I Z A Institute
of Labor Economics
Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 14720

Mobile Broadband Internet, Poverty and Labor Outcomes in Tanzania

Kalvin Bahia
Pau Castells
Genaro Cruz
Takaaki Masaki
Carlos Rodríguez-Castelán
Viviane Sanfelice

SEPTEMBER 2021

I Z A Institute of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 14720

Mobile Broadband Internet, Poverty and Labor Outcomes in Tanzania

Kalvin Bahia
GSMA

Pau Castells
GSMA

Genaro Cruz
GSMA

Takaaki Masaki
The World Bank

Carlos Rodríguez-Castelán
The World Bank and IZA

Viviane Sanfelice
Temple University

SEPTEMBER 2021

ISSN: 2365-9793

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Mobile Broadband Internet, Poverty and Labor Outcomes in Tanzania

What are the impacts of expanding mobile broadband coverage on poverty, household consumption and labor market outcomes in developing countries? Who benefits from improved coverage of mobile internet? To respond to these questions, this paper applies a difference-in-differences estimation using panel household survey data combined with geospatial information on the rollout of mobile broadband coverage in Tanzania. The results reveal that being covered by 3G networks has a large positive effect on total household consumption and poverty reduction, driven by positive impacts on labor market outcomes. Working age individuals living in areas covered by mobile internet witnessed an increase in labor force participation, wage employment, and non-farm self-employment, and a decline in farm employment. These effects vary by age, gender and skill level. Younger and more skilled men benefit the most through higher labor force participation and wage employment, while high-skilled women benefit from transitions from self-employed farm work into non-farm employment.

JEL Classification: F63, I31, L86, O12

Keywords: Africa, consumption, labor force participation, welfare, Tanzania

Corresponding author:
Carlos Rodríguez-Castelán
World Bank
1818 H Street N.W.
Washington, DC 20006
USA

E-mail: crodriguezc@worldbank.org

1 Introduction

Enabling universal access to the internet is deemed as a critical step towards achieving prosperity in developing countries. In line with this target, the digital landscape in Sub-Saharan Africa has been changing drastically with fast-growing mobile broadband internet networks, which have increased three-fold from 24 percent to 75 percent between 2010 and 2019 (GSMA, 2020). However, despite enthusiasm around the potential role that internet plays in spurring growth and tackling poverty across developing countries, there is limited evidence on the welfare effects of mobile broadband internet – particularly among the poor and vulnerable in Sub-Saharan Africa.[1]

Given this knowledge gap, this paper seeks to answer the following questions: what are the impacts of expanding mobile broadband coverage on poverty, household consumption and labor market outcomes in developing countries? And who benefits from improved coverage of mobile internet? These questions are particularly important in Africa where a predominant share of people have access to the Internet only through their mobile phones. In particular, Tanzania is among the top few countries where notable increases in mobile phone and smartphone penetration are expected in the coming years.[2] To answer these questions, we leverage three waves of a nationally representative longitudinal household survey on living standards in Tanzania with geospatial information on the rollout of mobile broadband coverage between 2008 and 2013, which shows 3G population coverage more than doubling from 16 percent to 35 percent. By matching the location of each household in the panel survey with coverage maps of mobile internet, we can determine with precision the time when individual households began receiving mobile internet coverage, and we can empirically test whether the staggered rollout of mobile internet networks has contributed to changes in welfare and

[1] Most hitherto studies focus almost exclusively on cellphone access – that is, second-generation (2G) technologies, those that enable voice, SMS, and limited internet access, while 3G technologies enable more rapid internet browsing and data downloading (Jensen, 2007; Labonne and Chase, 2009; Ky et al., 2018; Aker, 2011; Beuermann et al., 2012; Muto and Yamano, 2009; Blumenstock et al., 2020) – and fixed broadband Internet (Atasoy, 2013; Akerman et al., 2015; Hjort and Poulsen, 2019).

[2] Smartphone usage in Tanzania is expected to grow at an annual growth rate of 19 percent, reaching more than 30 million mobile subscriptions by the end of 2024 (Chen et al., 2020).

poverty reduction.[3]

We implement a difference-in-differences (DID) estimation method, which follows an intention-to-treat framework. Specifically, our analysis focuses on the effects of mobile broadband network coverage (or availability) instead of usage (or access) since the former is independent of individual household consumption decisions. Moreover, we perform additional validity checks to circumvent the potential concern regarding our empirical strategy that mobile broadband coverage has been gradually rolled out in a non-random manner, since operators tend to target more prosperous areas first. In these alternative specifications we control for local-level time trends and exploit the timing of the treatment to find more compatible control groups. We also conduct conditional pre-trend tests. Based on these methods, we conclude that the assumption of similar pre-treatment trends is likely to hold in our context. Finally, we also apply a doubly robust DID as suggested by Callaway and Sant'Anna (2020) to deal with potential bias that arises from the staggered DID setup where households were treated at different points in time.

Our main results show significant positive effects of mobile broadband coverage on household per capita consumption. Households that resided in areas covered by 3G experienced an 7-11 percentage point increase in total per capita consumption. These digital dividends materialize over time and become statistically significant after more than one year of exposure to 3G coverage. Mobile internet coverage also reduces the proportion of households below the national poverty line by 5-7 percentage points. These results are consistent and similar in magnitude to recent studies for Nigeria (Bahia et al., 2020), the Philippines (Blumenstock et al., 2020), and Senegal (Masaki et al., 2020).[4] These effects are heterogeneous,

[3]Individual coverage of mobile broadband is defined as the provision of 3G coverage, which enables high-speed access to the Internet, and excludes 2G coverage as it only provides for limited internet browsing and applications.

[4]Bahia et al. (2020) shows that having at least one year of mobile broadband coverage increases total consumption by 5.8 percent, and up to 9.2 percent after three years of more of coverage. Masaki et al. (2020) find that total consumption among households covered by 3G technology is about 14 percent greater than the total consumption of households not covered by 3G. Blumenstock et al. (2020) find that the introduction of a new phone tower in rural areas in Philippines led to an increase in household income of 17 percent, and increased household expenditures by 10 percent.

with higher welfare gains in urban areas and among households headed by female, poorer, or less-educated household heads.

Our analysis also shows that an important mechanism through which 3G coverage translates into higher household consumption and moving out of poverty is its impact on labor market outcomes, in line with previous studies (Bahia et al., 2020; Hjort and Poulsen, 2019). Working age individuals living in areas covered by mobile broadband internet witnessed an increase in labor force participation, wage employment, and non-farm self-employment by 3-8 percentage points after 1-2 years of 3G exposure. Living in areas covered by mobile internet also reduced farm employment by 4 to 9 percentage points. These results indicate that 3G coverage has facilitated a transition out of farm jobs into wage employment and non-farm self-employment. This is an important finding since farm employment in developing countries has been typically characterized by lower productivity and labor earnings (Schultz, 1956; Restuccia et al., 2008; McMillan and Rodrik, 2011).

These positive labor market outcomes of 3G coverage vary by age, gender and skill level. We find that younger and more educated men benefit the most through higher labor force participation and wage employment. Results also show that skilled women, those who are literate and with at least completed primary education, benefit from transitions from self-employed farm work into non-farm employment. But, differently to men, we do not find evidence of changes in female labor force participation or changes in wage employment for women. These findings are consistent with previous studies which suggest that, while women can benefit from digital technologies, they often face greater difficulties to leverage them due to a mix of social norms, intra-household dynamics, lack of access of productive assets, and being less likely than men to use the internet (Bimber, 2000; Klonner and Nolen, 2010; Zhao, 2020).

Our findings are relevant to the growing literature on the positive economic impact of digital technologies. However, while most studies have primarily focused on the economic effects of digital technologies such as cellular services (Jensen, 2007; Labonne and Chase, 2009;

Ky et al., 2018; Aker, 2011; Beuermann et al., 2012; Muto and Yamano, 2009; Blumenstock et al., 2020), or fixed broadband internet (Atasoy, 2013; Akerman et al., 2015; Hjort and Poulsen, 2019), in our analysis we focus on the role of mobile broadband internet, while controlling for other technologies such as 2G coverage. This evidence gap in the literature is worth highlighting given that the primary means to access the internet remains through mobile phones for most people in Africa.[5]

Our study also contributes to the broader literature studying the welfare effects of digital technologies, although, departing from previous studies, we focus on the effects on household consumption, poverty status and labor market outcomes. A large majority of existing studies instead focus on the impact of digital technology on other development outcomes – including, but not limited to, the labor market (Hjort and Poulsen, 2019; Klonner and Nolen, n.d.; Marandino and Wunnava, 2014; De los Rios, 2010; Guerrero and Ritter, 2014; Paunov and Rollo, 2015; Fernandes et al., 2019; Chun and Tang, 2018; Viollaz and Winkler, 2020), firm productivity (Abreha et al., 2021), input and output price and rural markets (Aker and Mbiti, 2010; Aker, 2011; Aker and Fafchamps, 2015; Kaila and Tarp, 2019; Tadesse and Bahiigwa, 2015), financial inclusion (Aker and Wilson, 2013; Ky et al., 2018), and access to capital markets (Hasbi and Dubus, 2020; Alibhai et al., 2018). Other studies have also shed light on the role that mobile-based financial services play in poverty reduction and facilitating consumption smoothing against exogenous risks (Jack and Suri, 2014; Suri and Jack, 2016; Blumenstock et al., 2016).

Our work is also similar to Hübler and Hartje (2016) which shows that the ownership of smartphones has positive impact on household income while it is important to note that our focus is the coverage of mobile broadband infrastructure instead of the ownership of smartphones per se.

The rest of this paper is structured as follows. Section 2 describes the data sources while Section 3 presents the estimation strategy. Section 4 discusses the results, and Section 5

[5]In 2020, mobile accounted for more than 98% of broadband connections in Africa (ITU, "Measuring digital development Facts and figures", 2020).

concludes.

2 Background and Data

Our analysis draws upon two data sets: geographical coverage of mobile networks and three rounds of the Tanzania National Panel Survey (NPS). By linking the location and the chronology of these data sets, we are able to determine the availability of mobile broadband at the exact household location.

2.1 Mobile Broadband Coverage Data

In this study, we look at mobile broadband network coverage (or availability). Coverage is distinct from usage - or access - which is when an individual has an active SIM card that can be used in a mobile phone to access the internet. We look at coverage because it is not determined at the household level and because coverage captures not only the direct impact of individuals accessing the internet but also spillover effects. The latter includes, for example: internet users sharing information with non-users; job creation and productivity gains among domestic firms due to more technology use and access to national and international markets; or more financial capital accumulation and utilization due to increased use of digital payment platforms and mobile banking.

Mobile networks can be divided into two components. The first is the core network, which ensures the intelligence of the network, such as switching user calls or routing user data to and from the internet. The second is the radio access network, which is the collection of relay sites (i.e. towers hosting base stations and radio equipment) that connects the user terminal (e.g. mobile phones) to the core of the network. Relay sites communicate with mobile phones in their vicinity using electromagnetic signals. The quality and availability of this communication link can be affected by several factors such as distance between the relay site and the mobile phone or the presence of obstacles (e.g. hills or buildings). A geographical area is considered covered when the signal of any relay site is strong enough for mobile phones in that area to establish a usable connection link with that relay site. The aggregated coverage of a mobile network is calculated by adding up the coverage of all the relay sites in its radio access network.

To produce the aggregate coverage data for Tanzania, we collected network infrastructure data directly from three Mobile Network Operators (MNOs) that accounted for more than 90 percent of the mobile market during the period of analysis. For each individual relay site we collected the following parameters: (i) location in geographical coordinates; (ii) height of the tower hosting the antennas; (iii) signal emitting power; (iv) antenna parameters such as the gain, azimuth, and tilt; (v) frequency band used; (vi) type of technology available (2G, 3G, or 4G); and (vii) date of deployment.

We calculated the coverage of each relay site using a Radio Propagation Model (RPM). RPMs are empirical mathematical models widely used by MNOs for planning the setup of their networks, allowing them to plan the location and characteristics of each relay site so as to maximize coverage and decrease costs. There are several RPMs available that are optimized for specific settings or technologies. We used an Irregular Terrain Model (ITM), also known as the Longley Rice model,[6] which is optimized to deliver accurate results in rural and peri-urban areas. [7]

The ITM uses two sets of input variables. The first are the technical parameters of each individual relay site that we collected from MNOs. The second are the characteristics of the transmission medium, such as the terrain profile[8] and the type of vegetation in the area. The output of the ITM model is a geocoded image showing the area covered with signal strength above a predefined threshold (see Figure 1 as an example). The predefined signal strength

[6]P.L. Rice, A.G. Longley, "Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain A computer method 1968," Essa Technical Report ERL 79-IT S67. Available: http://www.visuallmr.com/documentation/pathlossmodels/ntis.longleyrice.676874.pdf.

[7]We estimated coverage using the ITM model and MNO infrastructure inputs instead of collecting the coverage footprint estimated by MNOs themselves. This approach ensured consistency in the coverage modelling for each MNO network and across all the period of interest

[8]We used the SRTM 90m Digital Elevation Database created by NASA. See: https://cgiarcsi.community/data/srtm-90m-digital-elevation-database-v4-1/.

thresholds that we used are presented in Table 1.

During the period of analysis, from 2008/2009 to 2012/2013, 3G population coverage in Tanzania increased from 13 percent to 30 percent, while 2G coverage increased from 81 percent to 85 percent. None of the operators started to deploy 4G until after the period of analysis.

