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THE EMPLOYMENT EFFECTS OF MOBILE INTERNET IN DEVELOPING COUNTRIES

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ABSTRACT

We examine the employment effects of 3G mobile internet expansion in developing countries. We find that 3G significantly increases the labor force participation rate of women and the employment rates of both men and women. Our results suggest that 3G affects the type of jobs and there is a distinct gender dimension to these effects. Men transition away from unpaid agricultural work into operating small agricultural enterprises, while women take more unpaid jobs, especially in agriculture, and operate more small businesses in all sectors. Both men and women are more likely to work in wage jobs in the service sector.

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1 Introduction

Information and Communications Technology (ICT) is considered a great promise for low- and middle-income countries (LMICs), and is at the forefront of economic policy and development efforts. Many see it as a unique opportunity for these countries to connect their citizens to services and jobs and accelerate growth (World Bank, 2016). Access to the internet in particular can affect economic well-being in multiple, potentially inter-related ways by reducing information frictions, lowering search and transaction costs, and expanding opportunities for both businesses and consumers. Policy makers across the world see the potential to use internet-based technologies to jump-start a process of structural transformation in their countries, foster the growth of the service sector, and possibly spearhead a "leap-frogging" of their economies from traditional agriculture to modern services. Evidence on the extent to which this promise has materialized is limited.

Hjort and Poulsen (2019), study the arrival of fixed high-speed broadband internet across African countries and find substantial gains in employment rates, especially for high-skilled workers, and an increase in average incomes.[1] However, data from the International Telecommunications Union (ITU) shows very low rates of fixed broadband internet adoption in LMICs. As shown in Figure 1, the number of fixed broadband internet subscriptions increased from 1.3 to 13 per 100 people between 2005-21. In the same time period, the number of active mobile broadband internet subscriptions however, increased from just under 1 to 74 per 100 people.[2]

Given the much broader availability and adoption of mobile internet in LMICs, our paper focuses on examining the employment impacts of expansion in 3G network coverage in these countries. Compared to 2G networks (that allow access to a basic cellphone network and texts)[3], 3G networks were the first generation of telecommunications technology that allowed

[1] Bhuller et al. (2021) examine the expansion of broadband in a high-income country, Norway, and find evidence for increased job finding rates and starting wages, but not for job-to-job mobility or wage growth.

[2] This is consistent with the rapid increase in the number of mobile cellular subscribers in LMICs over the last two decades from 4.1 to 105.7 per 100 people (World Bank, 2021).

[3] There is a large literature examining the effects of 2G adoption on price dispersion (Jensen, 2007; Aker, 2010), learning (Aker et al., 2012), and mobile money (Jack and Suri, 2014, 2016); see Aker and Mbiti (2010) for a review.

users to access most features of the internet, including social media and websites. The effects of 3G internet have been examined in the context of political mobilization (Guriev, Melnikov and Zhuravskaya, 2021; Zhuravskaya, Petrova and Enikolopov, 2020). There is a nascent literature focusing on the economic impacts of 3G, but almost all of this work focuses on a few individual countries in Africa, and on outcomes other than employment.[4] In contrast, in this paper we provide evidence on the employment effects of 3G across multiple countries at different stages of economic development.[5]

There are three key challenges to identifying the causal effects of 3G internet on economic outcomes. First is the lack of reliable data across multiple low-income countries and over time. To overcome this challenge, we utilize data from IPUMS International (2020), which collates nationally representative surveys and censuses across multiple countries and over time, and harmonizes variables across them. Given the limitations of 3G data (discussed below), our final sample consists of 14 countries that span several stages of development and account for over a billion people worldwide (see Table C3). We use these data to construct measures of economic outcomes (such as labor force participation rates, employment choices, etc.) for sub-national regions (e.g., municipalities, districts, counties) within a country for the year in which the survey was implemented.

A second key challenge is the availability of comprehensive data on the expansion of 3G coverage at a local (sub-national) level across countries and over time. To deal with this issue we use maps for 3G network coverage from 2006-2015 collected by Collins Bartholomew Mobile Coverage Explorer. These maps are generated from submissions by mobile network operators around the world, who are members of the GSM Association. They consist of 1×1 km binary grid cells that take the value 1 if the cell has 3G coverage and 0 otherwise. We calculate a population-weighted measure of 3G coverage in each sub-national region and year, which we then combine with the IPUMS data.

[4]See Bahia et al. (2020, 2022); Masaki et al. (2020); Mensah et al. (2022); Viollaz and Winkler (2022).

[5]Mensah (2021) and Adema et al. (2022) also consider multiple countries, but the former focuses on nightlights rather than employment and the latter examines the desire to emigrate.

Lastly, the endogenous expansion of 3G networks poses a challenge to the identification of causal impacts. To address this concern, we employ an instrumental variable strategy that relies on the slower expansion of 3G networks in regions with a higher frequency of lightning strikes per square kilometer (Manacorda and Tesei, 2020; Guriev et al., 2021; Mensah, 2021). The identification strategy is based on the idea that equipment needed for mobile phone infrastructure is particularly sensitive to electrical surges caused by frequent lightning strikes, thus increasing expected costs and slowing the expansion of 3G internet (which we confirm in Figure A1 and in our first-stage regression reported in Table A1).[6] All regression specifications control for the extent of 2G coverage in a region and year. This control allows us to measure the impact of access to mobile *internet* – as opposed to cellphones more generally – and also proxies for unobservable factors (assessment of growth prospects, for example) that could affect the provision of cellphone networks in a region. Using this identification strategy, we examine the impact of 3G network expansion on employment outcomes in several sub-national regions. We are particularly interested in assessing whether 3G network adoption jump-started a process of structural transformation and delivered on the promise of "leap-frogging"– by tilting employment away from agriculture towards manufacturing and services.

Our results indicate a substantial increase of the labor force participation rate of women (FLFPR) in regions that adopt 3G. On average, for the countries in our sample, a 10 pp increase in 3G coverage increases FLFPR by 4.9 pp. This is a significant increase given that the average labor force participation rate of women is very low in developing countries (only 39 percent in the countries in our sample compared to over 80 percent for men). We also find that conditional on labor force participation, 3G coverage increased employment rates of both men and women. Hence, the first message of our analysis is that 3G has had meaningful, positive effects on the employment opportunities of both men and women.

Examining the type of jobs and sector of employment, the effects are more nuanced. We find no evidence of structural transformation, in the sense of sectoral reallocation of labor away

[6] Lightning is also correlated with rainfall, elevation and provision of 2G coverage, which could in turn affect the outcomes of interest. Therefore, we measure and control for these factors directly in our regressions. We discuss our empirical strategy in greater detail in Section 3.

from agriculture towards manufacturing and services in the aggregate. If anything, 3G expansion created additional jobs in agriculture as well as services. However, the evidence suggests that 3G coverage affected the *type* of jobs, with the effects being gender-specific. Specifically, men were more likely to substitute away from unpaid agricultural and service jobs (this is primarily unpaid family work) into self-employment, and specifically into operating small, owner-owned enterprises (OAEs) in agriculture. They were also more likely to transition to wage jobs in the manufacturing and service sectors. On the other hand, access to 3G resulted in more women taking unpaid jobs (presumably those vacated by men who transitioned out). We also see an increase in female-owned OAEs in agriculture and services, as well as in service sector wage employment. The second message of our analysis is therefore that expansion of 3G networks affected the type of jobs rather than the sector of employment of individuals, and that these effects were gender-specific. These results are robust to accounting for potential spatial spillovers as we show in Section 4.7.

Overall, our analysis suggests that the expansion of 3G networks has had strong, positive employment effects, particularly for women. However, these effects seem more consistent with the rise of a "gig-economy" than with the textbook case of structural transformation from agriculture to manufacturing and services. We discuss possible interpretations of these findings in Section 4.6 of the paper. Given that we do not observe wages or hours worked, we cannot assess how 3G ultimately affected welfare. Accordingly, we view this study as a first step in an endeavor of studying the effects of ICT on economic development.

2 Data

2.1 IPUMS Data

We use data from IPUMS International (2020) to measure employment effects. IPUMS collates census and large nationally representative sample survey data and makes it comparable across countries and over time. Importantly for this paper, all classifications related to labor force participation, the type of work, and industry of employment have been harmonized across countries and over time. Our final sample (see Table C3) consists of 14 developing countries (33 country-years). It covers over a billion people across the developing world and countries at different stages of economic development.

We restrict our sample to individuals between 18-65 years of age. The IPUMS collects information on whether an individual is working in the labor force, whether he/she is employed, and, conditional on employment, whether he/she is self-employed, a wage earner, or works in an unpaid job (see Table C1 for examples). Furthermore, for the self-employed, the IPUMS distinguishes between individuals who operate "Own-Account Enterprises" (OAE), i.e., small businesses where the business owners do not hire any workers, and "Employers," i.e., individuals who operate businesses with multiple employees. Conditional on working, the IPUMS also reports the industry of work. We follow Duernecker et al. (2016); Herrendorf and Schoellman (2018) to classify industries into agriculture, manufacturing and services (see Table C2). There is limited information on the number of hours worked and income earned by these individuals. Accordingly, we focus on employment outcomes in this paper.

2.2 Data on 2G and 3G Coverage

We use maps for 2G and 3G network coverage from 2006-2017 collected by Collins Bartholomew's Mobile Coverage Explorer. These maps are generated from submissions by mobile operators who are members of the GSM Association. The data consists of 1×1 km binary grid cells that take the value 1 if that cell has 2G (or 3G) network coverage and 0 otherwise.[7] The IPUMS data provide geographical locations up to Level 2 Administrative Units or sub-national regions, which we henceforth label as "regions". To combine the mobile network data with the IPUMS regions, we follow Guriev, Melnikov and Zhuravskaya (2021) to construct 2G and 3G coverage for each region and year as the total coverage across all grid cells in each region's

[7] If a grid is covered by 4G it would also have 3G coverage by our definition.

polygon weighted by the population density in each grid cell.[8] Appendix C.2 provides a detailed explanation of the mobile internet data along with the construction of these variables.

2.3 Geographic Data

We obtain data on lightning from NASA's Global Hydrology Resource Center as part of its LRM Time Series using the TRMM satellite (Cecil, 2006; Cecil et al., 2014). This data is available at a 1×1 km resolution covering 2000-2014.[9] As with the 3G data, we generate a population-weighted average number of lightning strikes per square km in a region and year. Since lightning data is correlated with precipitation, which can impact our main outcome variables, we collect precipitation data from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data archive (Funk et al., 2014) to construct the total (population-weighted) precipitation in a region and year. Lastly, we collect elevation data from the ETOPO1 data (Center., 2009) to calculate the average elevation of a region. We provide additional details in Appendix Section C.3.

