



International
Labour
Organization

► ILO Working Paper 180

September / 2026

► Mobile Internet and Employment

Evidence from 52 Countries

Authors / Paloma Carrillo, Marta Golin, David Bescond, Avichal Mahajan, Rémi Viné





Attribution 4.0 International (CC BY 4.0)

This work is licensed under the Creative Commons Attribution 4.0 International. See: <https://creativecommons.org/licenses/by/4.0/>. The user is allowed to reuse, share (copy and redistribute), adapt (remix, transform and build upon the original work) as detailed in the licence. The user must clearly credit the ILO as the source of the material and indicate if changes were made to the original content. Use of the emblem, name and logo of the ILO is not permitted in connection with translations, adaptations or other derivative works.

Attribution – The user must indicate if changes were made and must cite the work as follows: Carrillo, P., Golin, M., Bescond, D., Mahajan, A., Viné, R. *Mobile Internet and Employment: Evidence from 52 Countries*. ILO Working Paper 180. Geneva: International Labour Office, 2026. © ILO.

Translations – In case of a translation of this work, the following disclaimer must be added along with the attribution: *This is a translation of a copyrighted work of the International Labour Organization (ILO). This translation has not been prepared, reviewed or endorsed by the ILO and should not be considered an official ILO translation. The ILO disclaims all responsibility for its content and accuracy. Responsibility rests solely with the author(s) of the translation.*

Adaptations – In case of an adaptation of this work, the following disclaimer must be added along with the attribution: *This is an adaptation of a copyrighted work of the International Labour Organization (ILO). This adaptation has not been prepared, reviewed or endorsed by the ILO and should not be considered an official ILO adaptation. The ILO disclaims all responsibility for its content and accuracy. Responsibility rests solely with the author(s) of the adaptation.*

Third-party materials – This Creative Commons licence does not apply to non-ILO copyright materials included in this publication. If the material is attributed to a third party, the user of such material is solely responsible for clearing the rights with the rights holder and for any claims of infringement.

Any dispute arising under this licence that cannot be settled amicably shall be referred to arbitration in accordance with the Arbitration Rules of the United Nations Commission on International Trade Law (UNCITRAL). The parties shall be bound by any arbitration award rendered as a result of such arbitration as the final adjudication of such a dispute.

For details on rights and licensing, contact: rights@ilo.org. For details on ILO publications and digital products, visit: www.ilo.org/publns.

ISBN 9789220437445 (print), ISBN 9789220437452 (web PDF), ISBN 9789220437469 (epub), ISBN 9789220437476 (html). ISSN 2708-3438 (print), ISSN 2708-3446 (digital)

<https://doi.org/10.54394/00034480>

The designations employed in ILO publications, which are in conformity with United Nations practice, and the presentation of material therein do not imply the expression of any opinion whatsoever on the part of the ILO concerning the legal status of any country, area or territory

or of its authorities, or concerning the delimitation of its frontiers or boundaries. See: www.ilo.org/disclaimer.

The opinions and views expressed in this publication are those of the author(s) and do not necessarily reflect the opinions, views or policies of the ILO. During the preparation of this work, the authors utilized ChatGPT Enterprise for language review and refinement. Following the use of this tool, the authors carefully reviewed and edited all content as necessary and assume full responsibility for the document/publication's content. No material subject to intellectual property rights, including third party material, was used without acknowledgment and permission.

Reference to names of firms and commercial products and processes does not imply their endorsement by the ILO, and any failure to mention a particular firm, commercial product or process is not a sign of disapproval.

Information on ILO publications and digital products can be found at: www.ilo.org/research-and-publications

ILO Working Papers summarize the results of ILO research in progress, and seek to stimulate discussion of a range of issues related to the world of work. Comments on this ILO Working Paper are welcome and can be sent to carrillo@ilo.org.

Authorization for publication: Caroline Fredrickson, Director, Research and Statistics Department

ILO Working Papers can be found at: www.ilo.org/research-and-publications/working-papers

Suggested citation:

Carrillo, P., Golin, M., Bescond, D., Mahajan, A., Viné, R. 2026. *Mobile Internet and Employment: Evidence from 52 Countries*, ILO Working Paper 180 (Geneva, ILO).

<https://doi.org/10.54394/00034480>

Abstract

This paper examines how the expansion of 3G mobile internet affected labour force participation and employment composition across 52 countries, predominantly upper-middle-income and high-income countries, covering about 28 per cent of the global labour force, from 2004 to 2023. Using harmonized labour force survey microdata and high-resolution regional coverage maps, we employ fixed-effects OLS regressions and an instrumental-variable strategy exploiting regional variation in lightning density. Our main finding is that 3G expansion does not have uniform labour market effects: its consequences depend critically on where countries stand in the digital diffusion process and their level of economic development. In lower-income and lower-coverage settings, expanded connectivity raises participation and employment, with stronger gains for women, while in more developed and digitally mature settings, the same expansion reduces participation through falling employment, consistent with diminishing returns at later stages of diffusion. Employment gains in poorer contexts occur largely through own-account and family work and agriculture, pointing to more vulnerable forms of employment, whereas richer contexts see shifts toward wage employment, larger firms, and services. Gains also vary by worker characteristics, concentrating among those with basic or intermediate education while employment contracts for the highly educated and older workers in more advanced economies. Contrary to optimistic expectations, 3G expansion does not systematically narrow gender gaps; the most robust gendered finding is a widening of already large gender gaps in youth labour market disengagement, with young women in lower-income countries becoming relatively more likely to be neither employed nor in education or training. Overall, the results caution against viewing digital infrastructure as a technology with predictable labour market benefits, and suggest that connectivity policy must be embedded in a broader strategy addressing job quality, formalisation, and equitable access.

About the authors

Main authors

Paloma Carrillo is an Economist in the Research and Statistics Department of the International Labour Organization (ILO), where she has worked since February 2022, focusing on global and regional trends in gender differences in labour market outcomes and working conditions. She holds a PhD in economics from the Toulouse School of Economics.

Marta Golin is the Insights Lead, Work, Wages and Job Creation at the World Economic Forum. Before joining the Forum, she was an Economist in the Research and Statistics Department of the International Labour Organization. She holds a PhD in Economics from the University of Oxford. Her research interests and work focus on the determinants and consequences of gender differences in labour market outcomes, and which policies or interventions may help narrow existing gender gaps.

Contributing authors

David Bescond is a Data Scientist in the Research and Statistics Department of the International Labour Organization. His work focuses on developing and maintaining data collection and dissemination systems, and improving the quality, accessibility, and use of international labour statistics.

Avichal Mahajan holds a PhD in economics from the University of Geneva and has been an Economist in the Research and Statistics Department of the International Labour Organization since July 2021. His work focuses on the production, maintenance, and analysis of gender-disaggregated ILO modelled estimates.

Rémi Viné has been a Technical Officer in the Research and Statistics Department of the International Labour Organization since February 2025 and is a lecturer of statistics at the Geneva Graduate Institute. His work focuses on international migration and capital flows. He holds a PhD in international economics from the Geneva Graduate Institute.

Table of contents

Abstract	01
About the authors	01
Main authors	01
Contributing authors	02
Acronyms	08
► Introduction	09
► 1 Literature Review	13
1.1 Digital access and labour market outcomes	13
1.2 Gender impact of digital access in labour outcomes	14
► 2 Data and Variables	16
2.1 ILO Harmonized Microdata collection	16
2.2 Mobile coverage data	17
2.3 Sample selection	18
2.4 Variable definitions	19
Outcome variables from the ILO Harmonized Microdata collection	19
Variables from geocoded data	20
Summary statistics	21
► 3 Empirical Strategy	25
3.1 Estimation approach	25
3.2 Identifying assumptions	26
► 4 Results	28
4.1 Labour force participation and labour force composition	28
4.2 Mechanisms	34
4.3 Heterogeneity by individual characteristics	35
4.4 Employment composition	38
4.5 Employment quality	41
4.6 Gender ratios	43

► 5	Robustness and Limitations	46
5.1	Robustness checks	46
5.2	Limitations	47

►	Conclusion	49
---	-------------------	----

	Annex	51
	References	67
	Acknowledgements	71

List of Figures

Figure 1. 3G coverage in Mexico in 2009, 2014 and 2022	17
Figure A1. Regional 3G coverage over time by frequency of lightning strikes	51
Figure A2. First-stage coefficients when excluding country-income groups	52
Figure A3. First-stage coefficients when excluding individual countries	52

List of Tables

Table 1. Summary of countries in sample and representativeness	19
Table 2. Summary statistics for earliest year in sample of main dependent variable and endogenous variable by sex	22
Table 3. OLS results for the impact of regional 3G coverage on labour market outcomes	29
Table 4. IV results for the impact of regional 3G coverage on labour market outcomes	31
Table 5. OLS results for the impact of regional 3G coverage on labour market outcomes by initial 3G coverage	32
Table 6. OLS results for the impact of regional 3G coverage on labour market outcomes by broad country income group	33
Table 7. IV results for the impact of regional 3G coverage on labour market outcomes by age group	36
Table 8. IV results for the impact of regional 3G coverage on labour market outcomes by educational attainment	37
Table 9. IV results for the impact of regional 3G coverage on employment status and sectoral composition	39
Table 10. OLS results for the impact of regional 3G coverage on employment by firm size	40
Table 11A. IV and OLS results for the impact of regional 3G coverage on weekly hours actually worked	42
Table 11B. IV and OLS results for the impact of regional 3G coverage on the gender ratio of monthly earnings	43
Table 12. IV results for the impact of regional 3G coverage on gender ratios in labour market outcomes	45
Table A1. List of sample countries in the IV regression and their available regions and year observations.	53
Table A2. OLS results for the impact of regional 3G coverage on labour market outcomes by age group	54
Table A3. OLS results for the impact of regional 3G coverage on labour market outcomes by age group – Upper-middle-income and high-income countries	55
Table A4. OLS results for the impact of regional 3G coverage on labour market outcomes by age group – Low-income and lower-middle-income countries	55
Table A5. OLS results for the impact of regional 3G coverage on labour market outcomes by educational attainment	56
Table A6. OLS results for the impact of regional 3G coverage on labour market outcomes by educational attainment – Upper-middle-income and high-income countries	56
Table A7. OLS results for the impact of regional 3G coverage on labour market outcomes by educational attainment – Lower-middle-income and low-income countries	57
Table A8. IV results for the impact of regional 3G coverage on labour market outcomes by marital status	58
Table A9. OLS results for the impact of regional 3G coverage on labour market outcomes by marital status	58
Table A10. OLS results for the impact of regional 3G coverage on employment status and sectoral composition	59
Table A11. OLS results for the impact of regional 3G coverage on employment status and sectoral composition – Upper-middle-income and high-income countries	59

Table A12. OLS results for the impact of regional 3G coverage on employment status and sectoral composition – Lower-middle-income and low-income countries	60
Table A13. OLS results for the impact of regional 3G coverage on employment by firm size – Upper-middle-income and high-income countries	61
Table A14. OLS results for the impact of regional 3G coverage on employment by firm size – Low-income and lower-middle-income countries	61
Table A15. OLS results for the impact of regional 3G coverage on gender ratios in labour market outcomes	63
Table A16. OLS and IV results for the impact of regional 3G coverage on labour force participation and status on the population of individuals aged 15-64	64
Table A17. OLS results for the impact of regional 3G coverage on labour force participation and status, removing high-income countries from the sample	64
Table A18. OLS results for the impact of regional 3G coverage on labour force participation and status, removing countries with baseline coverage above 80 per cent	65
Table A19. Comparison of ANCOVA sample and full analysis sample	66
Table A20. ANCOVA results for the impact of regional 3G coverage on labour force participation and status	66

Acronyms

EMP2POP	Employment-to-population ratio
GSMA	Global System for Mobile Communications Association
ICLS	International Conference of Labour Statisticians
ILO	International Labour Organization
IV	Instrumental variable
ILOEST	ILO Modelled Estimates
LFPR	Labour force participation rate
NEET	Not in employment, education or training
OLS	Ordinary least squares
UNE2POP	Unemployment-to-population ratio

► Introduction

The rapid expansion of mobile broadband technologies over the past two decades has profoundly transformed people's daily lives and how they communicate, work and access economic opportunities. Today, 78 per cent of the global population owns a mobile phone (ITU, 2023), and nearly 67 per cent use the internet. Mobile broadband, particularly 3G networks, have been a key driver of this transformation. Unlike 2G networks, which enable voice calls and SMS but not meaningful internet access, 3G transformed mobile phones into internet access points, supporting a wide range of online activities, such as mobile banking, e-commerce, remote work, and digital learning. These advances can influence an individual's economic well-being in multiple ways, such as reducing information frictions, lowering search and transaction costs, enabling remote work and digital entrepreneurship, and allowing consumers and businesses to engage in more competitive marketplaces (Jensen, 2007; Aker, 2010; Bhuller et al., 2023).