2.2 Household Survey Data

Data on household welfare (e.g., consumption and poverty) and other household-specific characteristics are sourced from the first three rounds of Tanzania National Panel Surveys (NPS), conducted in 2008/2009, 2010/2011, and 2012/2013.[9] The NPS collected information on a wide range of topics including agricultural production, non-farm income generating activities, consumption expenditures, and a range of socio-economic characteristics. The panel structure of the survey data – tracking the same sample of households and individuals over time – allows us to explicitly control for household-specific and individual-specific characteristics. The NPS maintains a highly successful recapture rate (roughly 96% retention at the household level), thereby minimizing potential bias introduced by attrition. The original sample of the 2008/09 survey consisted of 3,265 households - the second round tracked 97 percent of these original households and the third round tracked 96 percent of the second round households.[10]

The core outcome variables of our interest derived from the household survey include total consumption (which is the sum of all food consumption and purchases, including meals outside home, as well as non-food expenditure such as education, housing rents, clothing, fuel, utilities, transportation, communication, reaction and other services), food consumption, and non-food consumption. The poverty status of households is calculated based on three different poverty lines: the basic needs poverty line defined on the basic needs approach –

[9] Although the first three rounds of NPS are real panel data, the last round (2014/15) was implemented as a cross-sectional survey based on a new redrawn sample. It is therefore excluded from this analysis.

[10] See more details on the tracking performance of NPS in the final report produced based on Wave 3 of NPS: https://microdata.worldbank.org/index.php/catalog/2252/download/34054

which measures the cost of acquiring enough food to provide adequate daily nutrition per person (food line) plus the cost of some non-food essentials (non-food component)[11] – as well as the international poverty lines of US$1.90 and US$3.20 per day (2011 PPP). All the monetary values in the surveys have been deflated to convert nominal values in real/constant values, using the Consumer Price Index (CPI) for Tanzania.

Figure 2 presents the location of the enumeration areas surveyed in NPS and shows which had access to 3G coverage in each round of NPS. We consider a household to have mobile broadband coverage when it is covered by a medium or strong signal in 3G. The two data sets were linked by matching the coverage footprint for each radio bearer with the almost exact locations of households based on GPS coordinates, which are much more precise than geo-referencing data used in previous studies.[12] Figure 3 shows the unweighted mean of select key welfare and labor outcome variables over the three waves for the treatment (3G coverage) and control groups (no 3G coverage).

2.3 Summary Statistics

Although our sample is not balanced across survey waves, it only includes households and individuals that have data for at least two points in time. Table 2 provides averages for the main variables in our study by survey wave. The first panel presents household level information. The outcome variables, log consumption and poverty rates, do not change considerably over time. By contrast the treatment variable, 3G coverage, increases by more than half from the first to the third survey wave, going from 16 percent of the household being under covered areas in 2008-2009 to 35 percent in 2012-2013. In term of control variables

[11]More specifically, for NPS, the poverty line was derived based on the cost of buying 2,200 calories per adult per day according to the food consumption patterns prevailing in a population whose per adult real consumption is below the median during a period of 28 days valued at prices faced by the reference population. The non-food component of the basic needs poverty line uses the average non-food consumption share of the population whose total consumption per adult is in the bottom 25 percent. See more details on the basic needs approach to derive the poverty line for NPS in World Bank (2019).

[12]More specifically, we rely on GPS coordinates of households with the maximum offset of 45 meters to assign to each household the initial date of coverage (if any) by any combination of radio bearer and signal strength. In contrast, other studies have relied on data integration using buffer sizes between 1 to 5 kms in urban areas, and 1 to 20 kms in rural areas (see for instance DHS – Demographic and Health Surveys).

and household profile we see that the majority of households own their dwelling, do not have access to electricity, are located in rural areas, and have a male and literate household head.

Panel B of Table 2 displays averages for key variables in our individual level sample. Around three-quarters of individuals in the sample (adults aged 15 to 64 years old) are in the labor force. Types of employment are also among our dependent variables and consist of four categories: wage employment, non-farm self-employment, farm employment, and other employment.[13] These categories are not mutually exclusive as individuals could report to work in more than one type of job. Most workers are employed in farming jobs. Employment rates in wage jobs and non-farm self-employment are of similar magnitude, with about 15% of individuals in our sample employed in these two categories. Around half of individuals have completed primary school and the vast majority are literate.

3 Empirical Strategy

We are interested in assessing how exposure to mobile broadband internet affects household and individual welfare and whether this impact may differ by various household and individual characteristics. However, identifying the impact of 3G coverage on welfare is not trivial because exposure to the treatment is not random. Households residing in areas with access to mobile broadband are likely to be distinct in several dimensions from households with no access. Mobile broadband internet is provided by profit-maximizing firms that supply the service where economic benefits are expected. This means that households which receive coverage are more likely to be economically prosperous, and therefore have means to consume the product.

In order to overcome this endogeneity issue we take advantage of the temporal and spatial variation in exposure to 3G by applying a DID approach that compares outcomes of households in treated and non-treated areas before and after mobile internet broadband

[13] Other employment is defined as an indicator variable equals to one when an individual responded that he/she works but did not report to work in neither of the other categories, i.e., on wage employment, non-farm self-employment, and farm self-employment.

expansion. To retrieve the effect of mobile broadband on household welfare and labor market outcomes, here denoted by β, we consider the following equation:

$$y_{it} = \beta coverage_{it} + \mathbf{X}_{it}\theta + \alpha_i + \alpha_t + \epsilon_{it} \tag{1}$$

in which i is a household or individual during period (survey wave) t. y denotes an outcome variable such as consumption or labor market participation. *coverage* is the variable of interest and is defined by an indicator variable equal to one if household or individual i is covered by a 3G network in time t and zero otherwise. $\mathbf{X}$ is a vector with time-varying control variables. These include household size, access to electricity and whether the household dwelling is owned, which are broadly in line with the controls used in the literature. Further, we add access to 2G coverage as control to ensure that the analysis isolates the impact of upgrading coverage to 3G and does not combine the impact of gaining 2G coverage. α_i denotes household fixed effects (or individual fixed effects depending on the outcome variable) which capture time invariant characteristics that could correlate to coverage and the dependent variable. α_t represents survey wave fixed effects and accounts for aggregate trends over time.

Our empirical strategy follows an intention-to-treat framework. That is, we look at mobile broadband network coverage (or availability) instead of usage (or access). We consider coverage instead of usage because the former is external to household decisions. Additionally, having 3G coverage as the variable of interest will not only capture the direct impact of households accessing the mobile broadband internet but also spillover effects.

The identification assumption in Equation 1 is that conditional on time fixed effects, household fixed effects and household time-variant characteristics contained in $\mathbf{X}$, coverage timing is orthogonal to unobserved characteristics related to economic development. A key assumption in the identification strategy is that all differences across treated and non-treated are accounted for, either by the household fixed effects (time invariant characteristics) or by the variables in $\mathbf{X}$ (time variant characteristics).

We also dis-aggregate the 3G coverage effect by time of exposure by adjusting Equation 1 and adding time exposure intervals, as stated below. It is important to assess how the varying lengths of treatment exposure have differential impacts on welfare because plausibly, the welfare impact of mobile internet (if any) may not necessarily materialize immediately but take some time before it manifests any meaningful welfare effect. This exercise allows us to differentiate short and medium term effects.

$$y_{it} = \beta_1 less1year_{it} + \beta_2 1to2years_{it} + \beta_3 2to3years_{it} + \beta_4 more3years_{it} + \mathbf{X}_{it}\theta + \alpha_i + \alpha_t + \epsilon_{it} \quad (2)$$

Despite coverage not being determined at the household level, it could still be endogenous because mobile broadband coverage is not rolled out randomly. This is because operators tend to target more prosperous areas first, which in turn are likely to have higher consumption levels and lower poverty rates. Thus, even if longitudinal data is available, regional trends can correlate to mobile broadband coverage and the outcome variables. This means that households receiving mobile broadband coverage may not be comparable to non-treated households.

To address this concern, we implement two robustness checks to account for location time trends. The first check adds to Equations 1 and 2 non-linear time trends for each region in Tanzania.[14] The second validity check is based on the method discussed by Abadie (2005), and allows for non-linear time trends based on observed characteristics of the household location.[15] Since operators target certain areas with higher economic development (or expected development), allowing for regional trends or trends by observed characteristics of the household location in addition to household fixed effects should mitigate potential concerns about the identification strategy.

[14] Households in our sample reside in 30 regions.

[15] Specifically we add as controls to equations 1 and 2 dummy variables for each wave interacted with variables about the household: *i*) distance to major road; *ii*) distance to nearest population center; *iii*) distance to nearest border crossing; and *iv*) distance to headquarters of district of residence.)

We also carry out a conditional pre-trend test that provides evidence on whether the assumption of similar pre-treatment trends for the treated and non-treated holds for our analysis. Finally, we implement an additional analysis in which the sample is reduced to only include comparable observations. The idea is to explore the timing of the 3G coverage roll-out to find a control group more similar to treated units. Specifically, we use households/individuals treated later on in wave 3 as comparison group for households/individuals treated earlier.[16]

In our context treatment is not stagnated, as households are covered at different points in time. Recent advancement in the DID literature has shown that the two-way fixed effect (TWFE) DID estimation can yield biased estimates. This bias may result from the variance-weighting implicit in ordinary least squares, and more importantly due to the embedded use of past treated units as effective controls for later-treated units (Baker et al., 2021). This bias can be relevant particularly to our study given that our treatment was rolled out gradually to households across multiple time periods. In this sense, our sample deviates from the so-called canonical DID setup in which all the units in the treatment group receives the treatment at the same point in time.

To address this estimation challenge we take advantage of the recent method implemented by Callaway and Sant'Anna (2020) (C&S hereafter) that establishes a procedure[17] to 1) flexibly incorporate covariates into the staggered DID setup with multiple groups and multiple periods; 2) test pre-trends conditioned on those covariates; and 3) estimate group-time average treatment effects and aggregate them in flexible ways. Their proposed approach can also be implemented using doubly robust standard estimators, which rely on less stringent assumptions than the TWFE models (Sant'Anna and Zhao, 2020).

Finally we also look for evidence on heterogeneous effects by household profile and individual demographics. In particular, we study if and how mobile broadband internet affects

[16]Results of this analysis and the pre-trend test are provided in section 4.2 when implementing the Callaway and Sant'Anna (2020) method.

[17]This procedure can be implemented in the R "did" package.

female workers differently from males. To implement heterogeneous effects analysis we include an interaction between the variable of interest in Equation 1 and the characteristics of household or individuals. This approach allows us to separately estimate the effect of 3G coverage for groups in the population, and to also test whether these effects are statistically different across groups.

Inference in all estimations is done using robust standard errors clustered by survey enumeration area (EA), as the EA matches most closely to the area covered by a mobile site.

4 Results

4.1 Baseline Results

Table 3 displays estimates of parameters in equations 1 and 2 and household outcomes such as consumption and poverty status. In panel A, which displays estimates for 3G coverage, all coefficients are economically meaningful. In particular, based on the specification that includes fixed effects and control variables, we find that being covered is associated with a 7 percent increase in consumption, 6 percent increase in food consumption and 9 percent increase in non food consumption. We also observe a significant reduction of five percentage points in the basic need poverty rate (in wave 1, 19 percent of the households in our sample are classified as poor under the basic need poverty line). Poverty rates at the $1.9 and $3.2 PPP poverty lines also decline, however the coefficients are not statistically significant (in wave 1 39 percent and 65 percent of the households in our sample (unweighted) are classified as poor under the $1.9 and $3.2 PPP poverty lines, respectively). These results on poverty indicate that the effect of mobile internet is particularly strong for households that are poorer and teetering on the edge of the basic poverty line (the point at which they are not able to consume sufficiently to keep their daily calorie intake requirement).

Panel B presents estimates broken down by coverage exposure intervals. Significant effects on household consumption and poverty status are observed for households being covered for at least one year. Although the estimates change for coverage intervals greater than one year, with large standard errors we cannot reject that they are statistically equal to each other. Being covered for less than a year has a small and non-statistically significant effect on all of the household outcomes. It is also worth noting that if coverage expansion occurred in areas that were already growing (in terms of economic development and consumption), our estimates would overestimate the true effect of mobile broadband internet on household welfare. The fact that we do not observe statistically significant estimates for less than one year of coverage suggests that confounding factors are not overstating our estimates.

Table 4 shows estimates using individual-level data and dependent variables on labor market outcomes. We can see that 3G coverage is positively associated with a three percentage points increase in labor force participation. Most of the impacts on the labor market come from transitions across employment types. Specifically, we find that individuals in areas gaining 3G coverage leave farm jobs and increase wage employment and non-farm self-employment. Wage employment and non-farm self-employment increase by two and three percentage points respectively, while farm employment decreases by seven percentage points. These results are revealing as non-farm jobs can be perceived as a sign of prosperity for providing better working arrangements and more stable cash flow. It is notable that while farm self-employment reduced strongly for individuals treated with 3G coverage, participation in farm self-employment in Tanzania throughout the period remained fairly stable (Table 2).

Analyzing the estimates separately by time of coverage, we see a substantial and statistically significant effect in the medium-term on labor force participation, which expands by eight percentage points when individuals have been exposed to the mobile broadband internet for more than three years. The results also show that while there is an immediate and persistent reduction in farm employment from the first time of exposure, estimates for non-farm self-employment are only statistically significant after the first year of coverage, and for wage employment only after the second year of exposure to the technology. This suggests that transitions to higher-paying jobs take time to materialize once individuals gain coverage.