2.4 Sample Description

Table C3 provides details on the sample of regions we use in our analysis. The country-year observations are listed in Columns 1 and 2 of the table. While they do not capture the entire world, the included countries cover the full spectrum of economic development (Column 3), ranging from low-income countries (Rwanda, Uganda etc.), to lower-middle income countries (Indonesia, Bolivia, Philippines, etc.), to upper-middle income countries (Brazil, Mexico, etc.). Put together, they cover over a billion people worldwide, and over 600 million individuals in the working age population (Columns 4 and 5).

[8]The population weights are normalized to sum up to 1 for each region. We obtain the population data from the World Pop Data https://www.worldpop.org/geodata/listing?id=77. As an example, Figure C1 shows the regional 3G coverage for regions in our sample in 2009 and 2015. See Guriev et al. (2021) and Manacorda and Tesei (2020) for a detailed discussion of the construction and quality of these data.

[9]Due to the life span of the TRMM satellite, the data ends in mid-2014.

As reported in Column 6 of Table C3, across all countries in our sample, we have a total of around 7,000 sub-national regions (districts, counties, municipalities) and over 18,000 region-years. However, as we discuss in the next section, our empirical analysis (and hence the final sample) is restricted by the availability of data from all three sources: (i) outcome variables from the IPUMS; (ii) data on regional 2G and 3G coverage; (iii) data on geographical variables (especially lightning). As reported in Column 9, 87 percent of regions have complete data on all variables used in our analysis. In our preferred specification, we restrict the sample to those regions where we observe all variables. Subsequently, we show that our results are robust to removing this restriction. Our final sample consists of 6802 regions and 16,069 region-years.

Lastly, as discussed above, data on 3G coverage is only available after 2006, but our sample runs from 2000 to 2015. We use data from ITU (2021) to measure the year in which a country adopted 3G. For all countries in our sample, this year is between 2007-2010 (with the exception of Iran). We therefore set regional 3G coverage to be equal to 0 in a region prior to 2006, or prior to the year in which 3G was adopted in that country.

3 Empirical Specification

For each region r and year t, we construct measures of employment outcomes that are defined as the fraction of individuals in rt who report that outcome (for example, participate in the labor force, be self-employed, wage-earner, etc.). We calculate these measures separately for men and women in each rt, as well as within each sector (agriculture, manufacturing and services).[10] We estimate the following regression specification:

$$Y_{rt} = \alpha_r + \alpha_t + \beta \text{3G Coverage}_{rt} + \delta X_{rt} + \varepsilon_{rt} \tag{1}$$

where Y_{rt} denotes the primary outcome of interest (labor force participation rate, employment rate, type of employment, etc.). α_r are region fixed effects that control for all observable and

[10] We use population weights provided for aggregation to the rt level.

unobservable characteristics of a region that are time-invariant, while year fixed effects (α_t) take into account changes across all regions over time. X_{rt} is a vector of geographic controls (such as precipitation) that may affect the provision of 3G coverage in these areas as well as the outcomes of interest. These controls are important in the context of our Instrumental Variables strategy that we discuss next. Lastly, to isolate the effect of 3G coverage as opposed to general improvements in cellphone coverage, we also control for a region's 2G coverage in year t.

Identification: A natural concern with interpreting the coefficient of interest ($\hat{\beta}$) in Equation (1) as the causal impact of 3G is reverse causality: 3G is more likely to be introduced in areas that are developed or show promise for development. Furthermore, there could be omitted variables that drive the expansion of 3G coverage in a region and are also correlated with the outcomes of interest. We address these concerns as follows.

First, all our specifications include region fixed effects that account for all time-invariant differences across regions that affect the outcome variables. In addition, we control for the provision of regional 2G coverage in each year. This allows us to isolate the impact of 3G over and above general cellphone coverage. Furthermore, the 2G variable indirectly controls for other unobservable factors that may have affected the provision of mobile networks in a region, such as the region's economic development prospects.

Second, we employ an instrumental variables strategy that has been previously utilized in a different context: we use the (population-weighted) frequency of lightning strikes per square kilometer in a region r in year t to instrument for 3G coverage in a region (Manacorda and Tesei, 2020; Guriev et al., 2021). The argument follows from the fact that the equipment needed for mobile phone infrastructure is particularly sensitive to electrical surges due to frequent lightning strikes and is expensive to repair if damaged. Moreover, lightning severely interferes with the quality of radio wave transmissions, which affects the quality of reception. These factors make it less likely that 3G is installed in regions with a high frequency of lightning strikes. To examine this proposition, we calculate the average number of lightning strikes in a region between 2000-2014 and create a binary variable $1\{\text{Above Med. Lightning}_r\}$ that takes the value 1 if the region has an above-median number of lightning strikes and 0 otherwise. As is clear from Figure A1, 3G coverage is lower in regions with high (above-median) lightning strikes than in regions with lower strikes. We formalize this argument by estimating the following first-stage regression:

$$\text{3G Coverage}_{rt} = \alpha_r + \alpha_t + \gamma 1\{\text{Above Med. Lightning}_r\} \times t + \delta X_{rt} + \nu_{rt} \tag{2}$$

where the fixed effects (α_r and α_t) and the vector of control variables (X_{rt}) are the same as those described earlier for Equation (1). A potential threat to identification is that lightning is also correlated with rainfall, elevation and provision of 2G coverage, which could in turn affect the employment outcomes of interest. However, as noted earlier, we control for all these factors directly in our regression. Therefore, our identification relies on the assumption that conditional on the covariates and fixed effects, the frequency of lightning strikes affects employment outcomes only through its effects on the adoption of 3G. We estimate a robust and strongly negative first-stage relationship reported in Table A1.

4 Results

The data allows us to examine many different aspects of employment, such as the fraction of individuals in a region who are employer-entrepreneurs, i.e., own a firm and hire at least one worker, owner-operated entrepreneurs, i.e., own a firm but do not hire any workers, employed as workers in a wage job, or employed as unpaid workers (very common in agriculture and low-skilled services across countries in our sample). Moreover, since we observe the industry of work (with the exception of Armenia in 2001 and Uganda in 2014), we can examine how these outcomes vary across agriculture, manufacturing and services. Finally, we investigate whether 3G coverage has contributed to reallocation of labor from agriculture to manufacturing and services, as models of structural transformation would suggest.

The main results are presented in Tables 2 and 3, which are structured as follows. For each outcome variable Y_{rt}, we construct the fraction of individuals in a region r and year t who have this outcome. For example, Columns 1-2 of Table 2 examine the fraction of individuals in a region who participate in the labor force (LFP rate); Columns 3-4 focus on employment rate, and so on. The odd numbered columns report the OLS results from Equation (1), while the even numbered columns report the corresponding two-stage least squares instrumental variable (IV) estimates. Our discussion focuses on the IV results, but we report the OLS estimates for comparison. Panel A estimates the specifications (OLS and IV) for the entire sample, while Panels B and C restrict the sample to men and women respectively to examine differences across gender. To interpret the magnitudes of the coefficients, we report the corresponding sample averages for each outcome variable in Columns 2-4 of Table 1. Finally, to account for the large number of outcome variables (and hence hypotheses we are testing), we calculate both the conventional p-values and corresponding "q-values" for statistical inference. This q-value (Benjamini et al., 2006; Anderson, 2008) adjusts the conventional p-value for false detection rates when testing for multiple hypotheses.

4.1 LFP and Employment Rates

We first examine the impact of regional 3G coverage on labor force participation (LFP) and employment rates. Table 1 reports the averages of these variables across our sample before the adoption of 3G internet in the country. According to Columns 2-4 of Panel A, labor force participation rates are around 60 percent in our sample. However, as is well documented in the literature, there is a stark difference between LFP rates for men (84 percent) and women (39 percent). Moreover, conditional on participating in the labor force (Columns 5-7), women are more likely to be unemployed (14 percent) compared to men (9 percent).

How does the provision of 3G coverage impact LFP and employment rates? From Column 2 in Panel A of Table 2, we see that areas with 10 pp higher 3G coverage have 2.8 pp higher labor force participation rates on average.[11] However, as a comparison of Panels B and C reveals,

[11]From Table 1, the average regional 3G coverage in our sample is 46 percent (median is 43 percent); a 10 pp

this effect is entirely driven by women (4.9 pp) as opposed to men, for whom the magnitude is negative (-1.7 pp) but statistically insignificant from zero at conventional levels. This is unsurprising given that the LFP rate for men exceeds 80 percent, whereas it is only 39 percent for women (see Table 1). [12] Turning to Column 4, we see from Panel A that a 10 pp increase in 3G coverage increases the fraction of individuals who are employed by 2.1 pp. From Panels B and C, these effects range from 3.1 pp for men to 1.3 pp for women.

In Columns 5-12 of Table 2, we break down employment across various categories, i.e., self-employment, wage-employment, and unpaid work. Since the data reports the sectors in which individuals are employed (agriculture, manufacturing and services), we further examine whether the employment effects are driven by specific sectors. These results are reported in Tables A2-A4 of the Appendix.

4.2 Impact on Self-Employment

Our data allows us to examine two types of self-employment, "Employer Entrepreneurs," i.e., individuals who operate businesses that employ other workers, and "Own-Account Entrepreneurs" (or OAEs), i.e., individuals who operate small businesses that are self-owned and do not hire any other workers. Columns 5-7 of Table 1 show that, conditional on participating in the labor force, on average 39 percent of men and 24 percent of women in a region are self-employed. However, conditional on self-employment, the overwhelming proportion of them (around 90 percent) operate OAEs. Only a small fraction or men and women are employers. Furthermore, from Panels B-D in the same table, almost all OAEs (both men- and women-owned) are concentrated in agriculture and services. Specifically, around 60 percent of male-owned OAEs are in agriculture, followed by a third in services, and the rest in manufac-

higher 3G coverage therefore corresponds to a 20-25 percent increase in regional 3G coverage on average. The sample size is smaller in Columns 1 and 2 since some labor force surveys ask about the employment status of an individual, but conditional on not working, they do not distinguish between "inactive" and "unemployed"–an important distinction when measuring labor force participation.

[12]Our results on female LFP are in line with those reported in Viollaz and Winkler (2022) and Bahia et al (2020) for Jordan and Nigeria respectively - two countries that are not included in our sample; however, they differ from Bahia et al (2022) who find no effect on female LFP in Tanzania - a country that is also missing from our sample.

turing. On the other hand, half the women-owned OAEs are in services, followed by around 40 percent in agriculture, and the rest in manufacturing.