Mobile broadband has been particularly transformative in low- and lower-middle-income countries, where fixed-line infrastructure, such as fixed telephone lines and cables, remains limited and mobile phones constitute the primary means of internet access (Stork et al., 2013; ITU, 2023). In 2023, worldwide 95 per cent of the population was covered by at least 3G or above, although there are large discrepancies across income groups. For example, in low-income countries the population coverage reaches only 77 per cent, whereas it is nearly universal in high-income contexts (ITU, 2023). Despite its rapid diffusion, the potential economic benefits of mobile internet may not fully materialize or may do so unevenly across genders. Gender gaps in mobile phone ownership and digital literacy continue to persist. In low- and lower-middle-income countries, women are 14 per cent less likely than men to use mobile internet, as well as 14 per cent less likely to own a smartphone (GSMA, 2025). These disparities suggest that the labour market impacts of 3G coverage may differ systematically by gender.

Understanding these effects is particularly relevant given the persistence of global gender disparities in labour market outcomes. In 2025, the employment-to-population (EMP2POP) ratio of men stood at 69.5 per cent globally, compared with 46.3 per cent for women, a 23.2 percentage point gap, with even wider differences in many developing countries (ILOSTAT, 2025)¹. The diffusion of digital technologies such as 3G could, in principle, help narrow these disparities by facilitating access to information and new work arrangements (Henderson et al., 2026), or conversely, widen them if women face greater barriers to adoption and use.

A growing body of research has examined the relationship between internet access and labour market outcomes. Evidence from lower-coverage and earlier-diffusion contexts generally documents positive effects on employment, job matching, and labour force participation, with studies from both developing countries and early-stage diffusion episodes in developed economies pointing to reduced information frictions and improved market access as key mechanisms (Aker and Fafchamps, 2015; Hjort and Poulsen, 2019; Chiplunkar and Goldberg, 2022; Kuhn and Mansour, 2014). However, these positive effects appear to diminish or reverse as coverage matures: evidence from more advance or higher-coverage settings suggest smaller employment gains, consistent with diminishing returns at later stages of diffusion (Kolko, 2012). Moreover, while some studies consider gender-disaggregated outcomes, relatively little attention has been devoted to

¹ Figures based on ILO Modelled Estimates (ILOEST) using the 13th International Conference of Labour Statisticians (ICLS) definitions for employment.

how digital expansion affects gender gaps themselves or to whether the positive effects documented in developing contexts extend to more advanced economies.

In this paper, we analyse the expansion of 3G mobile network coverage between 2004 and 2023 across 52 countries, predominantly high- and upper-middle-income countries, representing approximately 28 per cent of the global labour force and covering all levels of economic development. Using harmonized labour force survey microdata from ILOSTAT combined with high-resolution regional coverage maps, we estimate the effects of 3G expansion on labour force participation, employment- and unemployment-to-population ratios, employment composition and sectoral allocation. For all these outcomes, we further investigate whether improved digital access has contributed to widening or narrowing existing gender gaps. The cross-country scope, long time horizon, and consistent harmonization of labour market variables allow us to provide one of the most comprehensive assessments of the labour market consequences of mobile broadband diffusion to date.

Identifying the causal impact of digital connectivity on labour market outcomes presents empirical challenges, as network rollout is typically correlated with economic development, infrastructure investment, and other region-specific factors. To address this concern, we first leverage ordinary least squares (OLS) regressions that include region and time fixed effects, as well as several variables that allow us to control for other trends in telecommunication technology diffusion and broader economic development. Second, to further tighten the causal interpretation of our results, we employ an instrumental-variable strategy that exploits regional variation in lightning strike frequency to predict 3G rollout, conditional on 2G coverage and other controls. Because lightning increases the cost of constructing and maintaining telecommunications infrastructure, it generates plausibly exogenous variation in 3G expansion across regions (Chiplunkar and Goldberg, 2022; Guriev et al., 2021; Adema et al., 2022; Jain and Stemper, 2026). We note that our instrumental variable strategy loses precision when the sample is split to examine heterogeneous impacts, as the first stage coefficient becomes statistically insignificant for some smaller subsamples. Therefore, we rely on OLS regressions for all discussion of heterogeneity in the impact of 3G expansion across country income groups or by baseline level of 3G coverage.

Preview of findings

Global results: Our findings show that the labour market effects of 3G expansion are highly context-dependent. In pooled OLS regressions, additional 3G coverage is associated with near-zero average effects on labour force participation, reflecting a small increase in the employment-to-population ratio that is broadly offset by a decline in the unemployment-to-population ratio. By contrast, the instrumental-variable estimates indicate more negative average effects: a 10-percentage-point increase in 3G coverage reduces labour force participation and the employment-to-population ratio by 1.3 and 2.7 percentage points respectively, while increasing the unemployment-to-population ratio by 1.4 percentage points. In both specifications, coverage and labour market outcomes are measured in the same survey year, so these effects are contemporaneous by construction. These differences between OLS and instrumental variable (IV) estimates are informative. Our IV strategy identifies a local average treatment effect that appears to place more weight on upper-middle- and high-income contexts, which entered our sample already at advanced stages of 3G diffusion, with average national coverage of 52 and 69 per cent respectively at the time of their earliest survey year, where the marginal returns to additional coverage expansion are therefore likely to be smaller or even negative.

Country-level heterogeneity: Looking beyond pooled averages, the results consistently point to strong heterogeneity by stage of digital diffusion and level of development. In countries with

low initial 3G coverage (i.e., those countries with coverage below the sample mean of 55.5 per cent when entering our sample), additional rollout is associated with higher labour force participation and employment, with particularly strong gains for women. By contrast, in countries with higher initial coverage, additional 3G expansion is associated with lower labour force participation, driven mainly by lower employment. A similar pattern emerges when splitting the sample by country income group. In low- and lower-middle-income countries, 3G rollout is associated with higher employment and lower unemployment, whereas in upper-middle- and high-income countries the average effects are mostly null in OLS, and the negative effects from the IV regressions are concentrated in the more advanced economies that dominate the first stage. Taken together, these results suggest that the labour market effects of 3G expansion depend critically on where countries stand in the digital diffusion process: early rollout appears more likely to relax binding information and access constraints, while later rollout may coincide with diminishing returns and labour market adjustment of a different nature.

Individual-level heterogeneity: The effects of 3G expansion also vary substantially across workers and across types of employment. Looking at heterogeneity by age, the negative IV effects are concentrated among older individuals, particularly those aged 55 and above, while younger individuals show more favourable participation responses. By education, gains in labour force participation and employment are concentrated among workers with basic or intermediate education, while both labour force participation rate (LFPR) and the employment-to-population ratio contract among individuals with advanced education. Finally, the estimates suggest somewhat more favourable employment effects for married women than for unmarried women.

Employment composition: We also show that 3G expansion affects not only whether people work, but also the type of work they do. In lower-income settings, additional coverage is associated with shifts away from employee status and toward own-account and, for women, contributing family work, pointing to a possible increase in vulnerable forms of employment. In more advanced contexts, the compositional shifts are more consistent with an increase in wage employment, reallocation out of agriculture and toward services and industry, and movement away from very small firms toward medium-sized firms. We further find that 3G expansion is not associated with significant changes in job quality, as measured by average weekly hours worked and the gender gap in monthly earnings among employees, for either gender, although we find some evidence that digital access may contribute to widening gender gaps in earnings in economically advanced contexts, and narrow them in lower-income and lower-coverage countries.

Gendered impacts: Finally, our analysis of female-to-male outcome ratios suggests that 3G expansion does not systematically narrow gender gaps in labour market outcomes. The most robust gendered pattern is not a general convergence in employment or unemployment, but rather a worsening of relative outcomes for young women in poorer settings, where the female-to-male NEET ratio rises with 3G coverage. In richer countries, where coverage expansion occurs from already high baseline levels, the effects on gender gaps operate primarily through sectoral composition rather than overall labour market attachment: women become relatively more concentrated in services and less concentrated in industry, consistent with digital connectivity reinforcing structural shifts already underway in these economies.

Taken together, our findings caution against viewing mobile broadband expansion as a technology with uniform labour market effects. Instead, 3G rollout reshapes labour force participation, employment composition, and gender inequalities in ways that vary systematically with countries' stage of digital development, labour market structure, and the characteristics of the workers exposed to it. Although 3G has been superseded by newer technologies, it constituted the first large-scale expansion of mobile broadband worldwide. Studying its diffusion therefore provides

insights into how general-purpose digital technologies interact with labour markets, offering lessons that remain relevant as economies adapt to subsequent waves of technological change.

These findings contribute to the literature in three main ways. First, they provide evidence from a large and diverse cross-country sample that the labour market effects of mobile broadband are highly non-linear and context specific. Second, they show that focusing only on aggregate employment effects risks missing important shifts in the composition and quality of jobs. Third, they highlight that digital infrastructure policy alone is unlikely to deliver inclusive labour market improvements unless accompanied by complementary interventions, including policies to support job quality, formalisation, and equal access to digital technologies for women and other disadvantaged groups.

The remainder of this paper is structured as follows. Section 1 reviews the literature on the impact of digital access on labour market outcomes, with a focus on gender-disaggregated effects. Section 2 presents the data used in our analysis. Section 3 describes our empirical strategy, which uses OLS regressions with fixed effects and an instrumental variable approach that exploits variation in lightning frequency. We discuss our results on various labour market outcomes by gender in Section 4. Section 5 provides robustness checks, and the last section concludes.

► 1 Literature Review

This paper contributes to two related strands of literature. The first examines the effects of digital infrastructure and internet access on labour market outcomes. The second, which builds directly on the first, focuses on whether and how digital expansion affects gender gaps in employment and job quality.

1.1 Digital access and labour market outcomes

A number of studies have explored how mobile ownership, smartphone ownership, internet use, and broadband influence various economic outcomes, including labour force participation, employment, and sectoral composition. The evidence, however, is far from uniform, and a key dimension along which findings diverge is the stage of digital diffusion and the level of economic development of the country at the time of study.

Evidence from lower-coverage and earlier-diffusion contexts, where connectivity was still expanding from a low base, generating high marginal returns to additional coverage, generally documents positive labour market effects, though with important nuance around job quality and composition. Early micro-level studies documented reductions in information frictions and improvements in job matching. In agricultural and informal settings in developing countries, 2G mobile coverage reduced price dispersion and expanded market access, primarily through voice calls and SMS rather than internet access ([Aker and Fafchamps, 2015](#), covering Niger over 1999–2008). In developed country contexts, [Kuhn and Mansour \(2014\)](#), studying the United States over 2005–2008, find that unemployed workers who searched for jobs online were re-employed approximately 25 per cent faster than comparable workers who did not, pointing to reduced search frictions as a key mechanism through which connectivity improves labour market matching.

More recent work exploiting broader rollout of fast internet in developing contexts has similarly found large positive effects on employment. [Hjort and Poulsen \(2019\)](#), exploiting the gradual arrival of submarine internet cables on Africa's coast between 2009 and 2014, a period during which only 13 per cent of Africans used the internet, find that the arrival of fast internet increased employment rates by between 3 and 13 per cent across 12 African countries. Importantly, these gains occurred broadly across the educational attainment range and did not displace jobs in unconnected areas, suggesting genuine net job creation rather than spatial reallocation. The employment gains were driven in part by increased firm entry, higher firm-level productivity, and expanded exports. [Bahia et al. \(2023\)](#) and [Bahia et al. \(2024\)](#) similarly find that exposure to 3G expansion in Tanzania (2008 to 2013) and Nigeria (2010 to 2016) increased labour force participation, wage and non-farm employment. [Chiplunkar and Goldberg \(2022\)](#), using data from fourteen developing countries between 2001 and 2016, a period when 3G coverage was still expanding from low baselines, find that 3G expansion increased labour force participation and employment for both women and men, with shifts in occupational structure including movements toward wage employment and services. However, positive effects on employment levels do not always translate into improvements in job quality or formality.

An early illustration of how the stage of diffusion shapes the nature of connectivity's labour market effects comes from [Kolko \(2012\)](#), who studies the rapid diffusion of fixed broadband in the United States between 1999 and 2006, a period during which household availability rose from

near zero to approximately 85 per cent. Despite finding a positive relationship between broadband expansion and local employment growth, Kolko documents that the share of working-age adults employed was unaffected, as population inflows absorbed job gains without raising residents' likelihood of finding work. This divergence between aggregate employment growth and individual-level employment rates suggests that even within a single diffusion episode, the benefits of connectivity may shift in nature as coverage matures, a pattern that motivates our focus on heterogeneity by stage of diffusion across countries.