4.2 Robustness Checks

The first robustness check is to control for location time trends in order to separate the impact of mobile coverage arrival from other ongoing trends in regional outcomes. Tables with estimates can be found in the appendix (Tables A1 and A2). While some estimates reduce in magnitude and in statistical significance, the findings for 3G coverage effect on household consumption and poverty status hold, especially after one year of coverage. A similar picture can be seen in terms of individuals' labor market outcomes, with the findings on employment broadly consistent, especially after one or two years of coverage. We conclude that in general these tests corroborate our findings.

The second robustness check is to use the C&S approach, the results of which are presented in Tables 5 and 6.[18] In this analysis, we examine how the welfare effect of exposure to 3G treatment may also vary depending on the length of exposure: the contemporaneous effect of 3G coverage (3G coverage), one or more years of coverage ($\geq$ 1 year), two or more years ($\geq$ 2 years), and three or more years ($\geq$ 3 years). These tables report group-time average treatment effects along with aggregated treatment effects using two different methods: (a) "event study effects" showing how average treatment effects vary with length of exposure to the treatment (event-study-type estimands); and (b) "event study with balanced groups" reporting average treatment effects by length of exposure using a fixed set of groups at all lengths of exposure.[19] In terms of the C&S test for the conditional parallel trends assumption, our results suggest little evidence to reject this assumption. The "group-time

[18]Note that in these tables, the control group is a group of households that were never exposed to the treatment throughout Waves 1-3 whereas we also report in Appendix A the results from using the "not yet treated", which include both the never treated as well as those households/individuals that, for a particular point in time, have not been treated yet (though they eventually became treated). The results do not significantly alter when the "not yet treated" is used as the control group (see Tables A3 and A4).

[19]It is important to note that when using the C&S approach, exposure is based on whether households were treated at the time of the relevant wave, rather than the time they initially received coverage.

average treatment effects" row in Tables 5 and 6 report both group-time average treatment effects identified in periods when $t \geq g$ (i.e., post-treatment periods for each group) as well as pseudo group-time average treatment effects when $t < g$ (i.e., pre-treatment periods for group g). The latter can be used as a pre-test for the parallel trends assumption (as long as we assume that the no-anticipation assumption indeed holds). None of the effects identified when $t < g$ are statistically significant.[20]

Turning to the treatment effects of 3G coverage, most of the group-time average treatment effects of 3G coverage on consumption are positive while these effects turn negative for poverty. Although group-time average treatment effects individually are not statistically significant, the event study (with balanced groups) aggregate effects are statistically significant (<0.05) for total consumption (only after one year of coverage), food consumption (only after one year of coverage), and poverty. The effects are no longer significant for non-food consumption. In terms of labor outcomes, the results are also consistent with our TWFE DID results. More specifically, the effects based on the C&S approach show statistically significant positive effects on labor force participation, wage employment (only after one year of coverage), other employment as well as the number of employments while significant negative effects are found for non-farm jobs, again providing evidence that 3G coverage enables individuals to transition out of farm jobs to other types of jobs. As seen in our baseline results (Table 3 and 4), some of the estimated effects are stronger for longer years of treatment exposure – particularly after one or more years of coverage for total consumption, food consumption, basic needs poverty, as well as wage employment.

The results of the C&S approach reported above use the never treated group – or the group of households/individuals that did not ever participate in the treatment across all the

[20]Along with the C&S test for the conditional parallel trend assumption, we also conducted the conventional test for the common trend assumption by evaluating whether changes in the outcome of interest between Wave 1 and Wave 2 are predicted by getting 3G coverage between Wave 2 and Wave 3, as suggested by Angrist and Pischke (2009) and following Bahia et al. (2020). In this test, we find evidence that future treatment (3G coverage at $t + 1$) significantly impacts consumption at t although no such effect is observed for poverty and labor outcomes. This casts some doubt on our results specifically on consumption in the TWFE framework but positive effects observed on consumption in the C&S framework suggest that these effects are not an artifact of pre-trends.

three waves – as the control group. However, we can also test how our results may alter once the control group includes the not-yet-treated households/individuals – which include the never treated as well as those households/individuals that, for a particular point in time, have not been treated yet (though they eventually become treated). The overall results largely stand robust when the not yet treated group is used as the control group instead of the never treated group (see Tables A3 and A4 in Appendix A).

4.3 Heterogeneous Effects

We first present results separating the 3G coverage effect by household profiles: household location and consumption level, and characteristics of the household head, including gender, literacy and age. Then we turn to estimates on labor market outcomes, showing the effects of 3G coverage by individuals' demographics. Lastly; we present results for a further level of dis-aggregation that interacts individuals' demographics and their gender.

Table 7 presents heterogeneous estimates by household profile. Households in urban areas or with a female head are predicted to have a larger gain in consumption and a greater reduction in poverty after being covered by the 3G technology. Interestingly, 3G coverage has large and statistically significant effects on low consumption or less educated households, while the estimated effects on high consumption or more educated households is statistically null. We do not find relevant differences by age of the household head.

Heterogeneous results on labor market outcomes are displayed in Table 8. For some outcomes we observe quite different results by gender. Mobile broadband internet is associated with a six percentage points increase in labor force participation for men, while it has zero impact on women's participation. The same pattern is observed for wage employment. 3G coverage is predicted to increase non-farm self-employment for males and females by two to three percentage points, however the effect is only statistically significant for males. The impact on farm employment is the same for men and women: for both genders 3G coverage is predicted to reduce farm self-employment by seven percentage points. This suggests that while female-headed households benefited more in terms of welfare, some of these gains were partly driven by improved labor market outcomes for men in those households.

The table also reveals some heterogeneous results on labor market outcomes by individuals' locality, education and age. Labor force participation for individuals in urban areas or with primary education increases by five and six percentage points respectively. These are in contrast to participation for individuals in rural areas or with less than primary education which remains unchanged. 3G coverage is associated with an increase in wage employment for male and younger adults. The impact on non-farm self-employment is even across demographics, but stronger for more educated individuals. All groups experience a statistically significant decrease in farm employment, especially individuals that are younger and less educated and live in rural areas.

Table 9 presents results dis-aggregated to a more granular level that separates the estimates by demographic groups as presented in Table 8 broken down by gender. While 3G exposure is associated with an increase of labor market participation for younger and more educated men, it is associated with a reduction in female labor market participation in rural areas and for illiterate women. The increase in wage jobs for male workers is driven by younger individuals. The increase in non-farm self-employment, for both men and women, is driven by more educated individuals. We observe a reduction in farm employment for all types of individuals.

Bringing these results together, we can conclude that mobile broadband drove significant welfare gains in Tanzania, which is consistent with previous studies. This was due in large part to improved labor outcomes, most notably for younger and more educated males that moved out of self-employed farm work to non-farm work and wage employment. This finding is perhaps partly explained by the fact that this group was more likely to use mobile internet once they received coverage. While the NPS does not include a question on individuals' use of mobile internet, a GSMA consumer survey carried out in 2018 in Tanzania found that women were 52% less likely to use mobile internet than men, while individuals in rural areas were 48% less likely to use mobile internet than urban residents. Another recent study for West Africa finds that women have a lower probability of adoption of mobile broadband of about 6 percentage points less than the average adoption rate (Rodriguez-Castelan et al. 2021).

On the other hand, the results also show that women who received 3G coverage moved out of self-employed farm work. Those women who were skilled (had at least a primary education and were literate) were able to transition to non-farm self-employment or other employment (which corresponds mostly to non-farm family work).[21] These findings are consistent with the broader literature, which suggests that while women can benefit from digital technologies, they often face greater difficulties to leverage mobile phones due to a mix of social norms, intra-household dynamics, lack of access of productive assets, and being less likely than men to use the internet. This suggests that while the provision of mobile broadband can enable improvements in welfare, it is not always sufficient in itself and further steps to reduce the gender gap in adoption and digital skills are necessary to ensure that all individuals can equally benefit from technology.

5 Conclusion

Over the past decade, investments in digital technology have been brought to the forefront of the global agenda for sustainable development. A lack of digital infrastructure is deemed as one of the key impediments to shared growth and prosperity in Africa, where a significant share of people remain unconnected. This paper sheds light on the welfare effects of mobile broadband infrastructure in Tanzania, one of the most populous countries in the Sub-Saharan Africa region. It leverages a data set that is nationally representative with detailed data on consumption and living standards, which tracks households over time and matches them

[21] Using information on primary activity in Waves 2 and 3, we identify that about 55% of workers in the category "Other employment" responded to be working as "unpaid family helper (non-agric)", 21% responded to be a paid employee and 17% responded to be non-farm self-employed without employees. From what we conclude that other employment mostly means helping family in a non agriculture job.

with precise mobile broadband coverage data from mobile operators. The results show that mobile broadband coverage had positive and significant impacts on consumption and poverty reduction, a finding that is consistent with studies that have found similar effects in other African countries (for example Nigeria and Senegal). This gives further assurance to policy makers about the positive effects that digital technology can deliver.

A key mechanism through which mobile broadband coverage translates into welfare gains is through its positive impact on labor outcomes. These positive labor outcomes are seen mostly among men – particularly younger and educated men. While educated women who received 3G coverage moved out of farm-work to other types of employment, they do not benefit to the same extent as men. This shows that while mobile technology can enable individuals to improve their welfare, some socioeconomic and demographic groups still face significant barriers to materialize the potential gains of being connected. This highlights the importance of ensuring that these underserved groups, particularly women but also older individuals, those living in rural areas, illiterate and the poor have the skills and resources to leverage the economic opportunities brought by digital technologies.

References

Abadie, Alberto, "Semiparametric difference-in-differences estimators," *The Review of Economic Studies*, 2005, *72* (1), 1–19.

Abreha, Kaleb, Jieun Choi, Woubet Kassa, Hyun Ju Kim, and Maurice Kugler, "Mobile Access Expansion and Price Information Diffusion: Firm Performance after Ethiopia's Transition to 3G in 2008," 2021.

Aker, Jenny and Kim Wilson, "Can Mobile Money Be Used to Promote Savings? Evidence from Northern Ghana," *SSRN Electronic Journal*, 02 2013.

Aker, Jenny C., "Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries," *Agricultural Economics*, 2011, *42* (6), 631–647.

_ **and Isaac M. Mbiti**, "Mobile Phones and Economic Development in Africa," *Journal of Economic Perspectives*, September 2010, *24* (3), 207–32.

_ **and Marcel Fafchamps**, "Mobile Phone Coverage and Producer Markets: Evidence from West Africa," *World Bank Economic Review*, 2015, *29* (2), 262–292.

Akerman, Anders, Ingvil Gaarder, and Magne Mogstad, "The skill complementarity of broadband internet," *The Quarterly Journal of Economics*, 2015, *130* (4), 1781–1824.

Alibhai, Salman, Niklas Buehren, Rachel Coleman, Markus Goldstein, and Francesco Strobbe, "Disruptive Finance : Using Psychometrics to Overcome Collateral Constraints in Ethiopia," Policy Research Working Paper 9386, World Bank, Washington, DC 2018.

Angrist, Joshua and Jorn-Steffen Pischke, *Mostly Harmless Econometrics: An Empiricist's Companion*, 1 ed., Princeton University Press, 2009.

Atasoy, Hilal, "The effects of broadband internet expansion on labor market outcomes," *ILR Review*, 2013, *66* (2), 315–345.

Bahia, Kalvin, Pau Castells, Genaro Cruz, Takaaki Masaki, Xavier Pedrós, Tobias Pfutze, Carlos Rodriguez-Castelán, and Hernan Winkler, "The Welfare Effects of Mobile Broadband Internet: Evidence from Nigeria," 2020.

Baker, Andrew, David F. Larcker, and Charles C. Y. Wang, "How Much Should We Trust Staggered Difference-In-Differences Estimates?," Working paper 736/2021, European Corporate Governance Institute March 2021.

Beuermann, Diether W., Christopher McKelvey, and Renos Vakis, "Mobile Phones and Economic Development in Rural Peru," *The Journal of Development Studies*, 2012, *48* (11), 1617–1628.

Bimber, Bruce, "Measuring the gender gap on the Internet," *Social science quarterly*, 2000, pp. 868–876.

Blumenstock, Joshua E., Nathan Eagle, and Marcel Fafchamps, "Airtime transfers and mobile communications: Evidence in the aftermath of natural disasters," *Journal of Development Economics*, 2016, *120*, 157–181.

Blumenstock, Joshuaa, Niall Keleher, Arman Rezaee, and Erin Troland, "The Impact of Mobile Phones: Experimental Evidence from the Random Assignment of New Cell Towers," 2020.

Callaway, Brantly and Pedro H.C. Sant'Anna, "Difference-in-Differences with multiple time periods," *Journal of Econometrics*, 2020.

Chen, Xiaomeng, Freeha Fatima, Naomi Halewood, Silvia Malgioglio, and Nobuo Yoshida, *Has the digital revolution come to Tanzania? Household survey findings on Mobile Phone Adoption*, World Bank, 2020.

Chun, Natalie and Heiwai Tang, "Do Information and Communication Technologies Empower Female Workers? Firm-Level Evidence from Viet Nam," ADB Economics Working Paper Series 545, Asian Development Bank May 2018.