Employers: Regional 3G coverage has a non-trivial impact on self-employment. However, the impact on employers is small. From Column 6 of Panel A in Table 2, a 10 pp increase in 3G coverage decreases the probability of being an employer by around 0.1-0.2 pp (for both men and women). Given that only a small fraction of individuals (3 percent on average) are employers (see Table 1), 3G coverage does not appear to have an economically significant impact on employer entrepreneurship.

Own-Account Entrepreneurs: In contrast, the effect on OAEs, which account for the overwhelming majority of the self-employed in our sample, is large. A 10 pp increase in 3G coverage increases the probability of operating an OAE by 2.2 pp (Column 8, Panel A of Table 2). Panels B and C of the same table reveal that men are more likely to operate OAEs (3.7 pp) than women (0.9 pp). As discussed earlier, the composition of OAEs varies across sectors with most of male-owned OAEs in agriculture and most female-owned OAEs in services. From Column 4 of Panel B in Tables A2-A4, we see that a majority of this increase in male-owned OAEs continues to be in the agriculture sector (3.8 pp), while changes in manufacturing and services are negligible. On the other hand, the increase in female-owned OAEs is spread across agriculture (0.3 pp), services (0.2 pp) and manufacturing (0.16 pp) (Panel C in these tables).

4.3 Wage Employment

We next examine the impact on wage employment. From Columns 5-7 of Table 1, conditional on participating in the labor force, over 40 percent of individuals (both men and women) are wage earners.[13] From Panels B-D, we see that conditional on having a wage job, over half of

[13] Note that since the IPUMS collates data from nationally representative labor force surveys as well as decadal censuses, it captures wage employment not only in formal sector jobs, but also in the informal sector.

the men (53 percent) work in services, followed by around 30 percent in agriculture, and the rest in manufacturing. In contrast, 75 percent of women have wage jobs in the service sector, followed by manufacturing (14 percent) and agriculture (9.3 percent). To examine how 3G coverage impacts wage employment, we turn to Column 10 of Table 2. A 10 pp increase in 3G coverage increases the fraction of wage employed individuals by 0.7 pp (Panel A). However, this is driven entirely by men (Panel B) as opposed to women (Panel C). Examining specific sectors, we see that both men and women are 2 pp and 0.55 pp more likely to get wage jobs in the services sector, where the majority of them work (Column 6, Panels B and C in Table A4). We do not find any impact of 3G coverage on agricultural wage jobs (Column 6, Panels B and C in Table A2). The estimated magnitudes are small and statistically insignificant at conventional levels. Lastly, men are slightly more likely (0.2 pp) and women slightly less likely (0.4 pp) to work in manufacturing wage jobs (Column 6 in Table A3).

4.4 Unpaid Work

From Table 1, conditional on participating in the labor force, 8 percent of men and 17 percent of women provide unpaid work. An overwhelming proportion of these unpaid jobs are concentrated in agriculture (87.5 percent for men and 82 percent for women), with some unpaid work in services (especially for women). The fraction of individuals working in unpaid jobs is 0.86 pp lower in areas with a 10 pp higher 3G coverage (Column 12 of Table 2). However this figure masks heterogeneity by gender, as shown in Panels B and C of Column 12 in Table 2: men are significantly *less* likely to work in unpaid jobs (by 2.4 pp), while women are *more* likely to work in them (by 0.6 pp).

Since most men and women work in unpaid agricultural jobs, it is not surprising that these changes are driven by the agricultural sector. As Column 8 of Tables A2-A4 show, the entire decline of unpaid work for men (Panel B) is driven by agriculture (Table A2), as opposed to manufacturing (Table A3) or services (Table A4). Similarly, from Panel C in the same set of tables, the increase in unpaid work for women is primarily concentrated in agriculture.

4.5 Sectoral Reallocation

In Table 3, we examine whether 3G coverage led to sectoral reallocation of labor away from agriculture and towards manufacturing or services. The results in Panel A referring to the whole sample indicate that the share of labor employed in agriculture and services increased slightly (0.6-0.9 pp), while the estimate for manufacturing is small and statistically insignificant. A breakdown of the results by gender in Panels B and C shows a similar pattern. Based on these results, there does not seem to be any strong evidence of major sectoral reallocation. Combined with the previous results from Tables 2, our analysis suggests that access to mobile internet affects the type of jobs (i.e., self-, vs. wage-, vs. unpaid employment) rather than the sector of employment.

4.6 Discussion

Many had hoped that ICT, enabled by fast internet, would allow people in LMICs to connect to better jobs and "leapfrog" from traditional sectors (i.e., agriculture) to the modern economy (dominated by services). Our results from studying the expansion of mobile internet do not support this structural transformation hypothesis. However, we do document significant, positive employment effects as a result of 3G expansion in both agriculture and services. Higher 3G coverage meaningfully increases female labor force participation rates and lowers the probability of remaining unemployed for both men and women. However, the changes in employment patterns are distinctly different for men and women. Men transition out of unpaid agricultural and service jobs into operating small agricultural OAEs or wage jobs in services. On the other hand, employed women either work in the unpaid jobs vacated by men, operate small OAEs in all sectors, or (like the men) are wage employed in the service sector.

Hence, to a certain extent, our results support the optimistic assessment of ICT as 3G coverage has led to better employment opportunities for individuals. However, the largest gains seem to be in agriculture and services. This presents an interesting conundrum related to the debate on whether mobile technologies can accelerate "structural transformation" (in the sense of labor moving away from agriculture towards more modern sectors). Overall, it seems that 3G coverage has affected the type of employment more than the sector of employment.

This pattern is more consistent with the rise of a type of "gig-economy" in developing countries than the textbook version of structural transformation. Indeed, lower communications and transactions costs associated with access to the internet are likely to have enabled individuals to become self-employed. We note that most of the businesses they start are small (owned and operated by a single individual) rather than enterprises with multiple employees. As noted earlier, most of them are found in agriculture. It is interesting to note that this pattern is most pronounced for men; while self-employment increases for women too, many women seem to enter the labor force to take the unpaid jobs vacated by men.

Overall, the effects of 3G on employment, while positive, are smaller and more nuanced than the effects documented by Hjort and Poulsen (2019) in the context of fixed broadband. This is not surprising given the differences between wired and mobile internet. Hjort and Poulsen (2019) attribute the large employment and income effects they find to entry of new firms, higher firm productivity and a rise in exports that collectively created new job opportunities in the treated areas. While our data do not include information on firms or exports, it is unlikely that 3G would have induced new firm entry or expansion to export markets given that is has substantially lower bandwidth than fixed broadband.[14] The more likely scenario is that access to 3G internet allowed individuals to connect and transact with each other by reducing information, search and transaction costs at a small scale. The increase in single-owned OAEs (but not larger businesses with multiple employees) is consistent with this pattern. Along the same lines, the increased connectivity afforded by the internet may have allowed more women to combine work and family, enter the labor force, and operate small businesses that tend to be associated with more flexible work arrangements. However, we do note that there is a non-negligible increase of women working in the unpaid jobs left by men.

[14] 5G coverage may have larger effects owing to better bandwidths, but 5G coverage is very limited even across most developed countries today.

4.7 Robustness

We undertake a series of further analyses to examine the robustness of our results to alternative specifications, data structures, and sample definitions. We describe them briefly here and relegate a more detailed discussion to Appendix B.

First, in Section B.1, we adopt a different estimation approach. While our main analysis exploits the panel structure of the data, we also estimate a specification based on an ANCOVA structure (McKenzie, 2012). The key tradeoff is that while we can no longer control for region fixed effects, we can now control for "baseline" pre-intervention (before 2009) values of the outcome variables along with a rich set of state and region characteristics, which proxy (among other things) for pre-trends in these regions that might have affected the expansion of 3G networks (for example, if telecom operators had based 3G expansion on such characteristics). The ANCOVA structure also allows us to flexibly incorporate changes to the surveys over time (recall periods, measurement of outcomes, etc.). From Tables B1 and B2, we see that our qualitative insights (with some minor exceptions that are discussed in the corresponding Appendix section) remain unchanged.

Second, in Section B.2, we examine the possibility of spatial spillovers of 3G across neighboring regions. Given the limitations of our data in capturing movement of people and resources, we adopt a strategy similar to Hjort and Poulsen (2019): we aggregate adjacent regions and re-estimate our specifications for these more aggregated regions. The results show no change in the qualitative results, with similar quantitative magnitudes in most cases (Table B3).

Third, in Section B.3, we conduct a placebo test and show that future values of 3G coverage in a region have no correlation with current employment outcomes in the region (Table B4).

Lastly, our sample is constrained by the availability of all outcome variables across regions (see Section 2.4). In Section B.4, we show that our results are unaffected if we ignore this restriction (Table B5).

5 Conclusion

This study set out to investigate the employment effects of 3G adoption in developing countries. Consistent with the widespread optimism around this technology, we document a significant increase in female labor participation rates and positive employment effects for both men and women. However, the results do not suggest any sectoral reallocation – employment opportunities are generated in both agriculture and services. The primary effect of 3G coverage seems to be moving individuals into self-employment (and in particular, small owner-operated businesses), along with wage jobs in the service sector. For women, the likelihood of doing unpaid work increases. These patterns are consistent with the emergence of a gig-economy enabled through lower information, communications and transactions costs.

Our work suggests several directions for further research. First, as we pointed out earlier, our data do not allow us to assess the impact of 3G on wages, incomes, quality of work, etc. in order to provide a comprehensive assessment of the impact of 3G internet on welfare. Richer, country-specific data sets such as time use surveys may enable us to shed light onto these issues and to study mechanisms driving the effects we document. Second, our framework is static in nature; while our analysis captures the short- and medium-run effects of internet access on jobs, it does not allow us to assess whether the changes we document are a first step towards a long-run transition process to a modern economy. Along these lines, one could for instance examine if 3G contributes to higher education and the acquisition of skills that may prove beneficial to the economy in the long run (Bessone et al., 2020). Finally, technology is constantly changing. 3G has been replaced by 4G and 5G in many advanced economies by now. Our results together with those of Hjort and Poulsen (2019) and Mensah (2021) provide reason for optimism as they suggest that technology can make a difference, but ultimately the results are proportional to the strength of the technology. 3G internet is more limited than fixed broadband, hence its effects on employment appear to be modest; but there is nothing to preclude that adoption of 5G by developing countries could have as large effects as those documented in the context of fixed broadband. We leave these questions to future work.