The existing literature has comparatively little to say about what happens at later stages of diffusion, when coverage is already high and the marginal returns to additional expansion are likely smaller. Most existing studies, including those from developed country contexts such as [Kolko \(2012\)](#) and [Kuhn and Mansour \(2014\)](#), studied periods of early or rapid rollout. This leaves open the question of whether the positive employment effects documented in low-coverage settings persist, diminish, or reverse as economies move further along the diffusion curve, a question that is directly relevant for policy as more countries approach near-universal coverage.

This gap in the literature motivates our analytical focus on heterogeneity by stage of diffusion and level of economic development. Our sample, which spans all income groups and covers a period during which average national 3G coverage ranged from 19 per cent in low-income countries to 69 per cent in high-income countries at the time of their earliest survey year, allows us to study both the early and later phases of digital diffusion within a single unified framework, and to provide direct evidence on a part of the diffusion curve that existing work has largely left unexamined.

1.2 Gender impact of digital access in labour outcomes

The literature on gender-specific effects of digital expansion mirrors the broader pattern documented in Section 1.1: findings tend to be positive in lower-coverage and lower-income contexts, while evidence from more advanced settings is sparse or absent. Most studies in this strand focus on developing countries or early-diffusion periods, which limits what can be inferred about how digital expansion shapes gender gaps across the full diffusion curve.

In lower-coverage and lower-income settings, increased internet access or mobile phone ownership is broadly associated with higher female labour force participation and employment ([Efobi et al., 2018](#); [Klonner and Nolen, 2010](#); [Ngoa and Song, 2021](#)). Digital expansion has also been linked to increases in female non-farm employment, rural self-employment, and measures of women's economic empowerment ([Li and Chen, 2025](#); [Wang and Zhang, 2022](#); [Rotondi et al., 2020](#)). These effects are typically attributed to reduced job search costs, improved information flows, enhanced market integration, and greater flexibility in balancing paid work with household responsibilities. As already discussed in Section 1.1, [Chiplunkar and Goldberg \(2022\)](#) provide the most comprehensive cross-country evidence in this vein, finding that 3G expansion increased employment for both women and men across fourteen developing countries, though with gains that were often larger for men and accompanied by a shift of women toward more vulnerable forms of work including unpaid agricultural employment. Even in these broadly positive contexts, then, absolute employment gains for women do not necessarily translate into a narrowing of gender gaps in employment quality or earnings. A striking illustration comes from [Barboni et al. \(2024\)](#), who find that a smartphone distribution programme targeting women in rural India widened rather than narrowed gender disparities in employment and information access, as men in the same households made greater use of the distributed devices. This suggests that positive effects of digital expansion on women's employment may depend not only

on connectivity levels but also on complementary barriers, such as digital skills or household bargaining power, that infrastructure alone cannot address ([Begazo et al., 2023](#)).

Evidence from single-country studies reinforces this nuance. [Viollaz and Winkler \(2021\)](#) show that broadband expansion in Jordan increased female labour force participation primarily among unmarried women, with stronger effects among older and more educated women, suggesting that gains are uneven within the female population even in settings where the overall direction is positive. [Kusumawardhani et al. \(2023\)](#), studying Indonesia over 2008–2018, find that while internet availability modestly increased young and low-educated women's probability of holding a full-time job, it simultaneously reduced their chances of holding a formal or skilled job, pointing again to a tension between employment quantity and quality.

Critically, however, almost all of this evidence comes from developing country or early-diffusion contexts. Very little is known about how digital expansion affects gender gaps, as opposed to separate male and female outcomes, in more advanced or later-diffusion settings. Moreover, as noted in Section 1.1, studies rarely examine participation, employment, and unemployment jointly, which is particularly limiting for the study of gender gaps: a connectivity-driven increase in female participation that outpaces employment gains would raise female unemployment rather than improve women's labour market position, a dynamic that examining employment alone would miss entirely. This paper addresses these gaps by examining gender ratios, rather than separate male and female outcomes, across a sample spanning all income groups and a wide range of baseline coverage levels, thereby evaluating the external validity of earlier findings and assessing how the effects of digital expansion on both labour market outcomes and gender gaps vary across income groups, stages of diffusion, and worker characteristics.

► 2 Data and Variables

This section describes the data used in our analysis and the variables that we construct and use in the regressions.

2.1 ILO Harmonized Microdata collection

A common challenge in cross-country analyses of digital expansion is the reliance on heterogeneous data sources, often combining population censuses, household surveys, and labour force surveys into a panel format. While censuses provide broad coverage, they are not always designed to measure labour market dynamics according to internationally harmonized statistical standards, particularly with respect to definitions of employment and unemployment. Moreover, mixing different survey instruments over time may introduce artificial variation arising from changes in questionnaire design, sampling frames, or definitions rather than genuine labour market shifts. Such inconsistencies can generate measurement noise and bias estimated effects.

The [ILO Harmonized Microdata](#) collection addresses these concerns by collating labour force surveys, household surveys, and censuses from over 180 countries and harmonizing them to ensure cross-country and intertemporal comparability. All dependent variables used in our analysis are drawn from this harmonized dataset. We prioritize labour force surveys whenever available, as they follow internationally agreed statistical standards for measuring employment, unemployment, and labour force status. In addition, we implement cleaning procedures to retain only series that are comparable over time, excluding survey waves where definitional changes or methodological breaks compromise consistency. These steps aim to ensure that variation in labour market outcomes reflects real economic changes rather than inconsistencies in survey design.

For the purpose of this analysis, we apply the following criteria for survey and sample selection. First, we compile all available microdata from 2004 to 2024. This period coincides with the time when the 3G mobile internet technology was developed and rapidly expanded, and for which we also have information on 3G mobile internet coverage (see more details below). Second, as our analysis exploits variation in mobile internet coverage across regions within a country and over time, we restrict the analysis sample to surveys from the ILO Harmonized Microdata collection that contain information on the region of residence of respondents.

With regard to geographical information from the ILO microdata, in 2023 the ILO launched a geocoding exercise in which selected surveys from the ILO Harmonized Microdata collection were harmonized to record information on sub-national geographic variables for each country and year. The sub-national regions may be defined by districts, counties, municipalities, or states. For the purpose of our analysis, we retain all surveys that include information on the sub-national location of residence of respondents, and where we could match this geographical information to standard levels of regional boundaries.²

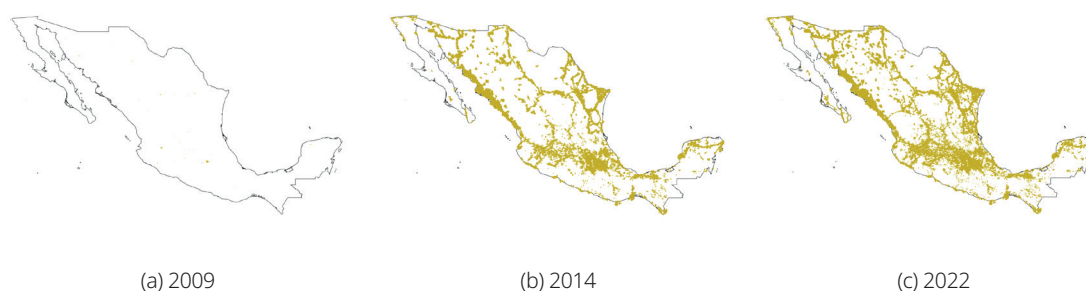
In terms of sample selection, we restrict the sample to individuals of at least 15 years of age (working-age individuals), as our primary interest is investigating the impact of 3G mobile internet expansion on labour market outcomes.

² Annex Table A1 reports the sources of all administrative level shapefiles used in this paper.

2.2 Mobile coverage data

We use global maps of 2G and 3G network coverage from 2009 to 2022 collected by Collins Bartholomew's Mobile Coverage Explorer. These maps are generated from submissions by mobile operators who are members of the Global System for Mobile Association (GSMA). Each annual map consists of 1x1 km grid cells that contain information on whether there is 2G or 3G coverage.³ Figure 1 displays an example of 3G coverage for Mexico in 2009, 2014 and 2022. For each year, areas shown in mustard colour had 3G coverage and areas in white did not. We combine these mobile network data with population density maps from 2010⁴ to create population-weighted measures of 2G and 3G coverage for each subnational region.

► **Figure 1. 3G coverage in Mexico in 2009, 2014 and 2022**



An important feature of the Collins Bartholomew dataset is that the maps may reflect the underlying coverage information of the year it was last updated. Mobile operators only update their submissions intermittently, and the most recent available coverage information is carried forward until a new update is received. Although the earliest maps we use are dated 2009, for some countries the underlying data used to populate the 2009 map originate from earlier years. Collins Bartholomew has a historical series and for the countries in our sample, the earliest underlying 3G coverage information dates as far back as 2004. Thus, if no new operator submissions were made between 2004 and 2009, the 2009 map reflects the 2004 coverage configuration.

A further limitation is that Collins Bartholomew maps do not capture all operators, and some report infrequently, meaning that reported and actual coverage may not coincide and under-coverage is likely. Nonetheless, to our knowledge no globally comparable alternative currently exists. One emerging approach uses social media data to construct subnational estimates of mobile internet adoption by gender (Breen et al., 2025; Kashyap et al., 2020), but such data are proprietary, not easily accessible, and available only from 2015 onwards, which would substantially limit our sample period. We therefore rely on Collins Bartholomew as the most comprehensive and consistent global source currently available, while remaining mindful of its limitations.

³ The data assume that if a cell is covered by 3G, it would also have 2G coverage. This reflects the standard deployment sequence whereby operators virtually never establish 3G coverage in areas without prior 2G coverage, and is consistent with the approach taken in related studies using similar mobile coverage data (Chiplunkar and Goldberg, 2022).

⁴ Population density maps come from the *Gridded Population of the World (GPW)* collection, now in its fourth version (GPWv4) adjusted to population totals from the United Nations World Population Prospects: The 2015 Revision.

With these limitations in mind, and to ensure that our 3G coverage measure reflects reasonably recent network information, we apply a cleaning rule based on the timeliness of operator updates. For each country, we retain coverage observations only for years in which the most recent underlying operator submission is no more than three years old.⁵ For example, if Zimbabwe last reported a 3G network update in 2019, we treat the 3G coverage maps valid for labour force surveys conducted in 2019, 2020, 2021, and 2022. However, a labour force survey from 2024 would not be paired with the 2019 3G map because the underlying information is more than three years old. Moreover, the last reported 3G network data is only used once for the nearest available survey year. For example, if Zimbabwe has no labour force survey data for 2019, but had data for 2021 and 2022, Zimbabwe's 2019 3G map will be matched with the 2021 labour force survey, but not with the labour force survey from 2022. The reason is that there would be no variation in 3G coverage over time between these two surveys, as 3G coverage information would be artificially carried forward for two years instead of one.

This cleaning and matching procedure ensures that our measure of digital connectivity reflects near-contemporaneous network conditions rather than outdated operator reports. Importantly, it also prevents the mechanical reuse of identical coverage maps across multiple survey years, which would otherwise introduce artificial serial correlation in the measurement of 3G coverage. By restricting repeated matches of unchanged network configurations, we ensure that the identifying variation in the regressions corresponds to genuine changes in underlying infrastructure expansion rather than duplicated observations. As a result, the effective sample size more accurately reflects independent variation in 3G deployment across regions and over time.⁶

2.3 Sample selection

The final sample is restricted by the availability of data from (i) outcome variables from the ILO Harmonized Microdata collection at the sub-national level, and (ii) 2G and 3G coverage data. Table 1 summarises the sample used in the analysis. The 52 countries with data on at least labour force participation rates and 3G coverage represent 28 per cent of both the global population and the global labour force. While not globally representative, the sample spans all income levels: 4 low-income, 8 lower-middle-income, 16 upper-middle-income, and 24 high-income countries, covering between 15 and 55 per cent of each income group's labour force.

The sample also captures meaningful variation in the stage of digital diffusion, which is central to our analysis. With survey years spanning from 2004 to 2023, our sample covers a large arc of 3G expansion, from its early rollout to near-universal coverage in some contexts. This time horizon, combined with the income group diversity of the sample, means we observe countries at very different stages of the diffusion process. High-income countries enter the sample as early as 2004, already at an average national 3G coverage of 69 per cent, while low-income countries enter later, from 2012 onward, at an average coverage of only 19 per cent. By the latest survey year, coverage had increased substantially across all groups, reaching 34 per cent in low-income

⁵ The three-year threshold is a pragmatic choice balancing data currency against sample size. We verified that our main results are robust to alternative thresholds: using a two-year window yields a smaller sample but qualitatively similar results, while a four-year window retains more observations without meaningfully altering the estimates.

