to answer a call from an unknown caller, but we have no evidence to support this conclusion.

our measure of predicted expenditures yielded a statistically insignificant coefficient. Finally, there was no clear relationship between years of schooling and phone sharing, or household size and phone sharing.[9]

B. Mobile Relationships

Finally, we asked all survey respondents about the people with whom they talk regularly. Respondents were asked to estimate how many times in the past week they had talked to three categories of contacts: friends, family, and business. If the respondent was unable to provide an estimate, the surveyor asked about the past 24-hour period, and multiplied the response accordingly. Thus, the estimates are quite noisy, because of measurement error, reporting bias, and also because many respondents did not draw clear distinctions between the different types of contacts. For instance, while the 'family' category was relatively unambiguous, some respondents found our distinction between 'friends' and 'business contacts' to be somewhat contrived.

With these caveats in mind, we do note significant differences in the reported behavior of men and women. As can be seen in Panel B of Table IV, men report a larger number of total calls, as well as more frequent contact with friends and business contacts; women report more frequent contact with family, though this last difference is not statistically significant. These trends are generally consistent with qualitative observations of gender dynamics surrounding mobile phone use in developing countries.[10] However, in other dimensions of phone use, the behavior of men and women appears quite similar (Panel C of Table IV). Unfortunately, our current analysis is limited by the coarseness of the survey questions. In future work we hope to further probe gender differences in reported phone usage.

[9]There was, however, a statistically significant correlation between the number of adults in the household and the likelihood of the phone being shared, presumably due to the increased demand for the phone by individuals proximate to the phone owner.

[10]In Ghana, for instance, [7] observes, "men are more likely to use the phone to communicate with friends, to make business and work-related calls, and to make calls relating to religious affairs, although this is still only a relatively minor use. On the other hand, a greater proportion of women make family calls."

VI. Observed Patterns of Phone Use

Until now, we have focused on the *reported use* of mobile phones, as described by the respondents during phone interviews. As has been noted previously, however, such data is likely to be quite noisy and biased. Fortunately, we have a much more reliable measure of *actual use*: the call detail records (CDR) obtained from the mobile operator, which provide an itemized list of all network activity for each of our respondents. In Table V, we summarize this usage using the same metrics as in Table I. In addition, we compute the following:

- *In/Out-degree*: Number of different people to whom/from whom, calls were made/received.
- *Clustering*: Percentage of first-degree contacts that have contacted each other.
- *Betweenness*: Average shortest path between the user and 50 randomly sampled numbers.
- *Me2U transfers*: Interpersonal transfers of airtime made over the network.
- *Districts*: Number of political districts in which the phone was used. Rwanda has 30 districts.

Aggregate statistics on phone use are presented in Table V, column 1. The average Rwandan completes 190 calls per month, each of which lasts an average of 32 seconds. It is difficult to find recent, comparable figures from other countries, but both numbers are lower than appears to be the case in most industrialized nations. For instance, estimates of use in the U.S. are closer to 204 calls per month, lasting roughly three minutes each; in India, the industry average is 377 minutes of use per month.[11] These differences are most likely due to the per-second fee structure and the high cost of a phone relative to daily income.[12]

A. Differences by gender

Within the sample of phone users, there are large differences in phone utilization across demographic groups. In column 6 of Table V, we highlight the differences between men and women. To summarize the results: between genders there are significant

[11]http://blogs.zdnet.com/ITFacts/?p=314, accessed Mar. 2010.

[12]To provide some context, a three minute call in Rwanda costs roughly $0.60, which amounts to 0.06 percent of the average GDP per capita.

TABLE V
ACTUAL PHONE USE, COMPUTED FROM TRANSACTION LOGS

	(1) All	(2) Men	(3) Women	(4) "Rich"	(5) "Poor"	(6) MvW	(7) RvP
Panel A: Domestic and International Calls							
Activation date	1/12/08	1/29/08	12/26/07	07/08/06	02/05/08	-	-
Days of activity	770.3	743.4	823.8	994.6	548.1	0.38	0.0001
Avg. call length	31.7	29.7	35.7	39.8	28.4	0.014	0.0001
Calls per day	6.25	6.32	6.09	8.42	6.47	0.82	0.26
Net calls per day (out-in)	0.087	0.31	-0.37	0.76	-0.31	0.02	0.29
Int'l calls per day	0.084	0.071	0.11	0.13	0.066	0.11	0.065
Net int'l calls (out-in)	-0.014	-0.0018	-0.038	-0.031	-0.028	0.031	0.89
Panel B: Social Network Structure							
Degree	734	772.6	657.2	1240.7	498.8	0.56	0.037
In-degree	488.2	488.5	487.6	721.5	369.1	0.99	0.02
Out-degree	433	475.9	347.7	798.1	280.8	0.43	0.1
Daily degree	3.78	3.87	3.61	5.08	3.77	0.63	0.17
Net daily degree (out-in)	0.00027	-0.17	0.34	-0.47	0.41	0.15	0.19
Clustering	0.063	0.065	0.058	0.056	0.057	0.067	0.88
Betweenness	2.72	2.74	2.69	2.61	2.77	0.27	0.0033
Panel C: Other Behaviors							
Credit used per day	163.5	176.2	138.2	246.9	138.9	0.17	0.025
Max. recharge value	2756.3	2775.1	2718.9	3816.1	2228.5	0.89	0.013
Avg. districts per day	1.36	1.37	1.34	1.51	1.47	0.8	0.81
Avg. districts contacted	1.21	1.2	1.22	1.4	1.28	0.81	0.48
Me2U transfers per day	0.044	0.041	0.05	0.037	0.083	0.43	0.012
Net Me2U transfers per day	0.00038	0.0066	-0.012	0.0082	-0.012	0.011	0.14
N	901	645	256	180	180	-	-