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Tables and Figures

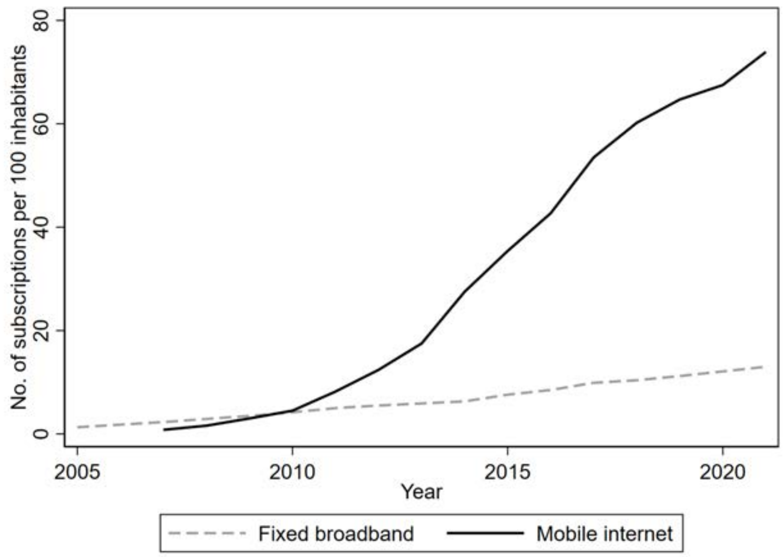


Figure 1: Broadband and Mobile Internet Subscribers in Low & Middle Income Countries

Data Source: Authors' calculations from International Telecommunications Union (ITU) Data.

Table 1: Summary Statistics

		Fraction of Total			Conditional on LFP		
	N	All	Male	Female	All	Male	Female
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Regional 3G Coverage	8779	0.46					
Panel A. Employment Choices							
LFP	7290	0.58	0.84	0.39	1.00	1.00	1.00
Employed	7290	0.55	0.77	0.33	0.96	0.91	0.86
Employer	7290	0.02	0.04	0.01	0.03	0.05	0.02
OAE	7290	0.18	0.29	0.09	0.31	0.34	0.22
Wage Employed	7290	0.26	0.36	0.17	0.52	0.43	0.43
Unpaid Workers	7290	0.07	0.06	0.07	0.09	0.08	0.17
Panel B. Fraction in Agriculture							
Employer	7279	0.01	0.02	0.00	0.02	0.03	0.01
OAE	7279	0.11	0.18	0.03	0.16	0.21	0.09
Wage Employed	7279	0.06	0.10	0.02	0.11	0.12	0.04
Unpaid Workers	7279	0.06	0.06	0.05	0.08	0.07	0.14
Panel C. Fraction in Manufacturing							
Employer	7279	0.002	0.003	0.001	0.003	0.004	0.002
OAE	7279	0.02	0.02	0.01	0.03	0.02	0.04
Wage Employed	7279	0.04	0.06	0.02	0.08	0.07	0.06
Unpaid Workers	7279	0.00	0.00	0.00	0.00	0.00	0.01
Panel D. Fraction in Services							
Employer	7279	0.008	0.01	0.004	0.01	0.015	0.01
OAE	7279	0.06	0.09	0.04	0.11	0.10	0.10
Wage Employed	7279	0.16	0.19	0.13	0.32	0.23	0.32
Unpaid Workers	7279	0.01	0.01	0.01	0.01	0.01	0.02
Frac Agri	7279	0.24	0.38	0.11	0.38	0.46	0.28
Frac Manf	7279	0.06	0.09	0.04	0.11	0.10	0.11
Frac Services	7279	0.24	0.31	0.18	0.47	0.37	0.47

Notes: This table provides the average across various variables calculated for all adults between ages 18-65 across in a sub-national region (district, county, municipality, etc.). We restrict our sample to those survey rounds in a country before it adopts 3G. Columns 2-4 reports the variable of interest as a fraction of the total population, men and women respectively. Columns 5-7 normalizes the variable of interest with respect to the the individuals in the labor force instead. Each variable of interest is the fraction of individuals in a sub-national region who LFP: participate in the labor force; Employed: are employed; Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Workers: work in unpaid jobs. Panel A reports the fractions across the entire sample, whereas Panels B-D report the averages in Agriculture, Manufacturing and Services respectively.

Table 2: Impact of Regional 3G Coverage on Employment Outcomes

	LFP		Employed		Employer		OAE		Wage-Employed		Unpaid	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Whole Sample												
3G coverage	0.066	0.284	0.086	0.213	-0.001	-0.021	0.064	0.224	0.027	0.069	0.001	-0.086
	(0.003)	(0.026)	(0.003)	(0.023)	(0.001)	(0.004)	(0.002)	(0.022)	(0.002)	(0.014)	(0.002)	(0.014)
p value	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.045}**	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.540}	{0.000}***
q value	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.016]**	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.133]	[0.001]***
R2 /F-stat	0.88	142.89	0.84	142.89	0.90	142.89	0.80	142.89	0.95	142.89	0.88	142.89
Panel B: Males												
3G coverage	0.039	-0.168	0.106	0.310	-0.001	-0.027	0.085	0.369	0.038	0.159	-0.017	-0.238
	(0.003)	(0.133)	(0.003)	(0.030)	(0.001)	(0.006)	(0.004)	(0.036)	(0.003)	(0.022)	(0.002)	(0.026)
p value	{0.000}***	{0.204}	{0.000}***	{0.000}***	{0.304}	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***
q value	[0.001]***	[0.086]*	[0.001]***	[0.001]***	[0.080]*	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***
R2/ F-stat	0.72	5.98	0.70	142.89	0.89	142.89	0.76	142.89	0.93	142.89	0.73	142.89
Panel C: Females												
3G coverage	0.022	0.492	0.064	0.132	-0.001	-0.015	0.041	0.090	0.015	-0.014	0.018	0.060
	(0.003)	(0.218)	(0.003)	(0.024)	(0.000)	(0.002)	(0.002)	(0.015)	(0.001)	(0.012)	(0.001)	(0.011)
p value	{0.000}***	{0.024}**	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.230}	{0.000}***	{0.000}***
q value	[0.001]***	[0.017]**	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.094]*	[0.001]***	[0.001]***
R2/ F-stat	0.93	5.98	0.91	142.89	0.86	142.89	0.81	142.89	0.95	142.89	0.93	142.89
Reg.	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13005	13005	16069	16069	16069	16069	16069	16069	16069	16069	16069	16069

Notes: Each outcome variable is the fraction of individuals in a region who are Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Work: work in unpaid jobs. Columns (1), (3), (5), (7), (9) and (11) report OLS results, whereas columns (2), (4), (6), (8), (10) and (12) report IV results with the Keibergen-Paap F-Statistic. The unit of observation is the smallest sub-national region (district, county, municipality, etc.). We include region and year fixed effects in all specifications, along with geographical controls such as rainfall, elevation and Regional 2G Coverage. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is $p< 0.01$, ** is $p< 0.05$ and * is $p< 0.1$.

Table 3: Impact on Employment Across Industries

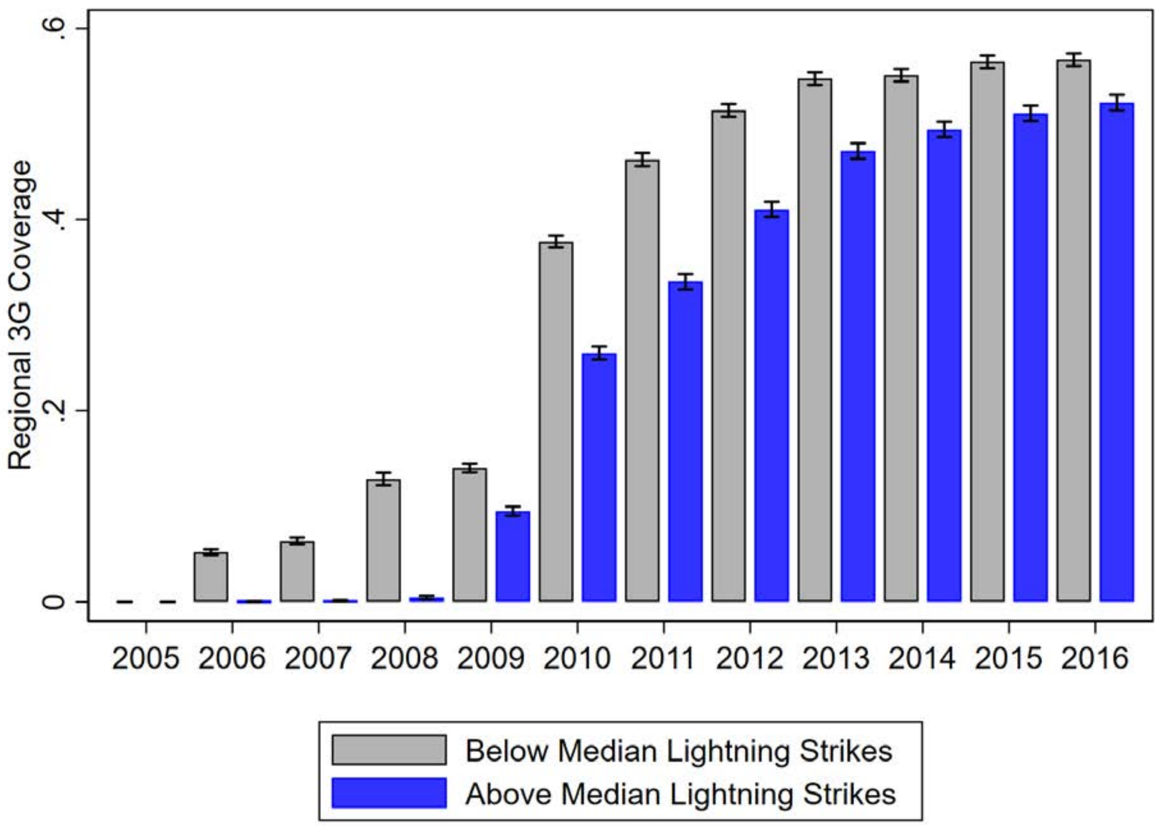
	Agriculture		Manufacturing		Services	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Whole Sample						
3G coverage	0.023	0.088	-0.007	-0.003	0.031	0.060
	(0.002)	(0.017)	(0.001)	(0.008)	(0.001)	(0.010)
p value	{0.000}***	{0.000}***	{0.000}***	{0.701}	{0.000}***	{0.000}***
q value	[0.001]***	[0.001]***	[0.001]***	[0.221]	[0.001]***	[0.001]***
R2/ F-stat	0.94	141.85	0.92	141.85	0.96	141.85
Panel B: Males						
3G coverage	0.035	0.089	-0.015	0.012	0.035	0.099
	(0.003)	(0.022)	(0.001)	(0.010)	(0.002)	(0.015)
p value	{0.000}***	{0.000}***	{0.000}***	{0.251}	{0.000}***	{0.000}***
q value	[0.001]***	[0.001]***	[0.001]***	[0.101]	[0.001]***	[0.001]***
R2/ F-stat	0.94	141.85	0.92	141.85	0.95	141.85
Panel C: Females						
3G coverage	0.009	0.101	-0.001	-0.017	0.026	0.025
	(0.002)	(0.017)	(0.001)	(0.009)	(0.001)	(0.011)
p value	{0.000}***	{0.000}***	{0.601}	{0.069}*	{0.000}***	{0.017}**
q value	[0.001]***	[0.001]***	[0.137]	[0.037]**	[0.001]***	[0.014]**
R2/ F-stat	0.93	141.85	0.87	141.85	0.95	141.85
Reg.	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	15809	15809	15809	15809	15809	15809