⁶ We note that this cleaning procedure differs substantially from existing papers that make use of 3G data from the Collins Bartholomew's Mobile Coverage Explorer, in that most existing work carries forward submitted information on 3G coverage for all years until a new submission is made by a mobile operator. As a result, most existing work relies on mobile coverage data that is artificially repeated over time.

countries and 98 per cent in high-income countries, with the overall sample average rising from 56 to 81 per cent. This variation, both across income groups at a point in time and within countries over the sample period, provides the identifying variation exploited in our empirical strategy and allows us to study both early and later phases of digital diffusion within a single unified framework. Across all countries, the sample comprises 831 sub-national regions, including districts, counties, states, and municipalities, and 4,007 sub-national region-years.

► **Table 1. Summary of countries in sample and representativeness**

	No. of countries	No. of regions	% of countries*	% of group labour force	Earliest and latest survey year	Mean 3G coverage in earliest survey year (% national)	Mean 3G coverage in latest survey year (% national)
All sample	52	831	28	28	2004-2023	56	81
Low-income	4	39	15	15	2012-2021	19	34
Lower-middle income	8	175	21	15	2006-2023	39	65
Upper-middle income	16	303	32	28	2009-2023	52	76
High-income	24	314	38	55	2004-2023	69	98

Note: *Out of the 189 countries included in the ILO modelled estimates.

2.4 Variable definitions

Outcome variables from the ILO Harmonized Microdata collection

We start our analysis by looking at the extensive margin of participation in the labour force, then examine the composition of the employed population and finally analyse measures of job quality, as follows.

Extensive-margin labour market outcomes: We first examine the extensive margin of labour market adjustment by studying whether 3G coverage affects labour force participation and, conditional on participation, whether adjustment occurs through employment or unemployment. Labour force participation captures all individuals who are either in work (employed) or without employment, available for work and seeking work (unemployed), and examining both margins separately allows us to assess whether 3G coverage shifts the overall size of the active labour force, the share of that labour force that finds employment, or both. We consider three region-year outcomes: the labour force participation rate, defined as the labour force divided by the population aged 15 and above; the employment-to-population ratio, defined as total employment divided by the population aged 15 and above; and the unemployment-to-population ratio, defined as the number of unemployed individuals divided by the population aged 15 and above. All three variables are expressed with the population aged 15 and above as the denominator, so that changes in labour force participation, employment, and unemployment are measured relative to the same underlying population base. By construction, the sum of the employment-to-population ratio and the unemployment-to-population ratio yields the labour

force participation rate. Finally, we examine whether 3G coverage is associated with changes in attachment to both work and education for the youth by looking at the NEET rate, defined as the share of youth (15-24) who are not in employment, education, or training.

Employment composition by status in employment: We next examine whether 3G coverage affects the composition of employment across different employment statuses. Specifically, we consider the shares of employers, contributing family workers, own-account workers, and employees in total employment.⁷ Each variable is defined as the number of employed individuals in the relevant category divided by total employment in the region-year.⁸ These measures capture whether digital expansion is associated with shifts in the type of work, for example between wage employment and self-employment or between more and less formal forms of labour market attachment.

Sectoral composition of employment: We also study whether 3G coverage affects the sectoral composition of employment. We construct the shares of employment in agriculture, industry and services, each defined as employment in the relevant sector divided by total employment in the region-year. The three variables for sectoral employment shares sum to 1. These variables capture whether digital expansion is associated with a structural reallocation of labour across sectors of economic activity.

Employment composition by firm size: To study whether 3G coverage is associated with shifts in the distribution of employment across firms of different sizes, we construct measures of the employment share in firms with 1 to 4 workers, 5 to 49 workers, and 50 or more workers. Each variable is defined as employment in the corresponding firm-size category divided by total employment in a region-year.

Job quality and gender earnings gaps: We examine two additional outcomes among people in employment. First, we look at average weekly hours worked, measured as the mean number of hours worked per week by all people in employment, for the total population as well as for women and men separately. Second, we examine gender gaps in earnings among employees. Due to difficulties in comparing earnings levels across countries and over time, we construct this measure as the ratio of mean monthly labour income of female employees to that of male employees in a given region, using survey-based reported earnings data. This ratio captures whether 3G expansion is associated with a narrowing or widening of the gender earnings gap, rather than serving as a measure of absolute job quality.

Variables from geocoded data

We use geocoded data to obtain information on our main variable of interest, 3G coverage, as well as our instrument (a function of lightning strike frequency) and regional controls.

3G coverage: Our main measure of digital access is 3G coverage, defined as the population share covered by a 3G signal in region and year. This measure is constructed from georeferenced raster data at 1 km × 1 km resolution, where for each grid cell we obtain information on local

⁷ Employers are defined as those who operate their own business and hire at least one employee. Own-account workers are self-employed individuals who do not hire others. Contributing family workers are those who work without pay in a business operated by a household member. Employees are workers who hold paid employment jobs. Each variable is defined as the number of employed individuals in the relevant category divided by total employment

⁸ For all subcategories of employment, including sectors and employment status, a very small percentage of employed individuals are uncategorized and thus can be assumed to be close to zero.

population from the GPW and an indicator for whether 3G service is available from the Collins Bartholomew's Mobile Coverage Explorer. For each subnational region-year, we sum the population living in cells with 3G availability and divide by the total population across all cells in the region. For all mobile coverage data years, we use the 2010 population as reference. The resulting variable ranges from 0 to 100 and captures the extent to which the regional population is exposed to 3G network coverage. For each country, we define regions based on the administrative boundaries that correspond to the information contained in the ILO Harmonized Microdata.

2G coverage: We additionally construct a measure of 2G coverage following similar steps as for our main variable of interest – 3G coverage. If in a given year information on 2G coverage has not been reported by mobile operators, we use 2G coverage data from the latest available year for each region. Note that for a given cell to receive 3G signal does automatically imply that it also receives 2G signal, but not vice versa, as the 3G technology requires updated infrastructure to be deployed. We use the measure of 2G coverage as control, to account for any effects of technological development in a given region other than 3G mobile access that might impact labour market outcomes.

Lightning strikes: We measure lightning strike exposure at the region level using georeferenced raster data at 1 km × 1 km resolution, where for each grid cell we obtain information on the average monthly frequency of lightning strikes over the 2010–2023 period from the World Wide Lightning Location Network (WWLLN) Global Lightning Climatology (WGLC). For each subnational region, we aggregate cell-level lightning strike frequency using 2010 population weights, so that cells with larger populations contribute proportionally more to the regional measure. This yields a time-invariant measure of lightning strike exposure for each region. We then define an indicator equal to one if a region's lightning strike frequency is above the median across all regions in the sample, and zero otherwise. Our instrument is constructed by interacting this above-median indicator with year fixed effects.

Rainfall: We collect information on rainfall from the Climate Hazards Center Infrared Precipitation with Stations (CHIRPS v3) and construct a yearly measure of average, population-weighted rainfall for all subnational regions in our sample.⁹

Summary statistics

Table 2 presents summary statistics for the sample used in the analysis, providing an overview of key labour market outcomes and demographic characteristics for each region's earliest year in the sample. The average regional labour force participation rate in the first available survey year was 62.4 per cent, and the unemployment-to-population ratio was 4.8 per cent. Most workers in the first survey year were employees (68.8%), followed by own-account workers (22.5%), contributing family workers (6.1%), and employers (2.7%).

When examining these percentages by gender, the largest differences are that women are more likely to be contributing family workers than men, while men are more likely to be own-account workers. Regarding sectors, women tend to concentrate in the service sector (73.3%), while men are a bit less concentrated between agricultural (17.6%), manufacturing (29.5%) and services (52.9%). The share of youth classified as NEET (not in employment, education, or training) is 17.4 per cent, with young women having NEET rates that are 8.3 percentage points higher than those

⁹ Climate Hazards Center Infrared Precipitation with Stations version 3. CHIRPS3 Data Repository <https://doi.org/10.15780/G2JQ0P> (2025). Data was accessed on 9 September 2025.

of young men on average across the regions in the sample. Differences in the share of employees are smaller, with women having slightly higher shares. In contrast, men are more likely to be employers than women. Finally, employed men spend on average 5.8 hours more per week on paid work than employed women.

The average change in 3G coverage between the first and most recent year for the subregions was 27.4 percentage points, and the median change was 18.0 percentage points. Thus, there is substantial average variation in 3G coverage over time within our sample.

► **Table 2. Summary statistics for earliest year in sample of main dependent variable and endogenous variable by sex**

	Mean	Median	SD	Min	Max
<i>Panel A: Total</i>					
Labour force participation rate	62.4	63.2	8.6	32.6	93.1
Employment-to-population ratio	57.6	57.9	9.5	27.5	92.9
Employment-to-population ratio for married individuals	66.7	65.4	9.4	39.9	98.6
Unemployment-to-population ratio	4.8	4.7	2.8	0.0	24.5
NEET rate	17.4	16.9	8.1	0.0	58.8
Weekly hours actually worked in all jobs per employed person	40.2	39.2	3.7	20.1	57.3
Share of employers	2.7	2.4	3.7	0.0	27.4
Share of contributing family workers	6.1	1.6	8.9	0.0	70.5
Share of own account workers	22.5	19.1	15.7	2.7	90.5
Share of employees	68.8	75.3	22.4	3.7	94.9
Average monthly earnings of employees (USD)	1378.0	695.7	1308.9	27.5	4695.8
Share of agricultural and elementary employment	16.3	6.0	20.0	0.0	95.5
Share of employment in the service sector	61.5	66.0	17.5	2.6	93.7
Share of employment in firms with 1 to 4 workers	48.2	40.5	23.3	7.3	100.0
Share of employment in firms with 5 to 49 workers	26.9	26.5	11.6	0.0	59.2
Share of employment in firms with 50 or more workers	24.9	26.6	15.3	0.0	82.9
3G regional coverage	54.3	58.2	31.3	0.0	100.0
<i>Panel B: Women</i>					
Labour force participation rate	52.0	53.9	12.6	10.3	92.1
Employment-to-population ratio	47.8	49.1	12.9	6.9	91.9
Employment-to-population ratio for married individuals	52.9	54.2	15.6	4.6	99.2
Unemployment-to-population ratio	4.2	4.1	2.6	0.0	25.0

NEET rate	21.6	20.0	12.4	0.0	75.1
Weekly hours actually worked in all jobs per employed person	36.8	36.2	4.4	13.4	54.9
Share of employers	1.3	1.1	1.5	0.0	14.4
Share of contributing family workers	9.8	2.5	14.4	0.0	84.0
Share of own account workers	19.5	14.9	16.2	0.0	98.0
Share of employees	69.5	79.7	25.6	0.0	100.0
Average monthly earnings of employees (USD)	1175.1	637.6	1088.5	13.6	4390.7
Share of agricultural and elementary employment	14.2	3.2	20.7	0.0	98.7
Share of employment in the service sector	73.3	82.1	21.0	1.3	100.0
Share of employment in firms with 1 to 4 workers	47.5	45.4	26.5	0.0	100.0
Share of employment in firms with 5 to 49 workers	26.7	27.2	14.2	0.0	72.4
Share of employment in firms with 50 or more workers	25.8	26.6	17.1	0.0	93.2
<i>Panel C: Men</i>					
Labour force participation rate	73.3	73.5	8.0	42.7	100.0
Employment-to-population ratio	67.9	68.3	9.7	32.8	93.9
Employment-to-population ratio for married individuals	80.8	81.5	9.3	50.0	100.0
Unemployment-to-population ratio	5.4	5.1	3.2	0.0	24.9
NEET rate	13.3	13.4	6.0	0.0	48.9
Weekly hours actually worked in all jobs per employed person	42.6	41.4	3.4	26.4	59.5
Share of employers	3.4	3.1	4.5	0.0	32.1
Share of contributing family workers	3.8	1.0	6.0	0.0	58.5
Share of own account workers	24.5	20.2	15.9	0.7	87.4
Share of employees	68.3	72.8	20.4	5.4	94.7
Average monthly earnings of employees (USD)	1562.5	718.3	1531.5	29.0	5567.0
Share of agricultural and elementary employment	17.6	7.8	20.0	0.0	95.3
Share of employment in the service sector	52.9	54.6	15.2	4.1	90.6
Share of employment in firms with 1 to 4 workers	47.3	39.7	22.9	7.4	100.0
Share of employment in firms with 5 to 49 workers	27.6	28.0	11.4	0.0	66.4
Share of employment in firms with 50 or more workers	25.0	27.9	15.3	0.0	79.2

<i>Panel D: Difference between first and latest year in sample</i>					
Change in 3G coverage (p.p.)	27.4	18.0	28.9	0.0	100.0

Note: Summary statistics presented for the earliest year within the sample for each country. Source: ILO Harmonized Microdata collection and Collins Bartholomew's Mobile Coverage Explorer.