Notes: Mean values reported, weighted by sampling strata to produce averages representative of entire phone population. "Rich" and "poor" are defined as those respondents in the top and bottom 20% of the predicted expenditure distribution, respectively. Columns (6) and (7) report p-values from adjusted wald test for difference in means between columns (2) and (3), and (4) and (5), respectively.

differences in the length of calls made (women talk longer), in the direction of the calls (women receive more calls than they make; men are the opposite), in international calling (both men and women receive more than they make, but women receive even more than men), and in airtime gifts using the Me2U service (women receive more airtime). More broadly, men and women have comparably sized networks of contacts, but the networks of men tend to be more tightly clustered than those of women. Finally, we note that contrary to the large and significant differences in total calls *reported* by male and female respondents (discussed in the previous section), the actual difference is small and statistically insignificant.

Given the impersonal nature of our metrics, it is not simple to interpret these statistics. Evidence from the United States and Norway suggests that gender differences in phone use are not unique to developing countries [24][25]. Whether the differences seen in Rwanda reflect benign cultural differences or more insidious dynamics of power and domination is a deeper question that we will touch on in the later discussion.

B. Differences by socioeconomic status

While the differences by gender are somewhat ambiguous, the differences between socioeconomic groups are striking. To analyze phone utilization by socioeconomic strata, we ranked each of the respondents by predicted expenditures – a measure based on known asset ownership as discussed in section IV-B – then separately computed averages for the upper and lower quartiles. These statistics are presented in columns 4 and 5 of Table V; the test for a difference between the two populations appears in column 7.

Though the population of mobile phone users as a whole is considerably wealthier than the normal population (Figure 3), there are large and consistent differences in usage between the richest 25% and the poorest 25% of phone users. Across nearly every measure, the richer people utilize their phones more: in number of calls, length of calls, number of days on which the phone is used, size and structure of the social network, etc.[13] While some of these differences are not statistically significant, the overall relationship between utilization and socioeconomic status remains strong. As a secondary indication of the strength of the relationship, we note that a regression of predicted expenditures on the variables listed in Table V yields an R^2 of 0.15; a more flexible specification has a corresponding R^2 of 0.31.

VII. Discussion and Conclusion

The preceding analysis provides a quantitative perspective on the demographic and socioeconomic structure of mobile phone use in Rwanda. Though the analytic results are diverse, a relatively consistent picture begins to emerge: mobile phone use in Rwanda is far from uniform. There are significant and systematic differences not only in who *owns* the phone (section IV), but also in how different types of owners *use* the phone (sections V and VI). Specifically, phone owners are much more heavily male, they are better educated, they come from larger households, and they are substantially wealthier than those without mobile phones. Within the population of phone owners, there are differences in usage between men and women, particularly in reported phone sharing and types of calls made. Most notable, however, is the vast difference in utilization between poorer and richer phone owners, such that the upper income quartile uses their phones 30-100% more than lower quartile, depending on the measure of utilization.

Taken together, the evidence in this paper indicates that it is the privileged, male members of Rwandan society who disproportionately own and use mobile phones. Unfortunately, this pattern does not seem to be unique to Rwanda; similar patterns have been observed in East Africa [14] and other countries around the world [8]. Moreover, the same trends can be seen with other technologies in other contexts. For instance, [26] and [27] both observe that usage of telecenters is dominated by younger, more educated men.

While the preceding analysis is straightforward, we believe it is useful for a few distinct reasons. First, we believe there is intrinsic value in developing insight into daily patterns of use of such a massively popular technology, in part to help scholars and practitioners better understand how phone-based technologies are likely to be received and utilized. As we have seen, traditional Western models of phone use - and the potential design assumptions they impose - do not necessarily apply to the Rwandan context. Second, we hope our methods and analysis can inspire and be improved upon by other researchers. In particular, the coupling of anonymous call detail records with structured phone interviews should provide fertile ground for future work. Finally, by providing more reliable estimates of the distribution of phone access and use, we seek to inform policymakers about the potential distributional impacts of phone use in developing countries such as Rwanda. With mobile phones generating such massive levels of hype and investment, it is important to better understand who is - and who isn't - reaping the benefits of the new technology.

[13]The only exception is in utilization of Me2U - the system for interpersonal airtime transfers - whereby the poorer phone users appear to be significantly more active in the number of transfers. We believe this is because Me2U serves as a substitute for traditional financial services, and intend to investigate further in future work.

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