Notes: Panel A uses the entire sample, whereas Panels B and C restrict the sample to males and females respectively. Each outcome variable is the fraction of individuals in a sub-national region who work in Agriculture, Manufacturing and Services. Columns (1), (3) and (5) report OLS results, whereas columns (2), (4) and (6) report IV results with Keibergen-Paap F-Statistic. The unit of observation is the smallest sub-national region (district, county, municipality, etc.) available. All specifications have region and year fixed effects, and control for average rainfall and elevation in the region along with regional 2G coverage. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. * is p<0.1, ** is p<0.05 and *** is p<0.01.

NOT FOR PUBLICATION

A Additional Tables and Figures

Figure A1: Growth in Regional 3G Coverage by Frequency of Lightning Strikes



Notes: The figure illustrates the relationship between regional 3G coverage and the frequency of lightning strikes per area. In particular, it presents the evolution of regional 3G coverage in sub-national regions with high (above-median) frequency of lightning strikes per sq. km and low (below-median) frequency of lightning strikes per sq. km.

Table A1: First Stage Results

	3G Coverage	
	(1)	(2)
Above Med. × Year	-0.011***	-0.011***
	(0.001)	(0.001)
Region & Year FE	Yes	Yes
Controls	No	Yes
R2	0.74	0.74
N	16069	16069

Notes: This table reports the first stage results for the IV specification discussed in Equation (2) following Guriev et al. (2021); Manacorda and Tesei (2020). The unit of observation is the smallest sub-national region (district, county, municipality, etc.) of a country. Each region is assigned a binary variable that takes the value 1 if the region receives above-median lightning strikes per square kilometer on average, and 0 otherwise. We include region and year fixed effects in all specifications. Column 2 additionally controls for geographical controls such as rainfall and elevation and Regional 2G coverage. Robust standard errors are reported in parentheses. *** is $p < 0.01$, ** is $p < 0.05$ and * is $p < 0.1$.

Table A2: Employment Choices in Agriculture

	Employer		OAE		Wage-Employed		Unpaid	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Whole Sample								
3G coverage	-0.001	-0.016	0.048	0.205	0.003	-0.006	0.001	-0.081
	(0.000)	(0.003)	(0.002)	(0.020)	(0.001)	(0.008)	(0.001)	(0.013)
p value	{0.106}	{0.000}***	{0.000}***	{0.000}***	{0.001}***	{0.503}	{0.428}	{0.000}***
q value	[0.032]**	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.162]	[0.107]	[0.001]***
R2/ F-stat	0.84	141.85	0.82	141.85	0.88	141.85	0.88	141.85
Panel B: Males								
3G coverage	-0.001	-0.023	0.080	0.385	0.007	-0.007	-0.016	-0.221
	(0.001)	(0.005)	(0.004)	(0.037)	(0.002)	(0.014)	(0.002)	(0.025)
p value	{0.204}	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.620}	{0.000}***	{0.000}***
q value	[0.062]*	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.195]	[0.001]***	[0.001]***
R2/ F-stat	0.85	141.85	0.80	141.85	0.89	141.85	0.73	141.85
Panel C: Females								
3G coverage	-0.000	-0.010	0.016	0.034	-0.001	-0.003	0.017	0.056
	(0.000)	(0.001)	(0.001)	(0.009)	(0.001)	(0.005)	(0.001)	(0.010)
p value	{0.018}**	{0.000}***	{0.000}***	{0.000}***	{0.059}*	{0.573}	{0.000}***	{0.000}***
q value	[0.007]***	[0.001]***	[0.001]***	[0.001]***	[0.020]**	[0.181]	[0.001]***	[0.001]***
R2/ F-stat	0.65	141.85	0.84	141.85	0.77	141.85	0.93	141.85
Reg.	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	15809	15809	15809	15809	15809	15809	15809	15809

Notes: We restrict the sample to individuals employed in agriculture. Panel A uses the entire sample, whereas Panels B and C restrict the sample to males and females respectively. Each outcome variable is the fraction of individuals in a region who are Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Work: work in unpaid jobs. Columns (1), (3), (5), and (7) report OLS results, whereas columns (2), (4), (6) and (8) report IV results with the Keibergen-Paap F-Statistic. The unit of observation is the smallest sub-national region (district, county, municipality, etc.). We include region and year fixed effects in all specifications, along with geographical controls such as rainfall, elevation and Regional 2G Coverage. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is p< 0.01, ** is p< 0.05 and * is p< 0.1.

Table A3: Employment Choices in Manufacturing

	Employer		OAE		Wage-Employed		Unpaid	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Whole Sample								
3G coverage	-0.000	0.000	0.001	0.010	-0.007	-0.011	0.001	0.002
	(0.000)	(0.001)	(0.001)	(0.005)	(0.001)	(0.005)	(0.000)	(0.001)
p value	{0.009}***	{0.382}	{0.012}**	{0.032}**	{0.000}***	{0.046}**	{0.003}***	{0.220}
q value	[0.004]***	[0.135]	[0.005]***	[0.022]**	[0.001]***	[0.031]**	[0.002]***	[0.092]*
R2/ F-stat	0.72	141.85	0.82	141.85	0.94	141.85	0.63	141.85
Panel B: Males								
3G coverage	-0.000	0.001	-0.001	0.003	-0.010	0.018	-0.000	-0.002
	(0.000)	(0.001)	(0.001)	(0.004)	(0.001)	(0.009)	(0.000)	(0.001)
p value	{0.097}*	{0.154}	{0.217}	{0.438}	{0.000}***	{0.039}**	{0.296}	{0.071}*
q value	[0.030]**	[0.069]*	[0.062]*	[0.150]	[0.001]***	[0.026]**	[0.080]*	[0.037]**
R2/ F-stat	0.72	141.85	0.83	141.85	0.93	141.85	0.60	141.85
Panel C: Females								
3G coverage	-0.000	-0.000	0.003	0.016	-0.003	-0.037	0.001	0.005
	(0.000)	(0.000)	(0.001)	(0.007)	(0.001)	(0.005)	(0.000)	(0.002)
p value	{0.001}***	{0.539}	{0.000}***	{0.022}**	{0.000}***	{0.000}***	{0.000}***	{0.018}**
q value	[0.001]***	[0.172]	[0.001]***	[0.016]**	[0.001]***	[0.001]***	[0.001]***	[0.014]**
R2/ F-stat	0.62	141.85	0.78	141.85	0.92	141.85	0.58	141.85
Reg.	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	15809	15809	15809	15809	15809	15809	15809	15809

Notes: We restrict the sample to individuals employed in manufacturing. Panel A uses the entire sample, whereas Panels B and C restrict the sample to males and females respectively. Each outcome variable is the fraction of individuals in a region who are Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Work: work in unpaid jobs. Columns (1), (3), (5), and (7) report OLS results, whereas columns (2), (4), (6) and (8) report IV results with the Keibergen-Paap F-Statistic. The unit of observation is the smallest sub-national region (district, county, municipality, etc.). We include region and year fixed effects in all specifications, along with geographical controls such as rainfall, elevation and Regional 2G Coverage. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is p< 0.01, ** is p< 0.05 and * is p< 0.1.

Table A4: Employment Choices in Services

	Employer		OAE		Wage-Employed		Unpaid	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Whole Sample								
3G coverage	-0.000	-0.001	0.009	0.005	0.036	0.122	-0.001	-0.004
	(0.000)	(0.001)	(0.001)	(0.005)	(0.001)	(0.012)	(0.000)	(0.002)
p value	{0.461}	{0.376}	{0.000}***	{0.355}	{0.000}***	{0.000}***	{0.001}***	{0.019}**
q value	[0.114]	[0.135]	[0.001]***	[0.129]	[0.001]***	[0.001]***	[0.001]***	[0.014]**
R2/ F-stat	0.80	141.85	0.88	141.85	0.95	141.85	0.65	141.85
Panel B: Males								
3G coverage	-0.000	0.001	0.006	-0.011	0.048	0.191	-0.001	-0.011
	(0.000)	(0.002)	(0.001)	(0.007)	(0.002)	(0.018)	(0.000)	(0.002)
p value	{0.646}	{0.770}	{0.000}***	{0.097}*	{0.000}***	{0.000}***	{0.000}***	{0.000}***
q value	[0.141]	[0.244]	[0.001]***	[0.048]**	[0.001]***	[0.001]***	[0.001]***	[0.001]***
R2/ F-stat	0.80	141.85	0.89	141.85	0.92	141.85	0.52	141.85
Panel C: Females								
3G coverage	-0.000	-0.003	0.013	0.022	0.024	0.055	-0.000	0.002
	(0.000)	(0.001)	(0.001)	(0.006)	(0.001)	(0.008)	(0.000)	(0.002)
p value	{0.321}	{0.018}**	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.588}	{0.437}
q value	[0.080]*	[0.014]**	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.137]	[0.150]
R2/ F-stat	0.72	141.85	0.83	141.85	0.96	141.85	0.66	141.85
Reg.	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	15809	15809	15809	15809	15809	15809	15809	15809

Notes: We restrict the sample to individuals employed in services. Panel A uses the entire sample, whereas Panels B and C restrict the sample to males and females respectively. Each outcome variable is the fraction of individuals in a region who are Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Work: work in unpaid jobs. Columns (1), (3), (5), and (7) report OLS results, whereas columns (2), (4), (6) and (8) report IV results with the Keibergen-Paap F-Statistic. The unit of observation is the smallest sub-national region (district, county, municipality, etc.). We include region and year fixed effects in all specifications, along with geographical controls such as rainfall, elevation and Regional 2G Coverage. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is $p< 0.01$, ** is $p< 0.05$ and * is $p< 0.1$.