► 3 Empirical Strategy

3.1 Estimation approach

To identify the causal impact of access to 3G mobile coverage on the labour market outcomes of women and men, we employ an instrumental variable approach with fixed effects. For each region r and year t , we construct measures of labour market outcomes that are either: (1) defined as the fraction of individuals in rt who report a given outcome, for example, employment (i.e., the employment-to-population ratio), unemployment, the labour force; (2) shares of different employment categories within total employment in rt (e.g., employment by status, sector or firm size); (3) gender ratios, calculated as the ratio of the outcome for women to that for men, for example the ratio of female to male employees' monthly pay; or (4) outcomes in levels for our measures of employment quality, i.e. average weekly hours actually worked.¹⁰ We calculate these measures using population weights at the rt level for men and women separately (except for gender ratios). We construct weights for each outcome as the ratio of a country's 2010 population to the maximum number of non-missing observations available for that outcome within the country, calculated separately by sex. This weighting scheme ensures that regions from countries with fewer available survey years are not systematically downweighted relative to those with more observations, while still anchoring the weights to a fixed population benchmark. In practice, the weights are proportional to population size, adjusted for data availability.

First, we estimate the following OLS regression specification:

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

where Y_{rt} denotes the outcomes of interest (e.g., employment-to-population ratio, unemployment-to-population ratio, share of employment type, etc.). α_r represents region fixed effects that control for all observable and unobservable time-invariant characteristics of a region, while α_t represents year fixed effects, capturing common changes across all regions over time. X_{rt} is a vector of geographic controls (2G coverage and rainfall) that may affect the provision of 3G coverage in these areas as well as the outcome of interest. The inclusion of 2G coverage by region and year helps isolate the effect of 3G coverage, distinguishing it from broader trends in cell phone coverage that may be linked to labour market developments.

A natural extension would be to examine whether effects are immediate or accumulate over time, as some studies find accumulated impacts of mobile internet on economic outcomes (Bahia et al., 2024). However, the irregular spacing of surveys across countries, with some countries having as few as two observations in total, makes both a lagged analysis and a formal examination of effect accumulation infeasible, as lags would represent different time horizons across countries and yield non-comparable estimates. Furthermore, countries with a sufficient number of observations to construct lags are predominantly high-income, meaning any lagged analysis would not be representative of the full cross-country variation that motivates our paper. We acknowledge this as a direction for future research as higher-frequency harmonised data becomes available across a broader set of countries.

¹⁰ Note that for gender ratios, whenever either the denominator or the numerator is zero, the corresponding gender ratio is not constructed.

While the inclusion of region and time fixed effects helps mitigate concerns about omitted-variable bias by absorbing time-invariant regional characteristics and common time trends, reverse causality remains a concern since 3G rollout may be endogenous to contemporaneous local economic conditions. We therefore additionally employ an instrumental variable approach to further tighten the causal interpretation of our coefficient of interest, β . Because the rollout of 3G networks may be endogenous to (unobserved) local economic conditions, we instrument 3G coverage using the interaction between an indicator for whether a region has above-median lightning strike frequency and year fixed effects. As can be seen from Figure A1, higher lightning strike frequency is significantly associated with lower 3G coverage at the regional level, especially in the early years of 3G rollout. The first stage therefore exploits differential changes over time in 3G rollout between high- and low-lightning regions, and the second stage uses this predicted variation to estimate the causal effect of 3G coverage on labour market outcomes. The first-stage equation we estimate is as follows:

$$3G_{Coverage_{it}} = \zeta_r + \zeta_t + \gamma \text{Lightning}_r \times \text{Year}_t + X_{it}\delta + \eta_{it}$$

where $\text{Lightning}_r \times \text{Year}_t$ is the indicator for a region having lightning frequency above median, interacted with year fixed effects.

3.2 Identifying assumptions

The validity of our empirical strategy rests on two conditions. First, relevance: regional lightning strike frequency must be a strong predictor of 3G rollout, conditional on 2G coverage and other controls. Figure A1 provides visual evidence supporting this relationship: regions with below-median lightning strike frequency consistently exhibit higher 3G coverage than regions with above-median frequency throughout the entire period, with a gap of approximately 20 percentage points in most years. However, the figure also reveals that this gap remains relatively stable over time, with both groups expanding at broadly similar rates. This implies that the instrument operates primarily through cross-sectional differences in coverage levels between regions rather than through differential trends in the pace of rollout. Once region fixed effects are included, which absorb these time-invariant cross-sectional differences, the identifying variation comes from the more modest differential in the rate of 3G expansion between high- and low-lightning regions over time. This explains why the first-stage F-statistic of 9.2, while meeting conventional thresholds, sits at the boundary of standard weak instrument criteria.

Second, the exclusion restriction requires that lightning frequency affects labour market outcomes only through its effect on 3G coverage. The primary mechanism through which lightning affects 3G deployment is by raising infrastructure costs: lightning strikes damage telecom equipment and increase outage risk, making deployment in high-lightning areas more costly and less attractive for mobile operators. Since 2G and 3G require distinct tower infrastructure, this cost increase applies to 3G rollout even in areas already covered by 2G.

We use a time-invariant measure of long-run average lightning density rather than year-by-year variation, which reduces the risk that our instrument captures time-varying climate-driven shocks rather than structural geographic differences in infrastructure costs. Nonetheless, several potential threats to the exclusion restriction warrant discussion. Lightning frequency may correlate with climate conditions that independently affect labour markets through agricultural productivity; we address this by controlling for rainfall, the most direct climate-related channel. A further concern is the concurrent expansion of physical infrastructure, notably electricity grids and transport networks, which both lowers the cost of deploying 3G and independently improves

labour market conditions. A more serious concern is that lightning-ignited wildfires or damage to electricity grids could disrupt local economic activity directly, independently of 3G. While we cannot fully rule out these channels, we note that our instrument has been validated across a wide range of outcomes and contexts in the existing literature¹¹, and that our OLS results, which do not rely on the exclusion restriction, point in qualitatively similar directions, lending confidence that the IV results are not driven by instrument invalidity alone.

Given the inherent difficulty of fully validating any exclusion restriction, we treat the IV estimates as complementary to rather than strictly superior to the OLS results. The OLS specification with region and time fixed effects and 2G coverage controls already addresses the most important sources of omitted variable bias, including the concurrent expansion of physical infrastructure such as electricity grids and transport networks, which both lowers the cost of 3G deployment and independently improves labour market conditions, and which region fixed effects absorb to the extent that such expansion is time-invariant or slow-moving. The consistency between OLS and IV directions across specifications provides additional credibility to our findings.

¹¹ The lightning-strike instrument on 3G impacts has been used across a range of contexts, including protests and mobilization ([Manacorda and Tesei, 2020](#)), emigration intentions ([Adema et al., 2022](#)), employment outcomes ([Chiplunkar and Goldberg, 2022](#)), firm-level outcomes ([Caldarola, 2022](#)), financial analysts' performance ([Fang et al., 2023](#)), and policy and social outcomes ([Rezki, 2023](#)).

► 4 Results

Our analysis examines how expanded 3G coverage affects different dimensions of labour market performance for the total population and by sex. We begin by studying core indicators that capture whether individuals are working, seeking work or outside the labour force entirely. We also explore heterogeneity by looking at individuals from different age groups, education levels and marital status. Finally, after analysing shifts in the overall pool of workers and jobseekers, we focus on how 3G coverage relates to the type of jobs people hold, differentiating by type of employment, sector and firm size.

4.1 Labour force participation and labour force composition

Table 3 reports the baseline OLS estimates of the relationship between 3G coverage and labour market status in the working-age population (those aged 15+), considering labour force participation, the employment-to-population ratio, the unemployment-to-population ratio, as well as the share of youth aged 15-24 not in employment, education or training (NEET). We begin with OLS estimates for the full sample and then contrast them with results from our instrumental variable approach (see Table 4), reporting outcomes for the total population (Panel A) and separately for women and men (Panels B and C, respectively).

The OLS results suggest near-null average effects of 3G expansion on aggregate labour force participation rate for the total population. This pattern is driven by a statistically significant, albeit small in magnitude, increase in the employment-to-population ratio (EMP2POP), offset by a decrease in the unemployment-to-population ratio (UNE2POP), meaning that 3G coverage seems to be associated with a reallocation of the labour force from unemployment to employment, rather than increase participation overall. Across genders, the OLS coefficients of 3G coverage on LFPR remain statistically insignificant and close to zero for both men and women. The employment-to-population ratio increase that we find for the total population is driven by quantitatively similar employment increases for both men and women (although the coefficient is only significant at conventional levels in the male regression), whereas women exposed to additional 3G rollout see a slightly stronger decrease in unemployment in the full sample. Taken together, the OLS estimates do not indicate a broad-based increase in labour force participation following 3G rollout in the total sample of 52 countries.

However, column 4 of Table 3 suggests that 3G coverage is associated with deteriorating outcomes for youth, to the extent that the NEET rate increases by 0.2 percentage points for a 10-percentage-point increase in 3G rollout on average, although the coefficient is not significant at conventional levels. To put this increment in context, the average change in 3G coverage across subnational regions between the first and last survey year in our sample was 27.4 percentage points, with a median of 18 percentage points and considerable dispersion. A 10-percentage-point increase therefore represents a meaningful but not unusually large shift. Given an average NEET rate of 17.4 per cent in the first survey year across the 52 countries in the sample, a 0.2 percentage point increase corresponds to an increase of 1.1 per cent over the sample mean. The association between 3G rollout and the NEET rate is slightly stronger for women than it is for men.

► Table 3. OLS results for the impact of regional 3G coverage on labour market outcomes

	LFPR	EMP2POP	UNE2POP	NEET rate
<i>Panel A: Total</i>				
3G coverage (%)	0.01	0.01**	-0.01	0.02
	(.01)	(.01)	(.00)	(.02)
R2 (within)	.067	.088	.257	.089
<i>Panel B: Women</i>				
3G coverage (%)	0.0	0.01	-0.01*	0.03
	(.01)	(.01)	(.00)	(.02)
R2 (within)	.065	.096	.204	.091
<i>Panel C: Men</i>				
3G coverage (%)	0.01	0.01*	0.0	0.02
	(.01)	(.01)	(.01)	(.02)
R2 (within)	.109	.085	.272	.097
N	4007	4007	4007	4007
N. regions	831	831	831	831
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100) controlling for region and year fixed effects and region-specific controls. Standard errors clustered at the sub-national region level reported below coefficients. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Our OLS estimates control for two variables that allow to exclude that our coefficient of interest is biased by region-specific or time-specific trends, or by other telecommunication infrastructure development more broadly, as for example the rollout of 2G mobile internet. However, they remain subject to the risk of bias arising from unobserved factors that influence both 3G rollout and labour market outcomes. For this reason, we compare our OLS estimates with estimates from the instrumental variable approach, that provides a tighter causal interpretation of the effect of 3G rollout on labour market outcomes. Table 4 reports IV results for our main variables of labour force participation and composition. The first stage results show that our instrument, constructed by interacting the dummy for lightning frequency above the global median with year fixed effects, strongly predicts 3G rollout in the analysis sample: in regions with above-median lightning frequency, 3G coverage grows by 0.74 percentage points less than in regions with below-median lightning strike frequency. We note, however, that due to the double estimation step and resulting increase in estimation error, we can leverage our IV strategy only on the full sample of 52 countries, whereas any sample split based on country-characteristics leads to lack of power in our first-stage specification. Therefore, this section reports IV results only for the full sample of 52 countries and goes back to OLS estimates to comment on any heterogeneous effect of 3G coverage by country groups.

Looking at the second-stage results, the coefficients from the IV estimates paint a more negative picture than the findings from the OLS regressions. Instrumenting 3G coverage with a function of lightning strike frequency, we find that increases in coverage are associated with declines in labour force participation in the full sample: a 10 percentage-point increase in 3G coverage leads to a 1.3 percentage-point decline in LFPR, which corresponds to a decline of 2.1 per cent over the baseline mean of 62.4 per cent. This decline is driven by a 2.7 percentage-point decline in the EMP2POP ratio, which more than offsets the positive 1.4 percentage point effect of additional

3G coverage on the likelihood of seeking and being available for work (UNE2POP). Similar to the OLS results, gender differences in the effects of 3G coverage on labour force participation and status appear rather muted.

Across outcomes, the IV coefficients for the impact of 3G on labour force attachment and composition are consistently below the corresponding OLS estimates, indicating that instrumenting for 3G coverage shifts the results in a negative direction relative to OLS. The contrast between the OLS and IV coefficients is informative. While OLS estimates likely reflect endogenous rollout consistent with upward bias, with 3G expanding earlier in regions with stronger labour market growth trajectories, the IV strategy isolates variation in 3G coverage driven by exogenous differences in baseline lightning density. As a result, the IV coefficients can be interpreted as a local average treatment effect for the compliers, or in other words, they capture the impact of 3G expansion for regions where 3G rollout is more responsive to these exogenous factors. The more negative IV coefficients suggest that either OLS estimates are biased upward, and hence the causal effect of 3G coverage on labour market outcomes is more negative than implied by the OLS regression, or that in our analysis sample the local average treatment effect estimated by the IV coefficients is driven by countries where the labour market consequences of additional 3G expansion are less favourable than in the average country.