De los Rios, Carlos, *Welfare Impact of Internet Use on Peruvian Households*, Lima: Instituto de Estudios Peruanos, 2010.

Fernandes, Ana M., Aaditya Mattoo, Huy Nguyen, and Marc Schiffbauer, "The internet and Chinese exports in the pre-ali baba era," *Journal of Development Economics*, 2019, *138*, 57–76.

GSMA, *The State of Mobile Internet Connectivity 2020*, GSMA, September 2020.

Guerrero, M. Y. and P. Ritter, "The effect of internet and cell phones on employment and agricultural production in rural villages in Peru," Tesis de pregrado en Economía. Universidad de Piura. Facultad de Ciencias Económicas y Empresariales, Programa Académico de Economía y Finanzas, Piura, Perú 2014.

Hasbi, Maude and Antoine Dubus, "Determinants of mobile broadband use in developing economies: Evidence from Sub-Saharan Africa," *Telecommunications Policy*, 2020, *44* (5), 101944.

Hjort, Jonas and Jonas Poulsen, "The Arrival of Fast Internet and Employment in Africa," *American Economic Review*, March 2019, *109* (3), 1032–79.

Hübler, Michael and Rebecca Hartje, "Are smartphones smart for economic development?," *Economics Letters*, 2016, *141*, 130–133.

Jack, William and Tavneet Suri, "Risk Sharing and Transactions Costs: Evidence from Kenya's Mobile Money Revolution," *American Economic Review*, January 2014, *104* (1), 183–223.

Jensen, Robert, "The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector," *The Quarterly Journal of Economics*, 2007, *122* (3), 879–924.

Kaila, Heidi and Finn Tarp, "Can the Internet improve agricultural production? Evidence from Viet Nam," *Agricultural Economics*, 2019, *50* (6), 675–691.

Klonner, S. and P.J. Nolen, "Cell phones and rural labor markets: Evidence from South Africa," Working Paper 56, Verein für Socialpolitik, Ausschuss für Entwicklungsländer.

Klonner, Stefan and Patrick J Nolen, "Cell phones and rural labor markets: Evidence from South Africa," 2010.

Ky, Serge, Clovis Rugemintwari, and Alain Sauviat, "Does Mobile Money Affect Saving Behaviour? Evidence from a Developing Country," *Journal of African Economies*, 2018, *27* (3), 285–320.

Labonne, Julien and Robert S. Chase, "The power of information : the impact of mobile phones on farmers'welfare in the Philippines," Policy Research Working Paper Series 4996, The World Bank July 2009.

Marandino, Joaquin and Phanindra V. Wunnava, "The Effect of Access to Information and Communication Technology on Household Labor Income: Evidence from One Laptop Per Child in Uruguay," IZA Discussion Papers 8415, Institute of Labor Economics (IZA) August 2014.

Masaki, Takaaki, Rogelio Granguillhome Ochoa, and Carlos Rodriguez-Castelan, "Broadband Internet and Household Welfare in Senegal," Policy Research Working Paper 9386, World Bank, Washington, DC 2020.

McMillan, Margaret S and Dani Rodrik, "Globalization, structural change and productivity growth," Technical Report, National Bureau of Economic Research 2011.

Muto, Megumi and Takashi Yamano, "The Impact of Mobile Phone Coverage Expansion on Market Participation: Panel Data Evidence from Uganda," *World Development*, 2009, *37* (12), 1887–1896.

Paunov, Caroline and Valentina Rollo, "Overcoming Obstacles: The Internet's Contribution to Firm Development," *The World Bank Economic Review*, 04 2015, *29* $(\text{suppl}_1), S192--S204$.

Restuccia, Diego, Dennis Tao Yang, and Xiaodong Zhu, "Agriculture and aggregate productivity: A quantitative cross-country analysis," *Journal of monetary economics*, 2008, *55* (2), 234–250.

Sant'Anna, Pedro H.C. and Jun Zhao, "Doubly robust difference-in-differences estimators," *Journal of Econometrics*, 2020, *219* (1), 101–122.

Schultz, Theodore W, "Reflections on agricultural production, output and supply," *Journal of farm Economics*, 1956, *38* (3), 748–762.

Suri, Tavneet and William Jack, "The long-run poverty and gender impacts of mobile money," *Science*, 2016, *354* (6317), 1288–1292.

Tadesse, Getaw and Godfrey Bahiigwa, "Mobile Phones and Farmers' Marketing Decisions in Ethiopia," *World Development*, 2015, *68*, 296–307.

Viollaz, Mariana and Hernan Jorge Winkler, "Does the Internet Reduce Gender Gaps?: The Case of Jordan," World Bank Policy Research Working Paper 9183s, World Bank 2020.

World Bank, *Tanzania Mainland Poverty Assessment*, Washington, DC: World Bank, 2019.

Zhao, Jianmei, "Internet usage and rural self-employment in China," *Asian Perspective*, 2020, *44* (1), 77–101.

Figure 1: Area covered with signal strength

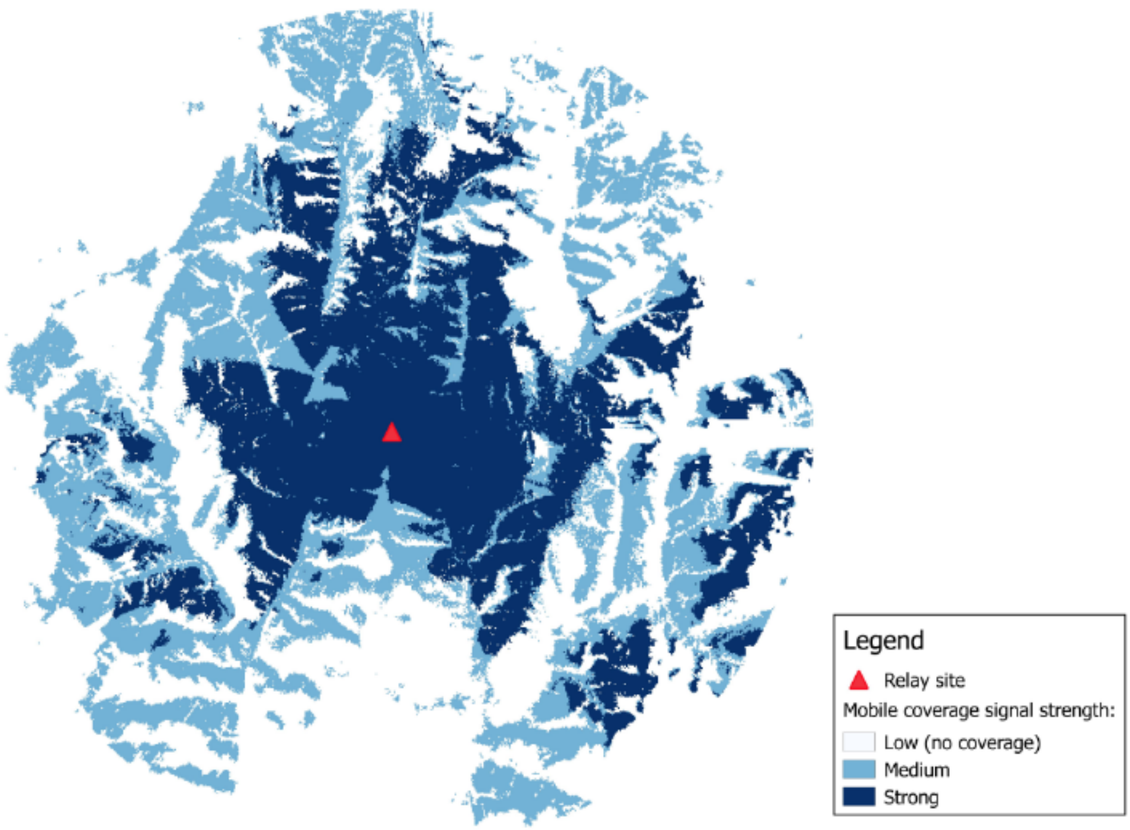
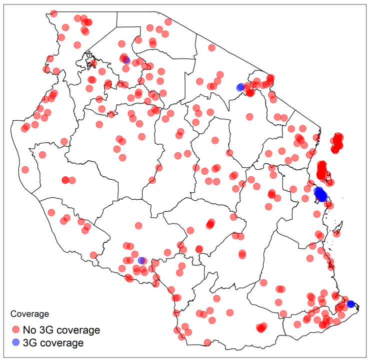
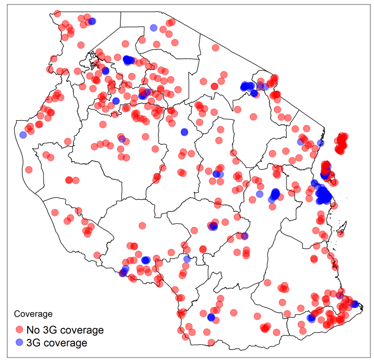


Figure 2: Coverage for surveyed locations in 2008 and 2013

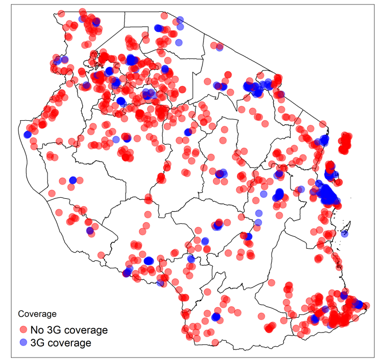
(a) Wave 1 (2008/09)



(b) Wave 2 (2010/11)



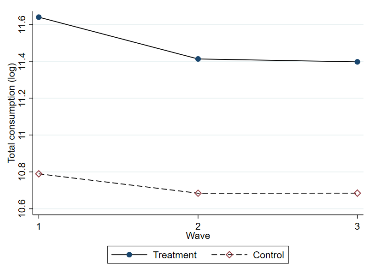
(c) Wave 3 (2012/13)



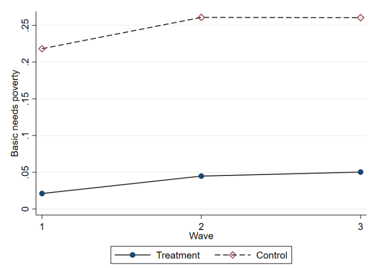
Note: This graph shows the locations of enumeration areas with access to 3G technology. Blue dots mean covered enumeration areas whereas red ones indicate no coverage.

Figure 3: Trends in key outcome variables: treatment vs. control groups

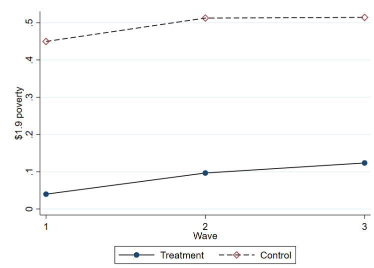
(a) Total consumption (log)



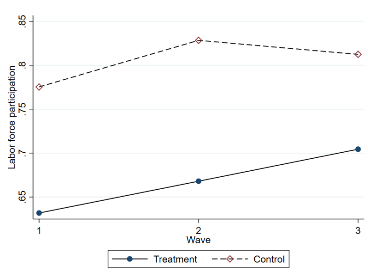
(b) Basic needs poverty



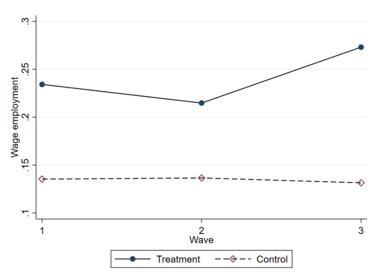
(c) $1.9 poverty



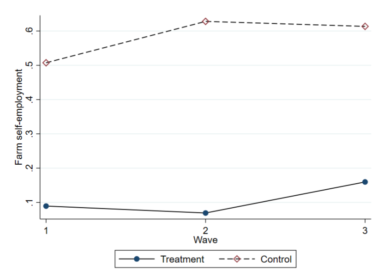
(d) Labor force participation



(e) Wage employment



(f) Farm self-employment



Note: This graph shows the unweighted mean of core welfare and labor indicators over three waves for the treatment vs. control groups.

Table 1: Signal strength thresholds

Radio technology	Medium signal strength	Strong signal strength
2G	-85 dBm	-73 dBm
3G	-91 dBm	-83 dBm
4G	-105 dBm	-95 dBm

Table 2: Summary Statistics.

	Wave 1, 2008-09	Wave 2, 2010-11	Wave 3, 2012-13
	A. Households		
Outcome Variables			
Total consumption	72398.34	71392.32	73536.83
Food consumption	42322.51	48892.47	64132.79
Non food consumption	18260.08	22517.49	28940.96
Poor (basic needs poverty line)	0.19	0.19	0.19
Extreme poor ($1.9 PPP poverty line)	0.39	0.38	0.38
Poor ($3.2 PPP poverty line)	0.65	0.65	0.64
Treatment Variables			
3G coverage	0.16	0.31	0.35
Less than 1 year 3G coverage	0.01	0.07	0.02
1-2 years 3G coverage	0.02	0.08	0.05
2-3 years 3G coverage	0.08	0.01	0.07
More than 3 years 3G coverage	0.05	0.15	0.21
Controls and demographics			
2G coverage	0.76	0.77	0.79
Ownership of dwelling unit	0.79	0.74	0.76
Access to electricity	0.21	0.24	0.27
Own at least one cellphone	0.45	0.62	0.72
Dwelling located in rural area	0.65	0.68	0.66
Household size	5.13	5.29	5.32
Female head of household	0.24	0.24	0.23
More primary educ. head household	0.21	0.22	0.22
Literacy status head of household	0.78	0.75	0.76
Age head of household	46.26	46.57	48.26
Observations	2752	3672	3465
	B. Individuals		
Outcome Variables			
Labor Force Participation	0.75	0.78	0.77
Wage Employment	0.15	0.16	0.18
Self-employed Non-farm	0.16	0.16	0.19
Self-employed Farm	0.44	0.45	0.45
Other Employment	0.11	0.09	0.06
Treatment Variables			
3G coverage	0.16	0.32	0.37
Less than 1 year 3G coverage	0.01	0.07	0.01
1-2 years 3G coverage	0.02	0.1	0.05
2-3 years 3G coverage	0.08	0.01	0.07
More than 3 years 3G coverage	0.05	0.15	0.22
Controls and demographics			
2G coverage	0.76	0.77	0.79
Female	0.52	0.52	0.52
More primary educ.	0.51	0.5	0.47
Literacy status	0.84	0.81	0.82
Age	31.41	31.36	33.02
Observations	7403	10376	9891

Table 3: DID results for household outcomes.