B Robustness of Results

In this section, we conduct a number of robustness tests to check the sensitivity of our results to alternative specifications, data structures and samples. Specifically, in Section B.1, we redo our analysis using an ANCOVA structure instead of panel analysis (McKenzie, 2012). In Section B.2, we check if our results are sensitive to spillovers to neighboring regions by aggregating data across adjacent areas. In Section B.3, we perform a placebo check and redo our analysis to show that current employment outcomes are uncorrelated with future availability of 3G coverage in a region. Lastly, while our preferred specification uses some sample constraints based on the availability of data (see Section 2.4), we redo our analysis with the entire sample, ignoring these data restrictions in Section B.4.

B.1 ANCOVA Analysis

Empirical Specification: While our benchmark specification uses the panel structure of the data, given that most countries have 2-3 rounds of data, we redo our analysis using an ANCOVA structure (McKenzie, 2012). We restrict our sample to country-years between 2009-2015 (when most countries in our sample adopted 3G). This leaves us with 9305 region-year observations. The key trade-off vis a vi the panel approach is that while we can no longer control for region fixed effects, we can now control for the "baseline" pre-intervention levels of the outcome variables, which proxy (among other things) for pre-trends in these regions. The ANCOVA structure also allows us to flexibly incorporate changes to the surveys over time (affecting recall periods, measurement of outcomes, etc.). For a region r in a state (country) s observed in a year t, we now estimate the following specification:

$$Y_{rt} = \alpha_s + \alpha_t + \beta \text{ 3G Coverage}_{rt} + \gamma Y_{r0} + \delta_1 X_{r0} + \delta_2 X_{rt} + \varepsilon_{rt} \quad (3)$$

$$\text{3G Coverage}_{rt} = \alpha_s + \alpha_t + \beta \text{ Lightning}_{rt} + \delta_1 X_{r0} + \delta_2 X_{rt} + \nu_{rt} \quad (4)$$

The key difference compared to the benchmark specification in the paper is that we now control for state fixed effects (α_s) instead of region fixed effects. In addition, Y_{r0} controls for the pre-intervention (before 2009) value of the outcome variable, which we calculate using the latest round of data for each country prior to 2009. Similarly, X_{r0} is a vector of baseline characteristics of a region r; we include log population, fraction of population living in urban areas, average household size, sex ratio, an index of assets, and the average literacy rates for men and women. These variables plausibly proxy for the stage of development of each region prior to the arrival of 3G. Since we now have a cross-section of data (with only two exceptions, Mexico and South Africa), our instrument (lightning strikes per square kilometer) now identifies variation in 3G coverage across regions conditional on the covariates. We estimate a strong first-stage with a Keibergen-Paap F-statistic between 40-50.

Results: Comparing the results of Table B1 with Table 2, we see that (with two exceptions discussed below) they are qualitatively similar across all outcome variables, for both men and women. Consistent with our previous analysis, we find that women are more likely to enter the workforce, and get employed in either unpaid work or operate OAEs, while men are less likely to be employed in unpaid work and instead start OAEs.

There are two differences however: First, Column 6 of Table 2, suggested that 3G coverage made both men and women *less* likely to be "Employers," while our results here (Table B1) show slightly positive effects. However, given that the fraction of individuals who are employers is very small (3 percent), this difference in the results does not have any important aggregate implications. Second, the effects of 3G on wage employment are now statistically insignificant at conventional levels. Hence the evidence on transition to wage employment is not as robust as the evidence on the other effects.

Regarding the impact of 3G on sectoral reallocation, the quantitative results in Table B2 look very similar to those in Table 3, though the statistical significance is lower for men. Overall, there seems to be no support for the hypothesis that mobile internet has contributed to a transition from agriculture to manufacturing and to services.

Table B1: Impact on LFP and Employment Type

	LFP		Employed		Employer		OAE		Wage-Employed		Unpaid	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Whole Sample												
3G coverage	0.027	0.075	0.029	0.152	-0.000	0.013	-0.005	0.197	0.030	-0.025	-0.010	-0.059
	(0.002)	(0.034)	(0.002)	(0.039)	(0.000)	(0.005)	(0.002)	(0.046)	(0.002)	(0.029)	(0.001)	(0.024)
p value	{0.000}***	{0.032}**	{0.000}***	{0.000}***	{0.388}	{0.014}**	{0.014}**	{0.000}***	{0.000}***	{0.399}	{0.000}***	{0.013}**
q value	[0.001]***	[0.034]**	[0.001]***	[0.001]***	[0.134]	[0.021]**	[0.009]***	[0.001]***	[0.001]***	[0.237]	[0.001]***	[0.021]**
R2 /F-stat	0.81	43.57	0.77	43.41	0.82	41.88	0.78	39.76	0.90	39.52	0.73	41.30
Panel B: Males												
3G coverage	0.025	-0.035	0.023	0.108	-0.001	0.017	-0.015	0.323	0.040	-0.040	-0.021	-0.201
	(0.003)	(0.039)	(0.003)	(0.047)	(0.001)	(0.008)	(0.003)	(0.076)	(0.003)	(0.042)	(0.002)	(0.048)
p value	{0.000}***	{0.370}	{0.000}***	{0.021}**	{0.445}	{0.040}**	{0.000}***	{0.000}***	{0.000}***	{0.339}	{0.000}***	{0.000}***
q value	[0.001]***	[0.222]	[0.001]***	[0.027]**	[0.153]	[0.038]**	[0.001]***	[0.001]***	[0.001]***	[0.206]	[0.001]***	[0.001]***
R2/ F-stat	0.51	48.69	0.60	43.68	0.81	41.60	0.70	39.72	0.85	41.29	0.55	43.70
Panel C: Females												
3G coverage	0.040	0.215	0.037	0.233	0.000	0.009	0.006	0.101	0.022	0.010	0.001	0.085
	(0.003)	(0.049)	(0.003)	(0.051)	(0.000)	(0.003)	(0.002)	(0.030)	(0.002)	(0.025)	(0.001)	(0.020)
p value	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.713}	{0.002}***	{0.001}***	{0.001}***	{0.000}***	{0.677}	{0.242}	{0.000}***
q value	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.209]	[0.005]***	[0.002]***	[0.003]***	[0.001]***	[0.353]	[0.089]*	[0.001]***
R2/ F-stat	0.88	46.92	0.85	42.87	0.76	42.38	0.84	42.17	0.92	39.40	0.83	40.15
Reg.	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	7773	7773	9305	9305	9305	9305	9305	9305	9305	9305	9305	9305

Notes: Panel A uses the entire sample, whereas Panels B and C restrict the sample to males and females respectively. Each variable of interest is the fraction of individuals in a sub-national region who LFP: participate in the labor force; Employed: are employed; Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Workers: work in unpaid jobs. Columns (1), (3), (5), (7), (9) and (11) report the results for the OLS specification whereas columns (2), (4), (6), (8), (10) and (12) report the results for the IV specification with Keibergen-Paap F-Statistic. The unit of observation is the smallest sub-national region (district, county, municipality, etc.) available, and we restrict our sample from 2009-2015 for when the 3G Coverage data is available across these countries. We include state and year fixed effects in all specifications, along with geographical controls such as rainfall, elevation and 2G Coverage. We also control for baseline characteristics for the sub-national region using the last round of surveys prior to 2009 such as population of the region, fraction in urban areas, average household size, sex-ratio, index of assets, fraction of adult and female literacy, along with the baseline value of the outcome variable. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is $p < 0.01$, ** is $p < 0.05$ and * is $p < 0.1$.

Table B2: Impact on Employment Across Industries

	Agriculture		Manufacturing		Services	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Whole Sample						
3G coverage	-0.015	0.035	0.002	0.053	0.032	0.052
	(0.002)	(0.036)	(0.001)	(0.022)	(0.002)	(0.028)
p value	{0.000}***	{0.335}	{0.202}	{0.016}**	{0.000}***	{0.068}*
q value	[0.001]***	[0.206]	[0.076]*	[0.021]**	[0.001]***	[0.054]*
R2/ F-stat	0.86	34.66	0.77	39.90	0.89	38.77
Panel B: Males						
3G coverage	-0.023	0.038	-0.001	0.013	0.039	0.040
	(0.003)	(0.057)	(0.002)	(0.028)	(0.002)	(0.037)
p value	{0.000}***	{0.503}	{0.471}	{0.641}	{0.000}***	{0.286}
q value	[0.001]***	[0.270]	[0.161]	[0.353]	[0.001]***	[0.184]
R2/ F-stat	0.85	33.62	0.79	39.84	0.86	36.28
Panel C: Females						
3G coverage	-0.004	0.072	0.005	0.090	0.028	0.066
	(0.002)	(0.029)	(0.001)	(0.025)	(0.002)	(0.028)
p value	{0.043}**	{0.014}**	{0.000}***	{0.000}***	{0.000}***	{0.020}**
q value	[0.022]**	[0.021]**	[0.001]***	[0.002]***	[0.001]***	[0.026]**
R2/ F-stat	0.85	40.23	0.66	41.03	0.88	42.36
Reg.	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	9191	9191	9191	9191	9191	9191

Notes: Panel A uses the entire sample, whereas Panels B and C restrict the sample to males and females respectively. Each outcome variable is the fraction of individuals in a sub-national region who work in Agriculture, Manufacturing and Services. Columns (1), (3) and (5) report the results for the OLS specification whereas columns (2), (4) and (6) report the results for the IV specification with Keibergen-Paap F-Statistic. The unit of observation is the smallest sub-national region (district, county, municipality, etc.) available, and we restrict our sample from 2009-2015 for when the 3G Coverage data is available across these countries. We include state and year fixed effects in all specifications, along with geographical controls such as rainfall, elevation and 2G Coverage. We also control for baseline characteristics for the sub-national region using the last round of surveys prior to 2009 such as population of the region, fraction in urban areas, average household size, sex-ratio, index of assets, fraction of adult and female literacy, along with the baseline value of the outcome variable. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is $p< 0.01$, ** is $p< 0.05$ and * is $p< 0.1$.