We can investigate whether the variation in our first stage regressions is coming from a specific set of countries by looking at how the relationship between lightning strike density and 3G rollout in the first stage of the IV approach changes when removing specific (subsets of) countries from the sample. Figure A2 shows the “leave-one-out” first-stage coefficient of our instrument on 3G coverage, where each bar corresponds to regressions run on a sample that excludes the countries belonging to the income group labelled at the bottom of the figure.¹² The graph shows that the instrument primarily shifts coverage in upper-middle- and high-income countries that were already relatively advanced in mobile internet diffusion, and which also constitute the vast majority of our observations. Indeed, when removing high-income or upper-middle-income countries from the sample, the first stage coefficient becomes insignificant and even switches sign. While our weighting scheme ensures that countries with fewer available survey years are not systematically downweighted within their income group, it does not alter the fact that high- and upper-middle-income countries constitute the majority of countries and regions in the sample. The instrument therefore draws disproportionately on variation from these contexts, a limitation that the weights cannot fully address. We note that high- and upper-middle-income countries are contexts where marginal gains from further coverage expansion are likely to be smaller and displacement effects more likely (Briglaue et al., 2024). Therefore, the IV estimate could be negative even when the pooled OLS estimate is close to zero, as the variation it is leveraging comes from a set of countries where the additional expansion of 3G rollout comes on top of already high coverage and likely has diminishing or negative returns.

¹²

Figure A3 additionally shows the leave-one-out coefficients when removing one country at a time from the sample.

► Table 4. IV results for the impact of regional 3G coverage on labour market outcomes

	LFPR	EMP2POP	UNE2POP	NEET rate
<i>First-stage results</i>				
Lightning x Year	-0.74***	-0.74***	-0.74***	-0.74***
	(.24)	(.24)	(.24)	(.24)
First-stage F-statistic	9.22	9.22	9.22	9.22
<i>Panel A: Total</i>				
3G coverage (%)	-0.13*	-0.27**	0.14**	0.02
	(.07)	(.11)	(.06)	(.12)
<i>Panel B: Women</i>				
3G coverage (%)	-0.17*	-0.29**	0.11**	-0.12
	(.09)	(.12)	(.05)	(.14)
<i>Panel C: Men</i>				
3G coverage (%)	-0.08	-0.25**	0.17**	0.18
	(.07)	(.12)	(.07)	(.12)
N	4007	4007	4007	4007
N. regions	831	831	831	831
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from IV regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage, 3G coverage is instrumented with an indicator for regional lightning frequency above the sample median interacted with year fixed effects. Standard errors clustered at the subnational region level reported below coefficients. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

To further test this hypothesis and better understand the source of the aggregate results, Table 5 presents OLS estimates when we split the sample by baseline 3G coverage. We calculate the average 3G coverage at the country level in the first year in which each country enters our dataset, and classify countries based on whether in that first year their coverage was above or below the sample mean (55.5 per cent national coverage). The heterogeneity is stark. In countries with below-average baseline coverage (columns 1-3), OLS estimates show that 3G rollout is associated with higher labour force participation rate, driven by both higher employment- and unemployment-to-population ratios. A 10-percentage point increase in 3G coverage leads to a 0.2 percentage point increase in LFPR driven by a 0.3 percentage point increase in the EMP2POP ratio for the total population. The positive effects on LFPR and employment are particularly strong for women, suggesting that digital infrastructure incentivises labour market attachment for disadvantaged groups. By contrast, in countries with above-average baseline coverage (columns 4-6), the pattern is reversed: a further expansion of 3G coverage is associated with lower labour force participation. This is driven primarily by a decline in the EMP2POP ratio, and the effects are similar in magnitude for men and women. These differences are economically meaningful and indicate that the pooled average masks sharply divergent effects across contexts.

► **Table 5. OLS results for the impact of regional 3G coverage on labour market outcomes by initial 3G coverage**

	Low-coverage countries			High-coverage countries		
	LFPR	EMP2POP	UNE2POP	LFPR	EMP2POP	UNE2POP
<i>Panel A: Total</i>						
3G coverage (%)	0.02***	0.03***	0.0	-0.03**	-0.03	-0.01
	(.01)	(.01)	(.01)	(.01)	(.02)	(.01)
R2 (within)	.084	.11	.428	.141	.194	.275
<i>Panel B: Women</i>						
3G coverage (%)	0.03**	0.03***	-0.01	-0.03**	-0.03*	0.0
	(.01)	(.01)	(.00)	(.01)	(.02)	(.01)
R2 (within)	.078	.109	.317	.129	.194	.246
<i>Panel C: Men</i>						
3G coverage (%)	0.02**	0.02**	0.0	-0.03**	-0.02	-0.02
	(.01)	(.01)	(.01)	(.02)	(.02)	(.01)
R2 (within)	.114	.108	.46	.243	.214	.281
N	1925	1925	1925	2082	2082	2082
N. regions	427	427	427	404	404	404
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

This split-sample evidence helps reconcile the null OLS estimates and the negative IV coefficients. If countries with higher baseline 3G coverage experience negative labour market effects from additional 3G expansion, while countries with below-average coverage experience gains, the pooled OLS estimates may average these opposite effects to a coefficient near zero. The more negative IV estimates may then reflect the fact that our identifying variation disproportionately loads on the set of countries with high initial coverage, or more generally on region-year observations where additional 3G rollout occurs at later stages of mobile internet diffusion.¹³

A related way to examine heterogeneity is to split countries by income group. To the extent that higher income countries also experienced 3G expansion earlier on, this exercise is qualitatively similar to splitting the sample by initial 3G coverage and a consistent set of results from these two exercises lends additional credibility to our OLS estimates. Table 6 shows OLS estimates separately for lower-middle-income and low-income countries (columns 1-3), and high-income and upper-middle-income countries (columns 4-6), respectively. The estimates align closely with those of the baseline-coverage split. For countries at lower income levels, 3G rollout is associated

¹³

Because the first-stage relationship becomes statistically weaker when splitting the sample by initial 3G coverage, we do not report nor discuss IV estimates for these subsamples in the main text. Nonetheless, exploratory analysis suggests that the first stage is stronger and more negative in observations with higher initial coverage and in later stages of rollout, with corresponding reduced-form coefficients also tending to be more negative. These patterns are consistent with the interpretation that the IV estimates place greater weight on region-year observations where 3G expansion occurs at more advanced stages of diffusion.

with more favourable labour market outcomes: LFPR for the total population increases by 0.2 percentage points for a 10-percentage-point increase in 3G coverage (although the coefficient is insignificant at standard confidence levels), and the EMP2POP ratio increases by 0.6 percentage points. In contrast, for countries in the higher income group categories, additional 3G coverage is associated with mostly null effects on labour force participation and status. The results are therefore consistent with a pattern of diminishing marginal returns to 3G expansion, especially in contexts where economic development is more advanced.

► **Table 6. OLS results for the impact of regional 3G coverage on labour market outcomes by broad country income group**

	Low and lower-middle income			High and upper-middle income		
	LFPR	EMP2POP	UNE2POP	LFPR	EMP2POP	UNE2POP
<i>Panel A: Total</i>						
3G coverage (%)	0.02	0.06*	-0.04***	0.01	0.0	0.0
	(.03)	(.03)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.233	.237	.447	.166	.231	.299
<i>Panel B: Women</i>						
3G coverage (%)	0.01	0.04	-0.04***	0.0	0.0	0.0
	(.03)	(.03)	(.01)	(.01)	(.01)	(.00)
R2 (within)	.245	.258	.269	.168	.291	.271
<i>Panel C: Men</i>						
3G coverage (%)	0.01	0.05*	-0.04***	0.01*	0.01	0.01
	(.02)	(.03)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.224	.215	.501	.232	.163	.302
N	647	647	647	3360	3360	3360
N. regions	227	227	227	604	604	604
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

These findings are also broadly in line with the existing literature. For countries at relatively low initial levels of mobile internet penetration, additional 3G coverage may relax information frictions, improve job search and matching, and widen access to labour markets, especially for previously underserved groups. By contrast, where baseline coverage and economic development are already high, further expansion may yield smaller matching gains while coinciding with labour-saving reorganisation, stronger competition, or compositional shifts that negatively weigh on aggregate participation and employment. Since the countries with above-average baseline coverage are predominantly high-income economies, the baseline-coverage results reinforce the interpretation from the income-group split.

Overall, the evidence points towards substantial heterogeneity in the labour market effects of 3G rollout, with the positive effects in poorer and less digitally connected countries being offset by negative effects in richer economies. Hence, the effect of 3G expansion on labour market

attachment critically depends on countries' stages of digital diffusion and level of economic development.

4.2 Mechanisms

The heterogeneous effects documented above are consistent with a framework in which the labour market consequences of 3G rollout depend on a country's stage of digital diffusion. In countries with lower income levels or low initial coverage, additional 3G availability is likely to relax binding constraints on labour market participation and job search. In countries with higher income levels or already broad baseline coverage, the same increment in coverage may instead generate smaller matching gains while amplifying supply-side competitive pressure and other channels that do not necessarily raise aggregate employment.

In lower-coverage settings, three mechanisms are likely to drive positive effects. First, 3G expansion reduces labour market frictions and improves matching efficiency. While direct evidence on 3G specifically is limited, the broader internet and broadband literature suggests that online search improves access to vacancies and raises match quality (Mang, 2012) and that broadband expansion increased online vacancy posting and reduced recruitment difficulties in Norway (Bhuller et al., 2020). Although these studies focus on developed countries, they examine earlier periods of technology diffusion when coverage was still expanding and connectivity represented a genuine new margin for job search, conditions that more closely resemble the early 3G rollout context in lower-income countries in the sample, even if labour market structures differ substantially. These mechanisms are likely to be at least as relevant for mobile internet in settings where 3G represents the primary mode of connectivity, and where geographic barriers and information frictions are greatest. Second, early rollout connects workers who were previously most constrained: Chiplunkar and Goldberg (2022) provide direct evidence that 3G expansion in developing countries raised employment for both men and women, with particularly strong effects for women facing high mobility frictions. Third, mobile internet can relax home-production constraints, making labour market attachment more compatible with care responsibilities. Evidence from high-speed broadband in the United States (Dettling, 2017) and from Arab countries (Zahidi, 2018) suggests this mechanism may also be relevant for 3G and across contexts. That said, the mechanism carries an ambiguous welfare interpretation regardless of context: 3G may increase female participation primarily through home-based or flexible arrangements, potentially raising employment without closing gaps in access to full-time and higher-quality jobs. Finally, in early phases of diffusion, firms are likely to use connectivity primarily to expand market access and improve operations rather than substitute away from labour (Falck, 2017), consistent with evidence on broadband rollout in Germany supporting firm entry and employment growth (Falck et al., 2015; Fabritz, 2013), though whether 3G operates through the same channels in lower-income settings remains an open question.

These gains are unlikely to persist linearly as coverage expands. Evidence on broadband diffusion suggests that socioeconomic benefits depend on context and stage, and are not uniform across places (Briglaue et al., 2024), a pattern that, if it applies to 3G, would imply diminishing returns as coverage matures. When coverage is already broad, the workers with the highest expected gains are already connected, and additional rollout reaches those with weaker complementary inputs such as poorer devices, lower digital skills, or weaker local demand. Beyond saturation, widespread connectivity, whether through broadband or mobile internet, can intensify competition, expose local workers to broader markets, and enable digital platforms to displace traditional employment in distribution, retail, and intermediation. Connectivity may also raise the value of non-work time, leading some groups, particularly in richer, more digitally mature

settings, to reduce labour market attachment in favour of consumption and leisure (Aguilar et al., 2021; Kopytov et al., 2023).¹⁴ Together, these forces are consistent with an inverted-U pattern in which early gains from 3G connectivity reverse as coverage approaches universality, though the precise turning point is likely to vary with income level, complementary infrastructure, and the availability of newer technologies.

4.3 Heterogeneity by individual characteristics

We next examine whether the labour market effects of 3G rollout vary across demographic and socioeconomic groups, starting by differential impacts by age. The IV estimates presented in Table 7 indicate that labour force participation significantly increases for young individuals (aged 15-24), with especially pronounced effects among women (columns 1-4) and declines for those aged 55 and above. The corresponding OLS estimates point in the same qualitative direction (see Appendix Table A2). Looking at heterogeneity by country income levels, OLS estimates from Appendix Table A3 show sharp declines in LFPR among individuals aged 55+ in upper-middle- and high-income countries and increases in participation for the youngest group (15-24), whereas in lower-income settings older individuals are the group contributing most strongly to gains in both labour force participation and employment (see Appendix Table A4).