Dep. Variable:	Consumption		Food consumption		Non food consumption		Basic Need Poor		Extreme poor ($1.9 PPP)		Poor ($3.2 PPP)	
A. Exposure effect												
3G coverage	0.08***	0.07***	0.07**	0.06**	0.10***	0.09***	-0.05***	-0.05***	-0.03*	-0.03	-0.02	-0.02
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Observations	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887
R-squared	0.79	0.81	0.73	0.74	0.83	0.83	0.57	0.58	0.65	0.66	0.72	0.73
B. Effect by time of 3G exposure												
< 1 year	0.01	0.00	-0.02	-0.02	0.07	0.06	-0.02	-0.03	-0.01	-0.01	0.01	0.01
	(0.03)	(0.03)	(0.04)	(0.03)	(0.05)	(0.05)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
1-2 years	0.11***	0.11***	0.11***	0.10***	0.11***	0.10**	-0.06***	-0.06***	-0.05**	-0.05**	-0.04	-0.03
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
2-3 years	0.08**	0.07**	0.09**	0.07*	0.11**	0.09**	-0.04**	-0.04**	-0.03	-0.02	-0.02	-0.01
	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
> 3 years	0.11***	0.10***	0.11***	0.10***	0.13***	0.11***	-0.06***	-0.07***	-0.02	-0.02	-0.03	-0.03
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
Observations	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887	9,887
R-squared	0.79	0.81	0.73	0.74	0.83	0.83	0.57	0.58	0.65	0.66	0.72	0.73
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Notes: All regressions includes household and wave fixed effects. Controls refer to 2G coverage, access to electricity, house ownership, wealth index and household size. Panel A and B use the same specifications but present results of separate regressions. In Panel A the treatment variable is indicator variable equal to one if the household is exposed to 3G in time t. In panel B the treatment variables are mutually exclusive dummies equal to one if the household in time t has been exposed to 3G for that time interval. Consumption variables are in log. Robust standard errors clustered at the EA level (410 clusters) are shown in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: DID results for individuals outcomes.

Dep. Variable:	Labor Force Participation		Wage employment		Self-employed Non-farm		Self-employed Farm		Other Employment		Number of employments	
A. Exposure effect												
3G coverage	0.03**	0.03**	0.03***	0.03**	0.03**	0.02**	-0.08***	-0.07***	0.03**	0.03**	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Observations	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604
R-squared	0.65	0.65	0.60	0.61	0.61	0.61	0.67	0.68	0.39	0.39	0.63	0.63
B. Effect by coverage time												
< 1 year	0.01	0.01	0.02	0.02	-0.03*	-0.03*	-0.10***	-0.09***	0.07***	0.06***	-0.04	-0.04
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
$1-2$ years	0.03*	0.02*	0.02	0.01	0.05***	0.04***	-0.08***	-0.07***	0.02	0.02	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)
$2-3$ years	0.03	0.03	0.06***	0.05***	0.04**	0.03**	-0.05***	-0.04**	-0.03	-0.03	0.02	0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
> 3 years	0.08***	0.08***	0.06***	0.04***	0.04***	0.04**	-0.09***	-0.07***	0.05***	0.05***	0.06**	0.06**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Observations	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604	27,604
R-squared	0.65	0.65	0.60	0.61	0.61	0.61	0.67	0.68	0.39	0.39	0.63	0.63
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Notes: All regressions includes individuals and wave fixed effects. Controls refer to 2G coverage, access to electricity, house ownership, wealth index and household size. Panel A and B use the same specifications but present results of separate regressions. In Panel A the treatment variable is indicator variable equal to one if the household is exposed to 3G in time t. In panel B the treatment variables are mutually exclusive dummies equal to one if the individual in time t has been exposed to 3G for that time interval. Robust standard errors clustered at the EA level (410 clusters) are shown in parenthesis. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 5: Results from Callaway Sant'Anna doubly robust estimation for welfare outcomes

Outcome	Consumption							
Treatment	3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects								
g=2 t =2	0.0702	0.0503	0.1209	0.0544	0.0393	0.0667	0.0757	0.0646
g=2 t =3	0.1094	0.054	0.0936	0.057	-0.0833	0.0874	0.0375	0.0676
g=3 t =2	0.1196	0.052	0.0379	0.0479	0.0708	0.0418	0.0969	0.0546
g=3 t =3	-0.0077	0.052	0.0755	0.0448	0.0292	0.0392	-0.0136	0.0432
Event study								
e = -1	0.1196	0.0549	0.0379	0.0518	0.0708	0.0434	0.0969	0.0535
e = 0	0.0484	0.0372	0.0966	0.0371*	0.0306	0.0346	0.0319	0.036
e = 1	0.1094	0.0501	0.0936	0.0581	-0.0833	0.0912	0.0375	0.0607
Overall	0.0789	0.0437	0.0951	0.044*	-0.0263	0.0542	0.0347	0.0462
Event study with balanced group								
e = 0	0.0702	0.0452	0.1209	0.0549	0.0393	0.0737	0.0757	0.0602
e = 1	0.1094	0.0528	0.0936	0.054	-0.0833	0.0894	0.0375	0.0619
Overall	0.0898	0.045*	0.1072	0.0505*	-0.022	0.0673	0.0566	0.0579
Outcome	Food Consumption							
Treatment	3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects								
g=2 t=2	0.0489	0.0461	0.1118	0.0573	0.0636	0.0732	0.0372	0.0582
g=2 t=3	0.1164	0.0532	0.0991	0.06	-0.0735	0.0927	-0.0056	0.0571
g=3 t=2	0.086	0.062	-0.012	0.0467	0.0439	0.0464	0.0735	0.0593
g=3 t=3	0.0078	0.0567	0.111	0.0465	0.0337	0.046	-0.0058	0.0491
Event study								
e = -1	0.086	0.0607	-0.012	0.0464	0.0439	0.0445	0.0735	0.0574
e = 0	0.0374	0.0374	0.1113	0.0367*	0.0379	0.0407	0.0161	0.0356
e = 1	0.1164	0.0543	0.0991	0.0619	-0.0735	0.0961	-0.0056	0.061
Overall	0.0769	0.0399	0.1052	0.0441*	-0.0178	0.0609	0.0053	0.0415
Event study with balanced group								
e = 0	0.0489	0.0477	0.1118	0.0574	0.0636	0.074	0.0372	0.0545
e = 1	0.1164	0.0548	0.0991	0.0587	-0.0735	0.0916	-0.0056	0.0598
Overall	0.0827	0.0466	0.1054	0.0501*	-0.0049	0.0714	0.0158	0.0489
Outcome	Non-food Consumption							
Treatment	3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects								
g=2 t=2	0.0817	0.0655	0.0971	0.0825	0.029	0.0978	0.1266	0.081
g=2 t=3	0.0752	0.0672	0.0636	0.0758	-0.054	0.133	0.0728	0.0825
g=3 t=2	0.1941	0.0808	0.1	0.0656	0.074	0.0606	0.0938	0.0826
g=3 t=3	0.0334	0.0708	0.0603	0.0543	0.0727	0.0509	0.0142	0.0591
Event study								
e = -1	0.1941	0.0791*	0.1	0.0652	0.074	0.0594	0.0938	0.0787
e = 0	0.0682	0.0503	0.0773	0.0451	0.0665	0.0473	0.0715	0.0495
e = 1	0.0752	0.0621	0.0636	0.077	-0.054	0.1173	0.0728	0.0833
Overall	0.0717	0.0538	0.0704	0.0569	0.0063	0.0759	0.0721	0.0592
Event study with balanced group								
e = 0	0.0817	0.0625	0.0971	0.0768	0.029	0.0862	0.1266	0.0795
e = 1	0.0752	0.0685	0.0636	0.0752	-0.054	0.1175	0.0728	0.0842
Overall	0.0785	0.0602	0.0803	0.0686	-0.0125	0.0888	0.0997	0.0731

Outcome		Basic Needs Poverty							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	-0.0596	0.0312	-0.0821	0.0363	-0.0137	0.0301	-0.0122	0.0202
g=2	t=3	-0.0589	0.0287	-0.0608	0.0352	-0.0091	0.0373	0.0011	0.0168
g=3	t=2	-0.0497	0.038	-0.0446	0.0307	-0.038	0.0259	-0.0292	0.0321
g=3	t=3	0.021	0.0283	-0.0084	0.0262	-0.012	0.0218	0.0004	0.0204
Event study									
	e = -1	-0.0497	0.0415	-0.0446	0.0332	-0.038	0.0263	-0.0292	0.0327
	e = 0	-0.0371	0.0213	-0.0426	0.023	-0.0122	0.0196	-0.006	0.0135
	e = 1	-0.0589	0.0254*	-0.0608	0.0368	-0.0091	0.0374	0.0011	0.0179
	Overall	-0.048	0.0224*	-0.0517	0.0264	-0.0107	0.0244	-0.0025	0.0145
Event study with balanced group									
	e = 0	-0.0596	0.0283*	-0.0821	0.0398	-0.0137	0.0281	-0.0122	0.0195
	e = 1	-0.0589	0.0288	-0.0608	0.0345	-0.0091	0.0399	0.0011	0.0174
	Overall	-0.0592	0.0244*	-0.0714	0.0362*	-0.0114	0.0334	-0.0056	0.017

Outcome		$1.9 poverty							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	-0.0656	0.0476	-0.0256	0.0308	-0.0324	0.0263	-0.0404	0.0411
g=2	t=3	-0.0814	0.0433	-0.0671	0.0397	-0.0363	0.029	-0.0318	0.0399
g=3	t=2	-0.056	0.0368	-0.0329	0.0335	-0.0312	0.0407	0.0744	0.0533
g=3	t=3	-0.0496	0.0398	-0.0145	0.0339	0.0062	0.0323	-0.0546	0.045
Event study									
	e = -1	-0.056	0.0402	-0.0329	0.0348	-0.0312	0.0441	0.0744	0.0559
	e = 0	-0.057	0.0255	-0.0161	0.0302	-0.0135	0.0197	-0.0444	0.0306
	e = 1	-0.0814	0.0449	-0.0671	0.0391	-0.0363	0.028	-0.0318	0.0394
	Overall	-0.0692	0.0307*	-0.0416	0.03	-0.0249	0.0209	-0.0381	0.031
Event study with balanced group									
	e = 0	-0.0656	0.0481	-0.0256	0.0309	-0.0324	0.0256	-0.0404	0.0388
	e = 1	-0.0814	0.0446	-0.0671	0.0419	-0.0363	0.0296	-0.0318	0.0422
	Overall	-0.0735	0.0393	-0.0464	0.032	-0.0344	0.0245	-0.0361	0.0352

Outcome		$3.2 poverty							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	-0.0404	0.0411	-0.0386	0.047	-0.1744	0.0594*	-0.1065	0.0387*
g=2	t=3	-0.0318	0.0399	0.0331	0.0415	-0.0913	0.045	-0.0812	0.0386
g=3	t=2	0.0744	0.0533	-0.0004	0.0391	-0.0708	0.0372	-0.0218	0.0419
g=3	t=3	-0.0546	0.045	-0.09	0.038	-0.0123	0.0369	0.0452	0.0403
Event study									
	e = -1	0.0744	0.0559	-0.0004	0.0436	-0.0708	0.0387	-0.0218	0.0471
	e = 0	-0.0444	0.0306	-0.0662	0.0287	-0.035	0.0325	-0.0321	0.0279
	e = 1	-0.0318	0.0394	0.0331	0.043	-0.0913	0.0496	-0.0812	0.044
	Overall	-0.0381	0.031	-0.0166	0.0339	-0.0631	0.0308*	-0.0567	0.0291
Event study with balanced group									
	e = 0	-0.0404	0.0388	-0.0386	0.0471	-0.1744	0.0658*	-0.1065	0.0404*
	e = 1	-0.0318	0.0422	0.0331	0.0403	-0.0913	0.0474	-0.0812	0.041
	Overall	-0.0361	0.0352	-0.0028	0.0372	-0.1329	0.0406*	-0.0939	0.033*

Notes: The table reports aggregated treatment effect parameters under the conditional parallel trends assumptions following Callaway and Sant'Anna (2020). The 'Group-time average treatment effects' row reports the average treatment effect for group g at wave t, where a "group" is defined by the time period when units are first treated. The row 'Event study' reports average treatment effects by the length of exposure to 3G coverage increase; here, e indexes the length of exposure to the treatment. The row 'Event study with balanced groups' reports average treatment effects by length of exposure using a fixed set of groups at all lengths of exposure; here, e indexes the length of exposure and the sample consists of households that have at least one year of exposure to 3G coverage. The column 'Single parameter' represents a further aggregation of each type of parameter. All the estimates in this table use the doubly robust estimator. * indicates that the 95% confidence intervals do not cover zero.