B.2 Spillovers Across Neighboring Regions

An important concern with the analysis of the regional impacts of 3G is potential movement of people and resources across neighboring areas to take advantage of the new technology. Ideally, we would examine directly how migration has responded to the arrival of 3G. However, our data does not allow us to track the movement of people across space. Therefore, we employ an alternative strategy, similar to Hjort and Poulsen (2019): we aggregate adjacent regions and re-estimate our specifications for these more aggregated regions. We report the results in Table B3. As we see, we have roughly half the number of observations, with a lower, but still strong Keibergen-Paap F-statistic of the first stage. Comparing the baseline results in Table 2 to Table B3, we see that this aggregation to larger regional units does not change the qualitative results. The quantitative results are also similar, mitigating concerns around spillovers across regions.

Table B3: Aggregating Over Adjacent Regions

	LFP		Employed		Employer		OAE		Wage-Employed		Unpaid	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Whole Sample												
3G Coverage	0.079	0.264	0.104	0.196	-0.002	-0.010	0.082	0.218	0.030	0.045	0.000	-0.075
	(0.004)	(0.025)	(0.004)	(0.022)	(0.001)	(0.003)	(0.003)	(0.021)	(0.002)	(0.013)	(0.002)	(0.014)
p value	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.007}***	{0.001}***	{0.000}***	{0.000}***	{0.000}***	{0.001}***	{0.901}	{0.000}***
q value	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.002]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.064]*	[0.001]***
R2 /F-stat	0.91	127.37	0.87	127.37	0.93	127.37	0.83	127.37	0.96	127.37	0.92	127.37
Panel B: Males												
3G Coverage	0.053	0.097	0.134	0.273	-0.002	-0.012	0.110	0.344	0.046	0.118	-0.021	-0.211
	(0.004)	(0.056)	(0.005)	(0.028)	(0.001)	(0.005)	(0.005)	(0.034)	(0.003)	(0.019)	(0.003)	(0.025)
p value	{0.000}***	{0.087}*	{0.000}***	{0.000}***	{0.056}*	{0.016}**	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***
q value	[0.001]***	[0.015]**	[0.001]***	[0.001]***	[0.008]***	[0.004]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***
R2/ F-stat	0.76	20.10	0.73	127.37	0.92	127.37	0.80	127.37	0.95	127.37	0.79	127.37
Panel C: Females												
3G Coverage	0.015	0.257	0.071	0.125	-0.001	-0.008	0.053	0.099	0.014	-0.026	0.020	0.056
	(0.004)	(0.078)	(0.004)	(0.024)	(0.000)	(0.002)	(0.003)	(0.015)	(0.002)	(0.012)	(0.002)	(0.012)
p value	{0.001}***	{0.001}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.035}**	{0.000}***	{0.000}***
q value	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.007]***	[0.001]***	[0.001]***
R2/ F-stat	0.96	20.10	0.94	127.37	0.90	127.37	0.85	127.37	0.96	127.37	0.95	127.37
Reg.	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	6519	6519	8051	8051	8051	8051	8051	8051	8051	8051	8051	8051

Notes: Panel A uses the whole sample whereas panels B and C restrict the sample to adult males and females respectively. Each variable of interest is the fraction of individuals in a sub-national region who LFP: participate in the labor force; Employed: are employed; Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Workers: work in unpaid jobs. Columns (1), (3), (5), (7), (9) and (11) report the results for the OLS specification whereas columns (2), (4), (6), (8), (10), (12) report the results for the IV specification. We include state and year fixed effects in all specifications, along with geographical controls such as rainfall, elevation and 2G Coverage. We also control for baseline characteristics for the sub-national region using the last round of surveys prior to 2009 such as population of the region, fraction in urban areas, average household size, sex-ratio, index of assets, fraction of adult and female literacy, along with the baseline value of the outcome variable. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is $p< 0.01$, ** is $p< 0.05$ and * is $p< 0.1$.

B.3 Placebo Check using Future 3G Coverage

We now consider another robustness check where we check the impact of future values of 3G coverage on current employment outcomes i.e., we estimate the following specification:

$$Y_{rt} = \alpha_r + \alpha_t + \beta 3\text{G Coverage}_{rt+1} + \delta X_{rt} + \varepsilon_{rt} \tag{5}$$

As reported in Table B4, we see that in all cases (except two), the estimated coefficients are statistically insignificant from zero at conventional levels. The only notable exception are the coefficients on the fraction of wage-employed individuals and women (Panels A and C of Column 5), and the fraction of men in unpaid work (Column 6).

Table B4: Placebo Check Using Future 3G Coverage

	LFP	Employed	Employer	OAE	Wage-Employed	Unpaid
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Whole Sample						
3G coverage$_{t+1}$	-0.021	-0.114	0.017	0.053	-0.198*	-0.086
	(0.095)	(0.107)	(0.014)	(0.082)	(0.109)	(0.071)
Panel B: Males						
3G coverage$_{t+1}$	-0.017	-0.153	0.034	0.012	-0.096	-0.219*
	(0.105)	(0.120)	(0.024)	(0.129)	(0.119)	(0.131)
Panel C: Females						
3G coverage$_{t+1}$	0.046	0.018	0.004	0.136	-0.260**	0.048
	(0.117)	(0.116)	(0.007)	(0.084)	(0.124)	(0.051)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	4972	4972	4972	4972	4972	4972

Notes: Panel A uses the whole sample whereas panels B and C restrict the sample to adult males and females respectively. Each variable of interest is the fraction of individuals in a sub-national region who LFP: participate in the labor force; Employed: are employed; Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Workers: work in unpaid jobs. We report the results for the IV specification in all columns. We include state and year fixed effects in all specifications, along with geographical controls such as rainfall, elevation and 2G Coverage. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is p< 0.01, ** is p< 0.05 and * is p< 0.1.

B.4 Using the Entire Sample

As discussed in Section 2.4, in our preferred specifications, we restrict our sample to those regions where we observe all outcome variables in Table 2. However, for some surveys in these countries, it is possible to measure some of the outcome variables (e.g., employment categories), but not others (e.g., unemployment status). We therefore redo our analysis using the entire sample and ignoring this restriction and report the results in Table B5. As the table demonstrates, the qualitative results and their quantitative magnitudes are similar to our main analysis in Table 2, reassuring us that our results are not sensitive to the sample selection.

Table B5: Using the Entire IPUMS Sample

	LFP		Employed		Employer		OAE		Wage-Employed		Unpaid	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Whole Sample												
3G coverage	0.064	0.253	0.078	0.167	-0.001	-0.021	0.064	0.224	0.027	0.069	0.001	-0.086
	(0.003)	(0.022)	(0.003)	(0.020)	(0.001)	(0.004)	(0.002)	(0.022)	(0.002)	(0.014)	(0.002)	(0.014)
p value	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.045}**	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.540}	{0.000}***
q value	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.009]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.064]*	[0.001]***
R2 /F-stat	0.88	173.53	0.84	173.53	0.90	142.89	0.80	142.89	0.95	142.89	0.88	142.89
Panel B: Males												
3G coverage	0.035	-0.099	0.095	0.246	-0.001	-0.027	0.085	0.369	0.038	0.159	-0.017	-0.238
	(0.003)	(0.060)	(0.003)	(0.025)	(0.001)	(0.006)	(0.004)	(0.036)	(0.003)	(0.022)	(0.002)	(0.026)
p value	{0.000}***	{0.101}	{0.000}***	{0.000}***	{0.304}	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***
q value	[0.001]***	[0.013]**	[0.001]***	[0.001]***	[0.054]*	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***
R2/ F-stat	0.73	21.19	0.70	173.53	0.89	142.89	0.76	142.89	0.93	142.89	0.73	142.89
Panel C: Females												
3G coverage	0.026	0.286	0.059	0.102	-0.001	-0.015	0.041	0.090	0.015	-0.014	0.018	0.060
	(0.003)	(0.079)	(0.003)	(0.021)	(0.000)	(0.002)	(0.002)	(0.015)	(0.001)	(0.012)	(0.001)	(0.011)
p value	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.000}***	{0.230}	{0.000}***	{0.000}***
q value	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.001]***	[0.027]**	[0.001]***	[0.001]***
R2/ F-stat	0.93	21.19	0.91	173.53	0.86	142.89	0.81	142.89	0.95	142.89	0.93	142.89
Reg.	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	13623	13623	16687	16687	16069	16069	16069	16069	16069	16069	16069	16069

Notes: Panel A uses the whole sample whereas panels B and C restrict the sample to adult males and females respectively. Each variable of interest is the fraction of individuals in a sub-national region who LFP: participate in the labor force; Employed: are employed; Employers: self-employed and operate a business that hires other workers; OAEs: operate own-account enterprises that do not hire any workers; Wage Employed: work in wage-employed jobs; Unpaid Workers: work in unpaid jobs. Columns (1), (3), (5), (7) (9) and (11) report the OLS results, whereas columns (2), (4), (6), (8), (10) and (12) report the IV results. All specifications have region and year fixed effects, and control for average rainfall and elevation in the region along with regional 2G coverage. Robust standard errors are reported in round parentheses, p-values in curly brackets and q-values (Anderson, 2008; Benjamini et al., 2006) in square brackets. *** is p< 0.01, ** is p< 0.05 and * is p< 0.1.

C Data Construction Details

C.1 IPUMS Data

Our primary data on regional outcomes comes from IPUMS International (2020). These are nationally representative data collated from labor force and household surveys, along with national censuses. For a country for which we have 3G coverage data, we use all surveys in that country after 2001. The entire list is provided in Table C3. We restrict our sample to ages 18-24 years. We follow Duernecker et al. (2016); Herrendorf and Schoellman (2018) and classify industries into agriculture, manufacturing and services. This classification is provided in Table C2. Furthermore, we use the harmonized classification by IPUMS to classify occupations into self-employment (entrepreneur and OAEs), wage employment and unpaid work as described in Table C1. We define a "region" at the Level 2 classification, which represents municipalities, districts and counties in these countries. For countries where Level 2 is unavailable, we use Level 1 (states) as a region. Within each region and year, we construct various outcomes variables that are defined as the fraction of individuals in that region and year who reported working in that occupation and industry. We calculate these measures separately for men and women, along with the total across all individuals and use population weights provided for aggregation to the region level.