Marked differences also emerge by education. The IV estimates from Table 8 suggest that labour force participation and employment contract for individuals with advanced education, whereas they increase for those with low and intermediary educational attainment. Results show a similar pattern across both higher- and lower-income settings (see Appendix Tables A6 and A7). In lower-income countries in particular, the positive employment and participation effects of 3G rollout appear to be concentrated among individuals with low levels of education. Taken together, these findings suggest that the gains from early-stage connectivity expansion in poorer settings may accrue mainly to lower-educated groups that were previously excluded from labour market opportunities, while in more advanced contexts additional rollout may be associated with weaker labour market attachment among more educated groups. These patterns are consistent with a mechanism in which basic connectivity lowers information barriers to labour market entry for lower-educated workers in poorer settings, for instance by facilitating job matching, coordinating informal trade, or accessing price information, rather than reflecting gains that require digital literacy or smartphone sophistication. This stands in contrast to evidence from targeted digital skills interventions, which tend to show larger gains for more educated groups. The difference may reflect the distinction between passive infrastructure rollout, which lowers information frictions for all workers regardless of education level, and active digital adoption, which favours those with higher baseline literacy and technology access.

¹⁴ An additional complication in interpreting late-stage 3G effects is that later phases of 3G diffusion may overlap temporally with the early rollout of 4G and other newer connectivity technologies. To the extent that 4G is introduced first in more economically active or urban labour markets, regions still receiving 3G expansion may simultaneously experience labour market adjustments driven by developments elsewhere, for instance, competitive pressure from newly connected 4G regions, potentially contributing to the negative effects observed at high coverage levels.

► Table 7. IV results for the impact of regional 3G coverage on labour market outcomes by age group

	LFPR	LFPR for 15-24	LFPR for 25-54	LFPR for 55 and above	EMP2POP	EMP2POP for 15-24	EMP2POP for 25-54	EMP2POP for 55 and above
<i>First stage</i>								
Lightning x Year	-0.74***	-0.74***	-0.74***	-0.74***	-0.74***	-0.74***	-0.74***	-0.74***
	(.24)	(.24)	(.24)	(.24)	(.24)	(.24)	(.24)	(.24)
F stat.	9.22	9.22	9.22	9.22	9.22	9.22	9.22	9.22
<i>Panel A: Total</i>								
3G coverage (%)	-0.13*	0.2*	-0.11*	-0.52**	-0.27**	-0.04	-0.3**	-0.53***
	(.07)	(.11)	(.06)	(.2)	(.11)	(.12)	(.12)	(.2)
<i>Panel B: Women</i>								
3G coverage (%)	-0.17*	0.22*	-0.18**	-0.45**	-0.29**	0.00	-0.35**	-0.44**
	(.09)	(.12)	(.09)	(.19)	(.12)	(.11)	(.14)	(.19)
<i>Panel C: Men</i>								
3G coverage (%)	-0.08	0.18	-0.06	-0.55***	-0.25**	-0.08	-0.28**	-0.59***
	(.07)	(.12)	(.06)	(.2)	(.12)	(.14)	(.12)	(.21)
N	4007	4007	4007	4005	4007	4007	4007	4005
N. regions	831	831	831	830	831	831	831	830
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from IV regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage, 3G coverage is instrumented with an indicator for regional lightning frequency above the sample median interacted with year fixed effects. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

► Table 8. IV results for the impact of regional 3G coverage on labour market outcomes by educational attainment

	LFPR	LFPR basic education and lower	LFPR intermediary education	LFPR advanced education	EMP2POP	EMP2POP basic education and lower	EMP2POP intermediary education	EMP2POP advanced education
<i>First stage</i>								
Lightning x Year	-0.74***	-0.97***	-0.98***	-0.97***	-0.74***	-0.97***	-0.98***	-0.97***
	(.24)	(.25)	(.25)	(.25)	(.24)	(.25)	(.25)	(.25)
F stat.	9.22	15.33	15.55	15.28	9.22	15.33	15.55	15.28
<i>Panel A: Total</i>								
3G coverage (%)	-0.13*	0.14*	-0.01	-0.25***	-0.27**	0.03	-0.11	-0.27***
	(.07)	(.07)	(.05)	(.08)	(.11)	(.08)	(.07)	(.09)
<i>Panel B: Women</i>								
3G coverage (%)	-0.17*	0.14*	0.05	-0.23**	-0.29**	0.08	-0.05	-0.26**
	(.09)	(.08)	(.06)	(.1)	(.12)	(.08)	(.07)	(.11)
<i>Panel C: Men</i>								
3G coverage (%)	-0.08	0.2**	-0.03	-0.27***	-0.25**	0.04	-0.14*	-0.27***
	(.07)	(.09)	(.05)	(.08)	(.12)	(.09)	(.08)	(.09)
N	4007	3880	3837	3858	4007	3880	3837	3858
N. regions	831	804	797	793	831	804	797	793
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from IV regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage, 3G coverage is instrumented with an indicator for regional lightning frequency above the sample median interacted with year fixed effects. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

When looking at heterogeneity in the effect of 3G by marital status, the IV estimates point to a slightly more favourable impact on employment for married women than for unmarried ones (see Table A8, and corresponding OLS results in Appendix Table A9). It is important to note that the sample is reduced when restricting the analysis to observations with marital status information, which limits statistical power and calls for cautious interpretation of these results. Nonetheless, they are consistent with the possibility that improved connectivity may ease coordination and flexibility constraints within households, with stronger labour market benefits for women, whose work decisions are closely tied to family organisation.

4.4 Employment composition

To assess whether the effects on labour force engagement are accompanied by changes in the structure and quality of jobs, we examine the distribution of workers across sectors, employment categories, including employers, contributing family workers, own-account workers, and employees, and firms of different sizes.

We begin with IV estimates of the impact of 3G coverage by status in employment, presented in Table 9. In the pooled sample, a 10-percentage point increase in 3G coverage is associated with a 3-percentage point decline in own account work.¹⁵ Magnitudes are similar across genders, with both men and women mostly reallocating towards wage employment. While insignificant, the results suggest as well a reallocation towards employers and contributing family work, with the increase in the share of employers being driven by men.

Consistent with the earlier labour force results, these findings appear to be driven largely by higher-income contexts, where the identifying variation is likely concentrated. The split by income group shows that this aggregate pattern masks substantial heterogeneity across contexts (see Tables A10 and A11 that present OLS results by country income group). In lower-income countries, there is a strong shift away from employee status and towards more vulnerable forms of employment, such as own account workers. Among women in particular, the coefficient on employee status is -0.24, alongside a large although statistically insignificant increase in contributing family workers (+0.11) and an increase in own-account work (+0.11). These results suggest that while 3G may support greater labour market participation in lower-income settings, part of this adjustment may occur through forms of employment that remain precarious, informal or weakly protected. This is an important policy consideration: an increase in employment is not necessarily synonymous with an improvement in job quality if it is driven by vulnerable employment rather than more stable wage work, and digital diffusion should be accompanied by policies that promote stable and quality employment for all. By contrast, in higher-income countries, women display the opposite pattern, with an increase in the share of employees and a decline in own-account and contributing family work. For men, the effect is directionally similar and comparable in magnitude.

Taken together, the results suggest that the employment effects of 3G depend not only on whether connectivity expands, but also on the stage of structural transformation at which expansion occurs. In lower-income contexts, connectivity may enable entry into self-employment and household-based production; in higher-income settings, it appears more closely associated with wage employment

¹⁵

The corresponding OLS results are presented in Appendix Table A10.

► Table 9. IV results for the impact of regional 3G coverage on employment status and sectoral composition

	Employers rate	Contributing family workers rate	Own account workers rate	Employees rate	Share services	Share agriculture	Share industry
<i>First-stage</i>							
Lightning x Year	-0.74***	-0.74***	-0.74***	-0.74***	-0.95***	-0.95***	-0.95***
	(.24)	(.24)	(.24)	(.24)	(.24)	(.24)	(.24)
F-stat.	9.22	9.22	9.22	9.22	15.36	15.36	15.36
<i>Panel A: Total</i>							
3G coverage (%)	0.04	0.09	-0.3**	0.18*	0.07	-0.33***	0.26***
	(.02)	(.07)	(.13)	(.11)	(.07)	(.1)	(.07)
<i>Panel B: Women</i>							
3G coverage (%)	0.01	0.07	-0.25**	0.17*	0.16**	-0.31***	0.15***
	(.01)	(.09)	(.12)	(.1)	(.07)	(.1)	(.05)
<i>Panel C: Men</i>							
3G coverage (%)	0.06*	0.06	-0.34**	0.22*	0.03	-0.35***	0.31***
	(.04)	(.05)	(.15)	(.13)	(.07)	(.11)	(.09)
N	4007	4007	4007	4007	3933	3933	3933
N. regions	831	831	831	831	818	818	818
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from IV regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage, 3G coverage is instrumented with an indicator for regional lightning frequency above the sample median interacted with year fixed effects. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

Turning to sectoral composition, the aggregate IV estimates show evidence of a decline in agricultural employment as 3G coverage rises, which is accompanied by an increase in both industry and service employment. The reallocation towards industry employment is stronger for men than it is for women, while the opposite is true for employment in the service sector. Once again, however, there is substantial heterogeneity by income group. In higher-income countries, 3G rollout is associated with a reallocation away from agriculture and toward services, especially for women, for whom the coefficients are -0.05 for agriculture and +0.04 for services. In lower-income countries, the pattern is reversed: employment shifts toward agriculture and away from services, with the effect statistically significant for men but not for women. This suggests that in lower-income settings, digital access may initially strengthen participation in traditional or household-based productive activities rather than accelerating a transition into services. In higher-income settings, by contrast, added connectivity appears to reinforce the ongoing movement of labour out of agriculture and into more service-oriented employment, potentially driven by an increase in gig-employment. From a policy perspective, these results suggest that

digital infrastructure alone is unlikely to generate the same pattern of structural transformation everywhere. In lower-income settings, complementary policies may be needed to ensure that improved connectivity translates into access to more productive work, rather than simply reinforcing low-productivity forms of employment.

► **Table 10. OLS results for the impact of regional 3G coverage on employment by firm size**

	EMP2POP restrict- ed sample	% firms with 1 to 4 workers	% firms with 5 to 49 workers	% firms with more than 50 workers
<i>Panel A: Total</i>				
3G coverage (%)	0.03**	0.02	-0.02	0.01
	(.01)	(.02)	(.02)	(.02)
R2 (within)	.138	.195	.186	.037
<i>Panel B: Women</i>				
3G coverage (%)	0.03*	-0.03	-0.01	0.04
	(.02)	(.02)	(.04)	(.04)
R2 (within)	.096	.157	.103	.082
<i>Panel C: Men</i>				
3G coverage (%)	0.03*	0.03	-0.04*	0.0
	(.01)	(.02)	(.02)	(.02)
R2 (within)	.182	.213	.2	.035
N	1495	1495	1495	1495
N. regions	400	400	400	400
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

Finally, digital expansion may also affect the scale at which economic activity takes place. Mobile broadband can reduce coordination costs, improve access to information, and facilitate market integration. These changes may enable firms to scale beyond subsistence levels or induce consolidation among smaller enterprises. To examine this dimension, in Table 10 we analyse how 3G coverage affects the distribution of employment across firm sizes. In the pooled OLS estimates, there is little evidence of major shifts in the size distribution of employment.¹⁶ The main pattern is a slight reallocation toward work in very small firms with 1–4 employees driven by men, although the coefficients are not statistically significant. This is consistent with the status-in-employment results and may reflect the entry or expansion of microenterprises following improved digital access. In higher-income countries, however, the pattern is different: employment shifts away from very small firms and mostly reallocates toward medium-sized firms with 5–49 employees (see Table A13). The shift away from small firms is larger for women. This may suggest that in higher-income contexts, additional connectivity supports firm growth and scaling rather than new micro-enterprise creation. However, the absence of significant large-firm expansion suggests that digital connectivity primarily affects the lower and middle segments of the firm-size distribution.

¹⁶

Due to sample size limitations, the first-stage IV results are too weak to be reliable.

In lower-income countries, women also tend to reallocate toward large firms, although the coefficient is imprecisely estimated and should be interpreted cautiously (see Table A14).