Table 6: Results from Callaway Sant'Anna doubly robust estimation for labor outcomes

Outcome		Labor force participation							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0762	0.0245*	0.0732	0.0268*	0.0943	0.0628	0.0383	0.0272
g=2	t=3	0.0914	0.0283*	0.1007	0.0341*	0.096	0.0409	0.0627	0.0267
g=3	t=2	0.0449	0.0285	0.0523	0.0242	0.0631	0.0211*	0.0436	0.0235
g=3	t=3	-0.0323	0.0293	-0.0186	0.0263	0.0232	0.0228	0.0624	0.022*
Event study									
	e = -1	0.0449	0.0274	0.0523	0.0241	0.0631	0.0222*	0.0436	0.0245
	e = 0	0.0467	0.0185*	0.0255	0.0177	0.0336	0.0214	0.0509	0.0174*
	e = 1	0.0914	0.0306*	0.1007	0.0357*	0.096	0.0419	0.0627	0.0278
	Overall	0.069	0.0206*	0.0631	0.0255*	0.0648	0.0269*	0.0568	0.0195*
Event study with balanced group									
	e = 0	0.0762	0.0263*	0.0732	0.0293*	0.0943	0.0651	0.0383	0.0281
	e = 1	0.0914	0.029*	0.1007	0.0339*	0.096	0.0401*	0.0627	0.0277*
	Overall	0.0838	0.0229*	0.0869	0.0301*	0.0952	0.0507	0.0505	0.0243*
Outcome		Wage Employment							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.011	0.0222	0.0782	0.0323	-0.0192	0.0241	-0.0068	0.0191
g=2	t=3	0.0317	0.0237	0.1663	0.0374*	0.0579	0.0237*	-0.016	0.0214
g=3	t=2	0.0171	0.0178	-0.0086	0.0189	-0.0234	0.016	-0.0317	0.0215
g=3	t=3	0.0572	0.0228*	0.0721	0.0167*	0.0639	0.0184*	0.0406	0.026
Event study									
	e = -1	0.0171	0.0191	-0.0086	0.0189	-0.0234	0.0177	-0.0317	0.0234
	e = 0	0.035	0.015*	0.073	0.0159*	0.0244	0.0156	0.0061	0.0154
	e = 1	0.0317	0.0253	0.1663	0.0348*	0.0579	0.0233*	-0.016	0.0236
	Overall	0.0333	0.0185	0.1197	0.0208*	0.0411	0.0161*	-0.005	0.0152
Event study with balanced group									
	e = 0	0.011	0.022	0.0782	0.0322*	-0.0192	0.0247	-0.0068	0.0201
	e = 1	0.0317	0.0242	0.1663	0.0367*	0.0579	0.0237*	-0.016	0.0232
	Overall	0.0214	0.0199	0.1223	0.0264*	0.0193	0.0223	-0.0114	0.0168

Outcome		Self-employed Non-farm							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0161	0.0238	-0.0227	0.0385	-0.0131	0.028	-0.009	0.0269
g=2	t=3	-0.008	0.0259	-0.0362	0.0449	-0.0193	0.028	0.022	0.0306
g=3	t=2	-0.0453	0.0196	-0.0101	0.0197	0.0291	0.0186	0.0098	0.036
g=3	t=3	0.05	0.0238	0.0141	0.0211	-0.0004	0.0247	-0.1251	0.0317*
Event study									
	e = -1	-0.0453	0.0194*	-0.0101	0.0176	0.0291	0.0201	0.0098	0.0374
	e = 0	0.0337	0.0151	0.0087	0.0191	-0.0064	0.0164	-0.0406	0.0223
	e = 1	-0.008	0.0292	-0.0362	0.0412	-0.0193	0.0282	0.022	0.0293
	Overall	0.0129	0.0179	-0.0138	0.0261	-0.0129	0.0186	-0.0093	0.0236
Event study with balanced group									
	e = 0	0.0161	0.0225	-0.0227	0.0379	-0.0131	0.0265	-0.009	0.0298
	e = 1	-0.008	0.0268	-0.0362	0.046	-0.0193	0.026	0.022	0.0279

Overall	0.0041	0.0207	-0.0295	0.0352	-0.0162	0.0238	0.0065	0.0252
Outcome	Self-employed Farm							
Treatment	3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects								
g=2 t=2	-0.009	0.0269	-0.0062	0.0295	-0.1102	0.0446*	-0.0663	0.0257*
g=2 t=3	0.022	0.0306	0.0123	0.0328	-0.0227	0.0478	0.0097	0.0249
g=3 t=2	0.0098	0.036	0.0034	0.0301	-0.0324	0.0247	-0.0402	0.0214
g=3 t=3	-0.1251	0.0317*	-0.0486	0.0263	-0.0134	0.02	-0.0139	0.0186
Event study								
e = -1	0.0098	0.0374	0.0034	0.0313	-0.0324	0.0233	-0.0402	0.0222
e = 0	-0.0406	0.0223	-0.0282	0.0182	-0.0275	0.0177	-0.0388	0.0154*
e = 1	0.022	0.0293	0.0123	0.0328	-0.0227	0.0493	0.0097	0.0249
Overall	-0.0093	0.0236	-0.008	0.0223	-0.0251	0.0284	-0.0145	0.0167
Event study with balanced group								
e = 0	-0.009	0.0298	-0.0062	0.0279	-0.1102	0.0452*	-0.0663	0.0261*
e = 1	0.022	0.0279	0.0123	0.0296	-0.0227	0.0501	0.0097	0.026
Overall	0.0065	0.0252	0.0031	0.0275	-0.0665	0.0415	-0.0283	0.0188
Outcome	Other Employment							
Treatment	3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects								
g=2 t=2	0.0609	0.0195*	0.049	0.0161*	0.1367	0.0378*	0.1167	0.0234*
g=2 t=3	0.0246	0.018	0.0435	0.018*	0.0148	0.0222	0.0167	0.0161
g=3 t=2	0.0128	0.0207	0.0546	0.0242	0.0714	0.018*	0.0365	0.0171
g=3 t=3	-0.0133	0.0229	-0.073	0.0201*	-0.0461	0.0179*	0.0059	0.0182
Event study								
e = -1	0.0128	0.0206	0.0546	0.0255	0.0714	0.0175*	0.0365	0.0152*
e = 0	0.0407	0.0159*	-0.0144	0.0145	-0.0195	0.0167	0.0585	0.0139*
e = 1	0.0246	0.0173	0.0435	0.017*	0.0148	0.024	0.0167	0.0161
Overall	0.0327	0.0158*	0.0146	0.0135	-0.0023	0.0146	0.0376	0.0115*
Event study with balanced group								
e = 0	0.0609	0.0183*	0.049	0.017*	0.1367	0.0397*	0.1167	0.0227*
e = 1	0.0246	0.018	0.0435	0.0161*	0.0148	0.0239	0.0167	0.0162
Overall	0.0428	0.0156*	0.0462	0.0138*	0.0757	0.0283*	0.0667	0.0149*
Outcome	Number of Employments							
Treatment	3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects								
g=2 t=2	0.0579	0.0288	0.0699	0.0333	0.0819	0.0597	0.0181	0.0323
g=2 t=3	0.0751	0.0306*	0.0795	0.0417	0.1222	0.0576	0.065	0.0375
g=3 t=2	0.0013	0.0406	0.0298	0.0303	0.0203	0.0277	0.002	0.0306
g=3 t=3	-0.0313	0.0427	-0.0143	0.032	0.0267	0.0279	0.0555	0.0283
Event study								
e = -1	0.0013	0.0407	0.0298	0.0324	0.0203	0.0299	0.002	0.033
e = 0	0.0336	0.022	0.0262	0.0213	0.0347	0.0253	0.0377	0.0196
e = 1	0.0751	0.0327	0.0795	0.0405	0.1222	0.0599	0.065	0.0389
Overall	0.0544	0.0245*	0.0529	0.0287	0.0785	0.037*	0.0514	0.0257*
Event study with balanced group								
e = 0	0.0579	0.0291	0.0699	0.0308*	0.0819	0.0567	0.0181	0.0328
e = 1	0.0751	0.0326*	0.0795	0.0406	0.1222	0.061	0.065	0.0377
Overall	0.0665	0.0272*	0.0747	0.0352*	0.102	0.0515*	0.0416	0.0307

Notes: The table reports aggregated treatment effect parameters under the conditional parallel trends assumptions following Callaway and Sant'Anna (2020). The 'Group-time average treatment effects' row reports the average treatment effect for group g at wave t, where a "group" is defined by the time period when units are first treated. The row 'Event study' reports average treatment effects by the length of exposure to 3G coverage increase; here, e indexes the length of exposure to the treatment. The row 'Event study with balanced groups' reports average treatment effects by length of exposure using a fixed set of groups at all lengths of exposure; here, e indexes the length of exposure and the sample consists of households that have at least one year of exposure to 3G coverage. The column 'Single parameter' represents a further aggregation of each type of parameter. All the estimates in this table use the doubly robust estimator. * indicates that the 95% confidence intervals do not cover zero.

Table 7: Heterogeneous Results - Households.

	Female head		Locality type		Consumption	
	No	Yes	Urban	Rural	Low	High
Dep. Variable: Consumption						
3G exposure	0.05*	0.14***	0.09***	0.05	0.09***	0.01
	(0.03)	(0.05)	(0.03)	(0.03)	(0.02)	(0.02)
Dep. Variable: Food consumption						
3G exposure	0.04	0.13**	0.09**	0.03	0.06**	0.02
	(0.03)	(0.06)	(0.04)	(0.04)	(0.03)	(0.02)
Dep. Variable: Non food consumption						
3G exposure	0.07**	0.14**	0.07	0.13***	0.11***	0.03
	(0.04)	(0.06)	(0.04)	(0.04)	(0.04)	(0.03)
Dep. Variable: Basic Need Poor						
3G exposure	-0.04**	-0.09**	-0.07***	-0.04*	-0.09***	-0.01
	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)	(0.01)
Dep. Variable: Extreme poor ($1.9 PPP)						
3G exposure	-0.01	-0.10***	-0.04	-0.03	-0.14***	0.07***
	(0.02)	(0.04)	(0.02)	(0.03)	(0.03)	(0.01)
Dep. Variable: Poor ($3.2 PPP)						
3G exposure	-0.02	-0.01	-0.02	-0.02	0.09***	-0.04*
	(0.02)	(0.04)	(0.03)	(0.03)	(0.02)	(0.02)

	Primary Educ. Head		Literacy status head		Age head > 50	
	Less	More	No	Yes	No	Yes
Dep. Variable: Consumption						
3G exposure	0.09***	0.04	0.12***	0.07***	0.06**	0.09**
	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)
Dep. Variable: Food consumption						
3G exposure	0.07**	0.05	0.08	0.07**	0.05*	0.08*
	(0.03)	(0.04)	(0.05)	(0.03)	(0.03)	(0.04)
Dep. Variable: Non food consumption						
3G exposure	0.15***	-0.01	0.19***	0.07**	0.09**	0.09*
	(0.04)	(0.05)	(0.07)	(0.03)	(0.04)	(0.05)
Dep. Variable: Basic Need Poor						
3G exposure	-0.06***	-0.03	-0.10***	-0.04***	-0.05***	-0.05*
	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)
Dep. Variable: Extreme poor ($1.9 PPP)						
3G exposure	-0.04*	-0.01	-0.04	-0.03	-0.03*	-0.03
	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)
Dep. Variable: Poor ($3.2 PPP)						
3G exposure	-0.03	0.01	-0.03	-0.02	-0.02	-0.00
	(0.02)	(0.03)	(0.04)	(0.02)	(0.02)	(0.03)

Notes: The table presents results separate regressions by heterogeneous category (every two columns) and by dependent variable. All regressions include household fixed effects, dummies for waves and controls. Consumption variables are in log. Robust standard errors clustered at the EA level (410 clusters) are shown in parenthesis. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 8: Heterogeneous Results - Individuals.

	Female		Locality type		Consumption	
	No	Yes	Urban	Rural	Low	High
Dep. Variable: Labor Force Participation						
3G exposure	0.06***	0.00	0.05***	-0.00	0.02	0.03**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
Dep. Variable: Wage employment						
3G exposure	0.06***	-0.00	0.03**	0.02	0.01	0.03***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Dep. Variable: Self-employed Non-Farm						
3G exposure	0.03**	0.02	0.02	0.03**	0.02	0.02**
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)
Dep. Variable: Self-employed Farm						
3G exposure	-0.07***	-0.07***	-0.04**	-0.10***	-0.09***	-0.05***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
Dep. Variable: Other Employment						
3G exposure	0.02	0.03**	0.01	0.04**	0.04**	0.02
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
Dep. Variable: Number of employments						
3G exposure	0.04*	-0.02	0.02	-0.01	-0.02	0.02
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)

	Primary Educ.		Literacy status		Age > 30	
	Less	More	No	Yes	No	Yes
Dep. Variable: Labor Force Participation						
3G exposure	-0.01	0.06***	-0.04	0.03**	0.05***	0.01
	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)
Dep. Variable: Wage employment						
3G exposure	0.03**	0.02*	0.01	0.02**	0.05***	-0.00
	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)	(0.01)
Dep. Variable: Self-employed Non-Farm						
3G exposure	0.01	0.04***	0.03	0.02**	0.02*	0.03**
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Dep. Variable: Self-employed Farm						
3G exposure	-0.09***	-0.05***	-0.09***	-0.06***	-0.09***	-0.04**
	(0.02)	(0.01)	(0.03)	(0.01)	(0.02)	(0.02)
Dep. Variable: Other Employment						
3G exposure	0.00	0.04***	0.03	0.02*	0.03**	0.02
	(0.02)	(0.01)	(0.03)	(0.01)	(0.01)	(0.02)
Dep. Variable: Number of employments						
3G exposure	-0.04*	0.05***	-0.02	0.01	0.01	0.01
	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.02)

Notes: The table presents results separate regressions by heterogeneous category (every two columns) and by dependent variable. All regressions include individual fixed effects, dummies for waves and controls. Robust standard errors clustered at the EA level (410 clusters) are shown in parenthesis. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 9: Heterogeneous Results by Gender - Individuals.