Table C1: Classification of Types of Employment

Code	Classification	Details
1.	Employer	Self-employed (unincorporated), self-employed (incorporated), employer, employer sharecropper
2.	OAE	Working on own account, self-employed domestic worker, subsistence worker, own account with and without temporary/unpaid help, member of cooperative, Kibbutz member, other self-employed
3.	Wage Employed	Management and non-management jobs, white (non-manual) and blue collar (manual), day laborer, employee with a permanent job or occasional, temporary, contract or without legal contract, wage/salary worker as an apprentice, religious worker or working in a non-profit, NGO, private or public sector job, paid family worker, cooperative employee, federal, state, local government employee, civil servants, local collectives, domestic worker (work for private household), seasonal migrant, other wage and salary jobs.
4.	Unpaid worker	Unpaid family worker, apprentice, unpaid or unspecified, trainee, works for others without wage

Table C2: Classification of Industries

IPUMS Classification	Industry Category
Agriculture	Agriculture, fishing & forestry
Manufacturing	Mining and construction
Services	Electricity, gas & water, wholesale & retail trade, transport & communications, hotels & restaurants, financial & business services, public administration, education & health services

Country	Year	GDP p.c.	Population (millions)		Number of Regions			
		2015 USD	Total	18-65 yrs.	Total	IPUMS	3G & Geog.	Final
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Armenia	2001	3607.29	2.93	2.02	11	11	11	11
Armenia	2011	3607.29	2.93	2.02	11	11	11	11
Bolivia	2001	3035.97	10.87	6.61	76	76	76	76
Bolivia	2012	3035.97	10.87	6.61	76	76	76	76
Botswana	2001	6402.91	2.12	1.30	21	21	21	21
Botswana	2011	6402.91	2.12	1.30	21	21	21	21
Brazil	2000	8813.99	204.47	142.24	2,040	2,040	2,040	2,040
Brazil	2010	8813.99	204.47	142.24	2,040	2,040	2,040	2,040
Cambodia	2004	1162.91	15.52	9.98	139	139	139	139
Cambodia	2008	1162.91	15.52	9.98	141	141	141	141
Cambodia	2013	1162.91	15.52	9.98	141	141	141	141
Costa Rica	2000	11642.78	4.85	3.35	55	55	55	55
Costa Rica	2011	11642.78	4.85	3.35	55	55	55	55
Ecuador	2001	6124.49	16.21	10.43	77	77	77	77
Ecuador	2010	6124.49	16.21	10.43	77	77	77	77
Indonesia	2005	3331.70	258.38	173.54	258	258	258	258
Indonesia	2010	3331.70	258.38	173.54	268	268	268	258
Iran	2006	4904.33	78.49	55.19	330	330	330	330
Iran	2011	4904.33	78.49	55.19	330	330	330	330
Mexico	2000	9616.65	121.86	79.99	2,330	2,330	2,330	2,330
Mexico	2005	9616.65	121.86	79.99	2,331	2,331	0	0
Mexico	2010	9616.65	121.86	79.99	2,331	2,331	2,331	2,331
Mexico	2015	9616.65	121.86	79.99	2,331	2,331	2,321	2,321
Philippines	2000	3001.04	102.11	64.45	1,274	1,274	1,274	1,274
Philippines	2010	3001.04	102.11	64.45	1,274	1,274	1,274	1,274
South Africa	2001	6259.84	55.39	36.38	17	17	17	17
South Africa	2007	6259.84	55.39	36.38	17	17	17	17
South Africa	2011	6259.84	55.39	36.38	17	17	0	0
South Africa	2016	6259.84	55.39	36.38	17	17	0	0
Uganda	2002	847.27	38.23	19.16	119	119	119	119
Uganda	2014	847.27	38.23	19.16	119	119	119	119
Zambia	2000	1338.29	15.88	8.22	55	55	55	55

Zambia	2010	1338.29	15.88	8.22	55	55	55	55
Total			2,224.62	1,468.44	18,454 [100%]	18,454 [100%]	16,079 [87.13%]	16,069 [87.07%]

Table C3: Sample Description

Notes: The above table reports the sample details for the analysis. Columns (1)-(2) report the country and year from the IPUMS data, while Columns (3)-(5) use data from the World Bank to report the real GDP per-capita in 2015 USD (Column 3) and the Total (Column 4) and Working Age (Column 5) population in 2015. Column (6) reports the total number of regions within each country and year in the IPUMS that have 2G/3G data. Column (7) reports the number of regions for which we have data on geographic variables (lightning, rainfall, etc.). Column (8) reports those that have data on all labor market outcome variables. Column (9) gives us the final sample, which has data on IPUMS, 3G and lightning. The World Bank Data was accessed here: https://databank.worldbank.org/source/world-development-indicators#

C.2 Mobile Internet Coverage Data

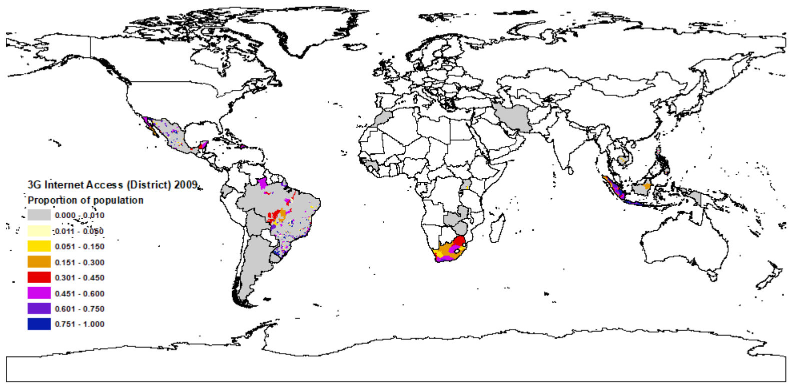
Data for mobile internet coverage is generated from maps of GSM (2G), 3G and 4G coverage collected by Collins Bartholomew's Mobile Coverage Explorer.These are maps generated from submissions by mobile operators who are members of the GSM Association provided between the years 2006-2017 (except 2010) for 3G/4G and 2000-2017 (except 2005 and 2010) for GSM. Data is available at a 1×1 km binary grid cells. Every empty pixel therefore corresponds to a zone with non-coverage (of 3G or GSM). We therefore code each pixel in a binary variable that takes the value 1 if there is some coverage in it, and 0 otherwise. Maps do not display geographic boundaries smaller than a country, and hence we complement them with the shape files provided by IPUMS for the Level 1 and Level 2 administrative boundaries.

We follow Guriev, Melnikov and Zhuravskaya (2021) and construct a population weighted fraction of a region that has access to mobile internet (either 2G or 3G). The population data are also available at the 1×1 km resolution and are obtained from the World Pop website:https://www.worldpop.org/geodata/listing?id=77. For a region r in a year t, we calculate mobile internet coverage as follows:

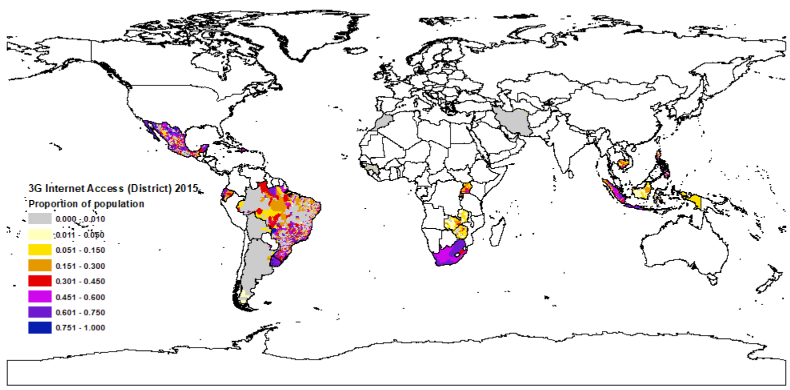
$$\text{Internet}_{rt} = \sum_{p \in r} 1\{\text{Coverage}\}_{prt} \times \theta_{pr,2001}$$

where: $1\{\text{Coverage}\}_{prt}$ takes the value 1 if a pixel p in a region r has internet coverage in year t and $\theta_{pr,2001}$ is fraction of individuals of that region who live in pixel p in 2001. Note that $\sum_p \theta_p = 1$.

Figure C1: Regional 3G Coverage Over Time



(a) Regional 3G Coverage in 2009



(b) Regional 3G Coverage in 2015

Notes: The above figure shows the 3G coverage for a region (as defined in the IPUMS) for 2009 and 2015 for our sample.

C.3 Lightning, Precipitation and Elevation Data

C.3.1 Lightning Data

Lightning data was obtained from from NASA's Global Hydrology Resource Center as part of its LIS/OTD 2.5 Degree Low Resolution Monthly Climatology Time Series (LRMTS) (Cecil, Buechler and Blakeslee, 2014; Cecil, 2006). For the relevant time frame, only data captured by the TRMM satellite is used, as that of OTD satellite only spans 1995-2000. Data is obtained as a raster with each grid corresponding to 2.5 $\times$ 2.5 degrees for each month, which is then averaged across months in a year. Owing to the life-span of the TRMM satellite, the data is only available between 2000-2013. Moreover, the equatorial orbit of the TRMM satellite implies that we only have lightning activity within +/- 38 degrees latitudes of the equator. However, a key advantage of the TRMM satellite is a detection efficiency of 70-90%, which is relatively high compared to a few other ground station-based lightning datasets such as WWLN, at a higher frequency resolution. We then use a similar method (as described in the previous section) to calculate a population-weighted coverage of lightning strikes in a region r in a year t. For the construction of our instrument (see Equation 2), we take the average over all years within a region r i.e., we calculate $\overline{X}_r = \frac{1}{T}\sum_t X_{rt}$ and construct a binary variable that takes the value 1 if $\overline{X}_r$ has a value above the median across all reagions and 0 otherwise.

C.3.2 Precipitation data

Precipitation Data is obtained from the Climate Hazards Group Infrared Precipitation with Station (CHIRPS) data archive (Funk, Peterson, Landsfeld, Pedreros, Verdin, Rowland, Romero, Husak, Michaelsen, Verdin et al., 2014), which is a quasi-global rainfall dataset spanning 50S-50N latitudes (and all longitudes), gridded 0.05-degree resolution, from 1981 to real time precipitation. The terrestrial precipitation estimates were obtained as an annual time series using the Version 2.0 released on 2015.02.12 and thereafter constantly updated. We then use a similar method (as described in the previous section) to calculate a population-weighted coverage of lightning strikes in a region r in a year t.

C.3.3 Elevation data

ETOPO1 Center. (2009) is a 1 arc-minute global relief model of Earth's surface that integrates land topography and ocean bathymetry. It is built from global and regional data sets and we use its "Ice Surface" (top of Antarctic and Greenland ice sheets) version grid-registered, which is not distinct from the "Bedrock" (base of the ice sheets) version for the purposes of countries within +/- 38 latitude. We then use a similar method (as described in the previous section) to calculate a population-weighted coverage of lightning strikes in a region r in a year t.