Dep Variable:	Labor Force Participation				Wage employment			
Subgroup:	Urban	Primary Educ.	Literacy status	Age ≤30	Urban	Primary Educ.	Literacy status	Age ≤30
For Males								
3G Exposure x No	0.05***	0.02	0.02	0.00	0.06**	0.06**	0.05	0.00
	(0.02)	(0.02)	(0.04)	(0.01)	(0.02)	(0.03)	(0.05)	(0.02)
3G Exposure x Yes	0.06***	0.09***	0.05***	0.11***	0.06**	0.05***	0.05**	0.11***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
For Females								
3G Exposure x No	-0.05**	-0.03	-0.07**	0.00	-0.01	0.01	-0.01	-0.01
	(0.02)	(0.02)	(0.03)	(0.02)	(0.01)	(0.01)	(0.03)	(0.01)
3G Exposure x Yes	0.04*	0.03*	0.02	0.00	0.01	-0.01	-0.00	0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)

Dep Variable:	Self-employed Non-Farm				Self-employed Farm			
Subgroup:	Urban	Primary Educ.	Literacy status	Age ≤30	Urban	Primary Educ.	Literacy status	Age ≤30
For Males								
3G Exposure x No	0.04*	0.03	0.06	0.03	-0.08***	-0.08***	-0.09	-0.04*
	(0.02)	(0.02)	(0.04)	(0.02)	(0.03)	(0.02)	(0.06)	(0.02)
3G Exposure x Yes	0.03	0.04**	0.03**	0.04**	-0.06***	-0.06***	-0.06***	-0.10***
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
For Females								
3G Exposure x No	0.03	-0.01	0.01	0.01	-0.12***	-0.09***	-0.10***	-0.03
	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)
3G Exposure x Yes	0.00	0.04***	0.02	0.01	-0.03	-0.05***	-0.06***	-0.10***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)

Dep Variable:	Other Employment				Number of employments			
Subgroup:	Urban	Primary Educ.	Literacy status	Age ≤30	Urban	Primary Educ.	Literacy status	Age ≤30
For Males								
3G Exposure x No	0.03	-0.01	0.02	0.00	0.04	-0.00	0.04	-0.00
	(0.02)	(0.02)	(0.05)	(0.02)	(0.03)	(0.03)	(0.07)	(0.03)
3G Exposure x Yes	0.01	0.04***	0.01	0.03*	0.04	0.07***	0.03	0.08***
	(0.02)	(0.01)	(0.01)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)
For Females								
3G Exposure x No	0.06**	0.02	0.04	0.03*	-0.05	-0.08**	-0.06	0.00
	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.04)	(0.03)
3G Exposure x Yes	0.01	0.05***	0.03**	0.04**	-0.00	0.03	-0.01	-0.04
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)

Notes: In each column the table presents results of separate regressions by category, by gender and by dependent variable. "Yes" and "No" refer to the subgroup category. All regressions include individual fixed effects, dummies for household wave and controls. Robust standard errors clustered at the EA level (410 clusters) are shown in parenthesis. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

AppendixA Web Appendix Tables and Figures

Table A1: Robustness checks for DID results for household outcomes, alternative specifications.

Dep. Variable:	*Consumption*			*Food consumption*			*Non food consumption*		
Specification:	Baseline	Region x Wave FE	Abadie (2005)	Baseline	Region x Wave FE	Abadie (2005)	Baseline	Region x Wave FE	Abadie (2005)
A. Exposure effect									
3G coverage	0.07***	0.05*	0.05**	0.06**	0.03	0.05	0.09***	0.11***	0.06*
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)
B. Effect by time of 3G exposure									
< 1 year	0.00	-0.01	-0.01	-0.02	-0.04	-0.03	0.06	0.06	0.04
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.05)	(0.05)	(0.05)
1-2 years	0.11***	0.10***	0.09***	0.10***	0.08**	0.09***	0.10**	0.16***	0.08*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.05)	(0.04)
2-3 years	0.07**	0.04	0.04	0.07*	0.04	0.05	0.09**	0.09*	0.06
	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)
> 3 years	0.10***	0.09**	0.06*	0.10***	0.07	0.07*	0.11***	0.18***	0.06
	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)

Dep. Variable:	*Basic Need Poor*			*Extreme poor ($1.9 PPP)*			*Poor ($3.2 PPP)*		
Specification:	Baseline	Region x Wave FE	Abadie (2005)	Baseline	Region x Wave FE	Abadie (2005)	Baseline	Region x Wave FE	Abadie (2005)
A. Exposure effect									
3G coverage	-0.05***	-0.05***	-0.04**	-0.03	-0.04*	-0.02	-0.02	-0.03	0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
B. Effect by time of 3G exposure									
< 1 year	-0.03	-0.02	-0.02	-0.01	-0.03	0.00	0.01	-0.00	0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)
1-2 years	-0.06***	-0.06***	-0.05**	-0.05**	-0.06**	-0.03	-0.03	-0.05**	-0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
2-3 years	-0.04**	-0.05**	-0.03	-0.02	-0.04	-0.00	-0.01	-0.03	0.00
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
> 3 years	-0.07***	-0.06**	-0.04*	-0.02	-0.04	0.01	-0.03	-0.07**	0.01
	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)

Notes: All regressions include household fixed effects, dummies for household wave and controls variables. Robust standard errors clustered at the EA level (410 clusters) are shown in parenthesis. Abadie (2005) refers to estimations including wave dummies times four variables at the household level: distance to nearest major road, distance to nearest population center with +20,000, distance to nearest border crossing, and distance to nearest headquarters of district of residence. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A2: Robustness checks for DID results for individuals outcomes, alternative specifications.

Dep. Variable:	*Labor Force Participation*			*Wage employment*			*Self-employed Non-Farm*		
Specification:	Baseline	Region x Wave FE	Abadie (2005)	Baseline	Region x Wave FE	Abadie (2005)	Baseline	Region x Wave FE	Abadie (2005)
A. Exposure effect									
3G coverage	0.03**	0.02	0.02	0.03**	0.02*	0.01	0.02**	0.02*	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
B. Effect by time of 3G exposure									
< 1 year	0.01	0.01	0.01	0.02	0.01	0.01	-0.03*	-0.03*	-0.03*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)
1-2 years	0.02*	0.02	0.02	0.01	0.01	0.00	0.04***	0.05***	0.04***
	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)
2-3 years	0.03	0.03*	0.02	0.05***	0.05***	0.03*	0.03**	0.04**	0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
> 3 years	0.08***	0.03	0.05***	0.04***	0.03*	0.02	0.04**	0.04**	0.02
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)

Dep. Variable:	*Self-employed Farm*			*Other Employment*			*Number of employments*		
Specification:	Baseline	Region x Wave FE	Abadie (2005)	Baseline	Region x Wave FE	Abadie (2005)	Baseline	Region x Wave FE	Abadie (2005)
A. Exposure effect									
3G coverage	-0.07***	-0.07***	-0.04***	0.03**	0.03**	0.01	0.01	0.00	0.00
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
B. Effect by time of 3G exposure									
< 1 year	-0.09***	-0.10***	-0.06***	0.06***	0.08***	0.05**	-0.04	-0.04	-0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
$1-2$ years	-0.07***	-0.06***	-0.04**	0.02	0.02	0.01	0.01	0.02	0.01
	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
$2-3$ years	-0.04**	-0.06***	-0.02	-0.03	0.00	-0.02	0.02	0.03	0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
> 3 years	-0.07***	-0.06***	-0.05**	0.05***	0.01	0.05**	0.06**	0.02	0.04
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)

Notes: All regressions include individual fixed effects, dummies for household wave and controls variables. Robust standard errors clustered at the EA level (410 clusters) are shown in parenthesis. Abadie (2005) refers to estimations including wave dummies times four variables at the household level: distance to nearest major road, distance to nearest population center with +20,000, distance to nearest border crossing, and distance to nearest headquarters of district of residence. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A3: Results from Callaway Sant'Anna doubly robust estimation for welfare outcomes

Outcome		Consumption							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0392	0.0463	0.131	0.0524*	0.0414	0.0589	0.0363	0.0472
g=2	t=3	0.1094	0.054	0.0936	0.057	-0.0833	0.0874	0.0375	0.0676
g=3	t=2	0.1196	0.052	0.0379	0.0479	0.0708	0.0418	0.0969	0.0546
g=3	t=3	-0.0077	0.052	0.0755	0.0448	0.0292	0.0392	-0.0136	0.0432
Event study									
	e = -1	0.1196	0.0549	0.0379	0.0518	0.0708	0.0434	0.0969	0.0535
	e = 0	0.0261	0.037	0.1012	0.0354*	0.0309	0.0355	0.0118	0.0323
	e = 1	0.1094	0.0501	0.0936	0.0581	-0.0833	0.0912	0.0375	0.0607
	Overall	0.0678	0.0409	0.0974	0.0423*	-0.0262	0.0531	0.0247	0.0421
Event study with balanced group									
	e = 0	0.0392	0.0447	0.131	0.0475*	0.0414	0.0649	0.0363	0.0468
	e = 1	0.1094	0.0528	0.0936	0.054	-0.0833	0.0894	0.0375	0.0619
	Overall	0.0743	0.0417	0.1123	0.0481*	-0.021	0.0651	0.0369	0.05
Outcome		Food Consumption							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0158	0.0451	0.1202	0.0537	0.0681	0.0675	0.0067	0.0478
g=2	t=3	0.1164	0.0532	0.0991	0.06	-0.0735	0.0927	-0.0056	0.0571
g=3	t=2	0.086	0.062	-0.012	0.0467	0.0439	0.0464	0.0735	0.0593
g=3	t=3	0.0078	0.0567	0.111	0.0465	0.0337	0.046	-0.0058	0.0491
Event study									
	e = -1	0.086	0.0607	-0.012	0.0464	0.0439	0.0445	0.0735	0.0574
	e = 0	0.0135	0.0383	0.1152	0.0393*	0.0385	0.0408	0.0006	0.0371
	e = 1	0.1164	0.0543	0.0991	0.0619	-0.0735	0.0961	-0.0056	0.061
	Overall	0.065	0.0398	0.1072	0.0444*	-0.0175	0.0602	-0.0025	0.0399
Event study with balanced group									
	e = 0	0.0158	0.0466	0.1202	0.0539*	0.0681	0.069	0.0067	0.0495
	e = 1	0.1164	0.0548*	0.0991	0.0587	-0.0735	0.0916	-0.0056	0.0598
	Overall	0.0661	0.0439	0.1097	0.0493*	-0.0027	0.0678	0.0005	0.0458
Outcome		Non-food Consumption							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0657	0.0639	0.1036	0.0713	0.0219	0.0896	0.0757	0.0633
g=2	t=3	0.0752	0.0672	0.0636	0.0758	-0.054	0.133	0.0728	0.0825
g=3	t=2	0.1941	0.0808	0.1	0.0656	0.074	0.0606	0.0938	0.0826
g=3	t=3	0.0334	0.0708	0.0603	0.0543	0.0727	0.0509	0.0142	0.0591
Event study									
	e = -1	0.1941	0.0791*	0.1	0.0652	0.074	0.0594	0.0938	0.0787
	e = 0	0.0567	0.0488	0.0804	0.0451	0.0656	0.0481	0.0456	0.0473
	e = 1	0.0752	0.0621	0.0636	0.077	-0.054	0.1173	0.0728	0.0833
	Overall	0.0659	0.0532	0.072	0.0525	0.0058	0.0769	0.0592	0.0568
Event study with balanced group									
	e = 0	0.0657	0.0595	0.1036	0.0738	0.0219	0.0769	0.0757	0.0667
	e = 1	0.0752	0.0685	0.0636	0.0752	-0.054	0.1175	0.0728	0.0842
	Overall	0.0705	0.0567	0.0836	0.0645	-0.016	0.0856	0.0742	0.0655

Outcome		Basic Needs Poverty							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	-0.0496	0.0296	-0.0701	0.0316	-0.0138	0.0273	-0.0143	0.0173
g=2	t=3	-0.0589	0.0287	-0.0608	0.0352	-0.0091	0.0373	0.0011	0.0168
g=3	t=2	-0.0497	0.038	-0.0446	0.0307	-0.038	0.0259	-0.0292	0.0321
g=3	t=3	0.021	0.0283	-0.0084	0.0262	-0.012	0.0218	0.0004	0.0204
Event study									
	e = -1	-0.0497	0.0415	-0.0446	0.0332	-0.038	0.0263	-0.0292	0.0327
	e = 0	-0.0299	0.0201	-0.037	0.022	-0.0122	0.0196	-0.0071	0.0133
	e = 1	-0.0589	0.0254*	-0.0608	0.0368	-0.0091	0.0374	0.0011	0.0179
	Overall	-0.0444	0.0225*	-0.0489	0.0264	-0.0107	0.0241	-0.003	0.014
Event study with balanced group									
	e = 0	-0.0496	0.0261	-0.0701	0.0338	-0.0138	0.0269	-0.0143	0.0167
	e = 1	-0.0589	0.0288	-0.0608	0.0345	-0.0091	0.0399	0.0011	0.0174
	Overall	-0.0543	0.0231*	-0.0655	0.0333*	-0.0115	0.03	-0.0066	0.0159
Outcome		$1.9 poverty							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	-0.0457	0.042	-0.0247	0.0284	-0.0338	0.0231	-0.0572	0.0414
g=2	t=3	-0.0814	0.0433	-0.0671	0.0397	-0.0363	0.029	-0.0318	0.0399
g=3	t=2	-0.056	0.0368	-0.0329	0.0335	-0.0312	0.0407	0.0744	0.0533
g=3	t=3	-0.0496	0.0398	-0.0145	0.0339	0.0062	0.0323	-0.0546	0.045
Event study									
	e = -1	-0.056	0.0402	-0.0329	0.0348	-0.0312	0.0441	0.0744	0.0559
	e = 0	-0.0478	0.0259	-0.016	0.0306	-0.0142	0.0208	-0.0565	0.0314
	e = 1	-0.0814	0.0449	-0.0671	0.0391	-0.0363	0.028	-0.0318	0.0394
	Overall	-0.0646	0.0302*	-0.0415	0.03	-0.0253	0.0214	-0.0441	0.0311
Event study with balanced group									
	e = 0	-0.0457	0.0404	-0.0247	0.0276	-0.0338	0.0228	-0.0572	0.0373
	e = 1	-0.0814	0.0446	-0.0671	0.0419	-0.0363	0.0296	-0.0318	0.0422
	Overall	-0.0635	0.0391	-0.0459	0.0308	-0.0351	0.0233	-0.0445	0.0342
Outcome		$3.2 poverty							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	-0.0432	0.0418	-0.1254	0.0474*	-0.0772	0.0407	0.0652	0.021*
g=2	t=3	0.0331	0.0415	-0.0913	0.045	-0.0812	0.0386	0.0914	0.0283*
g=3	t=2	-0.0004	0.0391	-0.0708	0.0372	-0.0218	0.0419	0.0449	0.0285
g=3	t=3	-0.09	0.038	-0.0123	0.0369	0.0452	0.0403	-0.0323	0.0293
Event study									
	e = -1	-0.0004	0.0436	-0.0708	0.0387	-0.0218	0.0471	0.0449	0.0274
	e = 0	-0.0683	0.0278	-0.0281	0.0336	-0.0172	0.0307	0.0387	0.0172
	e = 1	0.0331	0.043	-0.0913	0.0496	-0.0812	0.044	0.0914	0.0306*
	Overall	-0.0176	0.0339	-0.0597	0.0308	-0.0492	0.0284	0.065	0.0204*
Event study with balanced group									
	e = 0	-0.0432	0.044	-0.1254	0.0516*	-0.0772	0.0407	0.0652	0.0232*
	e = 1	0.0331	0.0403	-0.0913	0.0474	-0.0812	0.041	0.0914	0.029*
	Overall	-0.0051	0.0375	-0.1084	0.0338*	-0.0792	0.0323*	0.0783	0.0211 *

Notes: The table reports aggregated treatment effect parameters under the conditional parallel trends assumptions following Callaway and Sant'Anna (2020). The 'Group-time average treatment effects' row reports the average treatment effect for group g at wave t, where a "group" is defined by the time period when units are first treated. The row 'Event study' reports average treatment effects by the length of exposure to 3G coverage increase; here, e indexes the length of exposure to the treatment. The row 'Event study with balanced groups' reports average treatment effects by length of exposure using a fixed set of groups at all lengths of exposure; here, e indexes the length of exposure and the sample consists of households that have at least one year of exposure to 3G coverage. The column 'Single parameter' represents a further aggregation of each type of parameter. All the estimates in this table use the doubly robust estimator. * indicates that the 95% confidence intervals do not cover zero.

Table A4: Results from Callaway Sant'Anna doubly robust estimation for labor outcomes

Outcome		Labor force participation							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0547	0.023	0.0769	0.0626	0.0199	0.0267	0.0079	0.0163
g=2	t=3	0.1007	0.0341*	0.096	0.0409	0.0627	0.0267	0.0445	0.0193
g=3	t=2	0.0523	0.0242	0.0631	0.0211*	0.0436	0.0235	0.0104	0.0205
g=3	t=3	-0.0186	0.0263	0.0232	0.0228	0.0624	0.022*	0.0665	0.0325
Event study									
	e = -1	0.0523	0.0241	0.0631	0.0222*	0.0436	0.0245	0.0104	0.0201
	e = 0	0.0166	0.0177	0.031	0.0219	0.0422	0.0167*	0.0238	0.0152
	e = 1	0.1007	0.0357*	0.096	0.0419	0.0627	0.0278	0.0445	0.0189
	Overall	0.0587	0.0247*	0.0635	0.0274*	0.0524	0.019*	0.0341	0.0149*
Event study with balanced group									
	e = 0	0.0547	0.0241*	0.0769	0.064	0.0199	0.0265	0.0079	0.0172
	e = 1	0.1007	0.0339*	0.096	0.0401*	0.0627	0.0277*	0.0445	0.0214
	Overall	0.0777	0.0272*	0.0865	0.0504	0.0413	0.0232	0.0262	0.016
Outcome		Wage Employment							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0079	0.0163		0.0195	0.0773	0.0317	-0.0165	0.0243
g=2	t=3	0.0445	0.0193	0.0317	0.0237	0.1663	0.0374*	0.0579	0.0237*
g=3	t=2	0.0104	0.0205	0.0171	0.0178	-0.0086	0.0189	-0.0234	0.016
g=3	t=3	0.0665	0.0325	0.0572	0.0228*	0.0721	0.0167*	0.0639	0.0184*
Event study									
	e = -1	0.0104	0.0201	0.0171	0.0191	-0.0086	0.0189	-0.0234	0.0177
	e = 0	0.0238	0.0152	0.0297	0.0157	0.0729	0.0164*	0.0257	0.0149
	e = 1	0.0445	0.0189	0.0317	0.0253	0.1663	0.0348*	0.0579	0.0233*
	Overall	0.0341	0.0149*	0.0307	0.0175	0.1196	0.0206*	0.0418	0.0162*
Event study with balanced group									
	e = 0	0.0079	0.0172		0.0191	0.0773	0.0298*	-0.0165	0.0243
	e = 1	0.0445	0.0214	0.0317	0.0242	0.1663	0.0367*	0.0579	0.0237*
	Overall	0.0262	0.016	0.0159	0.0175	0.1218	0.0251*	0.0207	0.0218
Outcome		Self-employed Non-farm							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0032	0.0175	0.0443	0.0206	-0.0205	0.0415	-0.0288	0.0266
g=2	t=3	-0.016	0.0214	-0.008	0.0259	-0.0362	0.0449	-0.0193	0.028
g=3	t=2	-0.0317	0.0215	-0.0453	0.0196	-0.0101	0.0197	0.0291	0.0186
g=3	t=3	0.0406	0.026	0.05	0.0238	0.0141	0.0211	-0.0004	0.0247
Event study									
	e = -1	-0.0317	0.0234	-0.0453	0.0194*	-0.0101	0.0176	0.0291	0.0201
	e = 0	0.0134	0.0152	0.0473	0.0165*	0.009	0.0196	-0.0139	0.0167
	e = 1	-0.016	0.0236	-0.008	0.0292	-0.0362	0.0412	-0.0193	0.0282
	Overall	-0.0013	0.0144	0.0197	0.0175	-0.0136	0.026	-0.0166	0.0186
Event study with balanced group									
	e = 0	0.0032	0.0181	0.0443	0.0199*	-0.0205	0.0369	-0.0288	0.0258
	e = 1	-0.016	0.0232	-0.008	0.0268	-0.0362	0.046	-0.0193	0.026
	Overall	-0.0064	0.016	0.0182	0.0189	-0.0284	0.034	-0.0241	0.0231

Outcome		Self-employed Farm							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	-0.0288	0.024	-0.0341	0.0214	-0.1104	0.0429*	-0.0639	0.0245*
g=2	t=3	0.022	0.0306	0.0123	0.0328	-0.0227	0.0478	0.0097	0.0249
g=3	t=2	0.0098	0.036	0.0034	0.0301	-0.0324	0.0247	-0.0402	0.0214
g=3	t=3	-0.1251	0.0317*	-0.0486	0.0263	-0.0134	0.02	-0.0139	0.0186
Event study									
	e = -1	0.0098	0.0374	0.0034	0.0313	-0.0324	0.0233	-0.0402	0.0222
	e = 0	-0.055	0.0216*	-0.0416	0.018	-0.0275	0.0181	-0.0377	0.0145*
	e = 1	0.022	0.0293	0.0123	0.0328	-0.0227	0.0493	0.0097	0.0249
	Overall	-0.0165	0.0223	-0.0147	0.0214	-0.0251	0.0283	-0.014	0.0162
Event study with balanced group									
	e = 0	-0.0288	0.0245	-0.0341	0.0208	-0.1104	0.0432*	-0.0639	0.0247*
	e = 1	0.022	0.0279	0.0123	0.0296	-0.0227	0.0501	0.0097	0.026
	Overall	-0.0034	0.0238	-0.0109	0.024	-0.0665	0.0403	-0.0271	0.0175
Outcome		Other Employment							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.064	0.0194*	0.031	0.0158	0.1192	0.0345*	0.1101	0.0208*
g=2	t=3	0.0246	0.018	0.0435	0.018*	0.0148	0.0222	0.0167	0.0161
g=3	t=2	0.0128	0.0207	0.0546	0.0242	0.0714	0.018*	0.0365	0.0171
g=3	t=3	-0.0133	0.0229	-0.073	0.0201*	-0.0461	0.0179*	0.0059	0.0182
Event study									
	e = -1	0.0128	0.0206	0.0546	0.0255	0.0714	0.0175*	0.0365	0.0152*
	e = 0	0.043	0.0162*	-0.023	0.0156	-0.022	0.0169	0.0554	0.0142*
	e = 1	0.0246	0.0173	0.0435	0.017*	0.0148	0.024	0.0167	0.0161
	Overall	0.0338	0.0157*	0.0103	0.0135	-0.0036	0.0142	0.0361	0.0119*
Event study with balanced group									
	e = 0	0.064	0.019*	0.031	0.0154	0.1192	0.0372*	0.1101	0.0215*
	e = 1	0.0246	0.018	0.0435	0.0161*	0.0148	0.0239	0.0167	0.0162
	Overall	0.0443	0.0154*	0.0372	0.0125*	0.067	0.0273*	0.0634	0.0147*
Outcome		Number of Employments							
Treatment		3G coverage		≥ 1 year		≥ 2 years		≥ 3 years	
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
Group-time average treatment effects									
g=2	t=2	0.0463	0.0273	0.0412	0.0299	0.0656	0.0577	0.0009	0.0321
g=2	t=3	0.0751	0.0306*	0.0795	0.0417	0.1222	0.0576	0.065	0.0375
g=3	t=2	0.0013	0.0406	0.0298	0.0303	0.0203	0.0277	0.002	0.0306
g=3	t=3	-0.0313	0.0427	-0.0143	0.032	0.0267	0.0279	0.0555	0.0283
Event study									
	e = -1	0.0013	0.0407	0.0298	0.0324	0.0203	0.0299	0.002	0.033
	e = 0	0.0252	0.0232	0.0124	0.0225	0.0324	0.0258	0.0295	0.0201
	e = 1	0.0751	0.0327*	0.0795	0.0405	0.1222	0.0599	0.065	0.0389
	Overall	0.0501	0.0238*	0.0459	0.028	0.0773	0.0371*	0.0473	0.0261
Event study with balanced group									
	e = 0	0.0463	0.0275	0.0412	0.0298	0.0656	0.0571	0.0009	0.0323
	e = 1	0.0751	0.0326*	0.0795	0.0406	0.1222	0.061	0.065	0.0377
	Overall	0.0607	0.0265*	0.0604	0.0311	0.0939	0.051	0.0329	0.0303

Notes: The table reports aggregated treatment effect parameters under the conditional parallel trends assumptions following Callaway and Sant'Anna (2020). The 'Group-time average treatment effects' row reports the average treatment effect for group g at wave t, where a "group" is defined by the time period when units are first treated. The row 'Event study' reports average treatment effects by the length of exposure to 3G coverage increase; here, e indexes the length of exposure to the treatment. The row 'Event study with balanced groups' reports average treatment effects by length of exposure using a fixed set of groups at all lengths of exposure; here, e indexes the length of exposure and the sample consists of households that have at least one year of exposure to 3G coverage. The column 'Single parameter' represents a further aggregation of each type of parameter. All the estimates in this table use the doubly robust estimator. * indicates that the 95% confidence intervals do not cover zero.