Overall, the composition results reinforce the broader message from the labour force analysis: the effects of 3G rollout are highly context specific. In lower-income and lower-coverage settings, connectivity appears more likely to draw workers into employment through own-account work, contributing family work, microenterprises, and in some cases agriculture. In higher-income or more digitally mature settings, the compositional shifts are more consistent with wage employment, movement toward services, and firm expansion. These differences have clear policy implications. Expanding digital coverage can support employment growth, but without complementary interventions, such as support for formalisation, business upgrading, skills, and worker protection, it may also increase vulnerable employment. The results therefore suggest that digital infrastructure policy should be embedded within a broader employment strategy tailored to countries' stage of development and structural transformation.

4.5 Employment quality

Beyond employment composition, we examine hours worked and earnings to assess whether increases in digital access leads to improvements in metrics of employment quality. Table 11A presents IV (column 1) and OLS (columns 2 to 4) estimates for the impact of 3G coverage on the average weekly hours worked by all people in employment. In both the pooled IV and OLS regressions for the full sample, 3G coverage is associated with mostly insignificant changes in hours worked, with the exception of a significant but small increase in hours for men in the IV specification. OLS regressions by broad country income group confirm the mostly null impact of increased coverage on hours worked.

Table 11B presents IV and OLS results for the impact of 3G coverage on wage earnings.¹⁷ Because information on earnings is imprecisely measured in surveys, and comparisons of income levels across contexts is challenging due to the changing composition of the sample, we restrict the earnings analysis to examining whether 3G coverage widened or narrowed gender gaps in earnings. To do so, we construct a measure of earning ratios of employees between women and men by dividing the average monthly earnings of women in a given region-year cell by the average monthly earnings of men. Table 11B shows that 3G coverage slightly worsens gender disparities in earnings in the IV regressions: the earnings ratio between women and men's earnings worsens by 3.3 percentage points for a 10-percentage-point increase in 3G coverage. Although the coefficients are not statistically significant at conventional levels, the OLS results point to heterogeneity by country income group: gender gaps tend to narrow with higher 3G coverage in lower-income contexts, whereas they tend to widen in higher-income contexts. This evidence, which should be interpreted with caution, is suggestive of a potential role for digital infrastructure to narrow gender gaps in earnings in contexts where women's overall participation in the labour market is particularly difficult, but not in more developed contexts.

¹⁷ The relevance of wage earnings as a welfare indicator varies considerably across income groups. According to ILO modelled estimates for 2023, employees account for only 22 and 31 per cent of total employment in low- and lower-middle-income countries respectively, compared to 61 and 89 per cent in upper-middle- and high-income countries, limiting the interpretability of wage-based indicators in lower-income contexts where most workers are own-account or contributing family workers.

► Table 11A. IV and OLS results for the impact of regional 3G coverage on weekly hours actually worked

	IV	OLS – Full sample	OLS – Lower-income countries	OLS – Higher-income countries
<i>First-stage</i>				
Lightning x Year	-0.84***			
	(.26)			
F-stat.	10.48			
<i>Panel A: Total</i>				
3G coverage (%)	0.06	-0.01	-0.03	0.0
	(.04)	(.01)	(.03)	(.00)
<i>Panel B: Women</i>				
3G coverage (%)	0.01	-0.01	-0.06	0.0*
	(.03)	(.01)	(.05)	(0)
<i>Panel C: Men</i>				
3G coverage (%)	0.09**	0.0	-0.02	0.0
	(.04)	(.01)	(.03)	(0)
N	3571	3571	609	3008
N. regions	693	693	221	518
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from OLS and IV regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage of the IV regressions, 3G coverage is instrumented with an indicator for regional lightning frequency above the sample median interacted with year fixed effects. Columns 3 and 4 report results from OLS regressions on the subset of countries with low- and lower-middle income, and upper-middle and high income, respectively. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

► **Table 11B. IV and OLS results for the impact of regional 3G coverage on the gender ratio of monthly earnings**

	IV	OLS – Full sample	OLS – Lower-income countries	OLS – Higher-income countries
<i>First-stage</i>				
Lightning x Year	-1.21***			
	(.29)			
F-stat.	17.56			
<i>Panel A: Gender Ratio</i>				
3G coverage (%)	-0.33**	-0.03	0.04	-0.02
	(.13)	(.03)	(.08)	(.03)
R2 (within)		.499	.648	.103
N	2577	2577	593	1984
N. regions	563	563	200	363
Controls	Yes	Yes	Yes	-0.02
Fixed effects	Yes	Yes	Yes	.03

Note: The table shows results from IV and OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage of the IV regressions, 3G coverage is instrumented with an indicator for regional lightning frequency above the sample median interacted with year fixed effects. Columns 3 and 4 report results from OLS regressions on the subset of countries with low- and lower-middle income, and upper-middle and high income, respectively. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.6 Gender ratios

As shown in previous sections, digital expansion can have different effects across groups of workers, including by gender. To assess whether 3G expansion affects gender disparities directly, we estimate regressions using female-to-male ratios within regions, defined as (female outcome / male outcome $\times$ 100). This approach allows us to evaluate whether digital expansion narrows or widens gender differences, rather than merely affecting women and men separately. For indicators where female rates are lower than male rates, as for example the employment-to-population ratio, an increase in the ratio indicates convergence of women's outcomes toward those of men as driven by 3G rollout. In contrast, for indicators where female rates are higher than male rates (such as the NEET rate), an increase in the ratio indicates further divergence and a widening of gender differences.

Table 12 reports IV estimates where each dependent variable is defined as the ratio of the female outcome to the male outcome, as reported in the column header.¹⁸ The coefficients therefore capture whether 3G expansion changes women's labour market outcomes relative to men's, rather than changing levels separately by sex.

In the full sample, there is little evidence that 3G rollout systematically alters gender gaps in aggregate labour market attachment. The coefficient for the female-to-male employment-to-population ratio is negative and significant, suggesting that women's employment decreases more than men's, whereas the coefficient for unemployment-to-population ratio is small and statistically insignificant, suggesting no meaningful relative change in women's unemployment compared

¹⁸

Panel A of Appendix Table A15 reports the corresponding OLS results.

with men's as a result of 3G expansion. The one notable exception is the NEET ratio: a 10-percentage-point increase in 3G coverage is associated with a 12-percentage point decrease in the female-to-male NEET ratio, although the coefficient is insignificant at conventional levels. Given the higher NEET rate among women than among men, this implies that 3G expansion is associated with a relative narrowing of gender gaps in youth labour market disengagement. By contrast, there is no statistically significant evidence in the pooled sample that 3G rollout changes women's relative concentration in agriculture, services, industry, or in different employment-status categories.

Splitting the sample by country income group reveals more heterogeneity (see OLS results from Appendix Table A15). In upper-middle- and high-income countries, 3G expansion does not significantly affect the gender ratio in employment, unemployment, NEET, or employment status. However, it is associated with significant changes in sectoral composition: the female-to-male share in services rises, while the female-to-male share in industry falls. Quantitatively, a 10-percentage-point increase in 3G coverage raises the gender ratio in services by 0.04 and lowers the gender ratio in industry by 0.05. This suggests that in richer countries, additional 3G rollout is associated with women becoming more concentrated in services relative to men, and less concentrated in industry.

In low- and lower-middle-income countries, estimates are generally less precise, but one result stands out clearly: the female-to-male NEET ratio increases strongly with 3G coverage. The coefficient of 1.41, significant at the 5 per cent level, indicates that additional 3G rollout is associated with a marked widening of the gender gap in NEET, to the disadvantage of young women. A plausible interpretation of this pattern is that 3G expansion does not translate equally into effective connectivity for women and men. In many lower-income countries, women face significant barriers beyond infrastructure availability: lower rates of smartphone ownership, lower digital literacy, restricted control over household devices, and lower awareness of economic uses of mobile internet (GSMA, 2025; Begazo et al., 2023), potentially explaining why 3G rollout in lower-income settings is associated with a widening of the female disadvantage in NEET rather than a convergence, and why absolute employment gains for women do not translate into a narrowing of gender gaps more broadly.

For the other outcomes, including the gender ratios in employment, unemployment, sector, and employment status, the coefficients are not statistically significant. Even so, several point estimates suggest potentially relevant patterns: notably, higher relative female concentration in agriculture, contributing family work, and own-account work. Although these estimates are too imprecise to support strong conclusions, they suggest that additional 3G expansion in lower-income contexts contributes to widening gender gaps in vulnerable employment.

Overall, the results suggest that 3G expansion does not appear to systematically narrow gender gaps in core labour market outcomes. Instead, the most striking pattern is a widening of the female disadvantage in NEET in lower-income settings. In richer countries, the main gendered effect operates through sectoral composition rather than labour market attachment, with women shifting relatively more toward services and away from industry.

► Table 12. IV results for the impact of regional 3G coverage on gender ratios in labour market outcomes

	EMP2POP	UNE2POP	NEET	% Agriculture	% Services	% Industry	% Employees	% Contributing family workers	% Own account workers	% Employers
<i>First-stage</i>										
Lightning x Year	-0.74***	-0.74***	-0.74***	-0.92***	-0.95***	-0.95***	-0.74***	-0.53**	-0.74***	-0.75*
	(.24)	(.24)	(.25)	(.24)	(.24)	(.24)	(.24)	(.25)	(.24)	(.41)
First-stage F-statistic	9.22	9.22	9.18	14.59	15.36	15.4	9.22	4.58	9.20	3.42
<i>Second-stage</i>										
3G coverage (%)	-0.16*	0.05	-1.22	0.13	0.23	-0.11	0.16	-3.32	0.71*	0.70
	(.1)	(.46)	(.93)	(.27)	(.15)	(.21)	(.1)	(6.81)	(.43)	(.79)
N	4007	4007	3796	3849	3933	3885	3999	3530	3995	2195
N. regions	831	831	778	791	818	796	827	745	826	561
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from IV regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage, 3G coverage is instrumented with an indicator for regional lightning frequency above the sample median interacted with year fixed effects. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

► 5 Robustness and Limitations

5.1 Robustness checks

We perform several robustness checks to assess the validity of our results. First, we restrict the sample to the population of individuals aged 15–64, to ascertain that the impacts of 3G rollout that we estimate are not a reflection of higher digital connectivity pushing older segments of the population out of the labour market. Appendix Table A16 shows that our findings on labour force participation and status remain essentially unchanged when restricting the sample to individuals aged 15–64.

Second, to lend validity to our hypothesis that the labour market effects of 3G internet depend on countries' economic level of development, we estimate our regressions on a restricted sample that excludes high-income countries, where 3G coverage at baseline was just under 70 per cent on average and where returns to additional 3G rollout are likely to be diminishing. Appendix Table A17 shows OLS estimates run on a restricted sample that excludes high-income countries. In the restricted sample, 3G expansion is associated with an increase in LFPR, primarily driven by an increase in the employment-to-population ratio. This suggests that 3G mobile internet has positive employment effects across all country income levels but the most developed contexts. We additionally perform the related exercise of excluding from our sample all countries that had baseline 3G coverage above 80 per cent. The OLS results, reported in Appendix Table A18, show positive, albeit insignificant, effects of 3G internet expansion on LFPR and employment.

Lastly, we adopt a different estimation approach based on an ANCOVA structure (McKenzie, 2012). The ANCOVA approach requires the choice of a baseline period, based on which we can calculate initial levels of the outcome variables and include them as additional controls in the regressions, in lieu of regional fixed effects. Given the unbalanced nature of our panel, our choice of the baseline period aims at maximising country coverage, while at the same time choosing a period where 3G internet was on average at a relatively early stage of its diffusion. For these reasons, we choose as the baseline each country's first available survey year at or before 2012, and estimate the regressions on a sample of 36 countries. Appendix Table A19 provides a comparison of country coverage by income group between our main sample and the sample used for this robustness exercise.

Appendix Table A20 reports results from an ANCOVA specification that uses each country's first available survey year at or before 2012 as the baseline and is estimated on a smaller sample of 2,219 region-year observations across 517 regions, compared with 4,007 observations and 831 regions in the main specifications. The ANCOVA results should not be interpreted as directly comparable estimates of our parameter of interest, the coefficient associated with 3G coverage, since they differ from the main OLS and IV specifications in sample composition. In particular, because the ANCOVA requires countries to be observed at or before 2012 and again thereafter, it excludes a number of late-entering countries, which are disproportionately lower-income or lower-coverage settings. Any comparison with the main OLS and IV results should therefore keep in mind that differences may reflect both the estimation method and the underlying sample.

For the full sample, the ANCOVA results are close in spirit to the main OLS estimates, with 3G coverage being associated with positive but statistically insignificant changes in LFPR, driven by

a positive but insignificant increase in the EMP2POP ratio and a significant increase in the unemployment-to-population ratio. This suggests that, under ANCOVA, additional 3G coverage is associated with somewhat greater labour market attachment, but primarily through higher unemployment rather than higher employment. Gender differences in terms of labour force participation and status within the labour force remain small.

Looking at employment composition, results from the ANCOVA specification presented in Appendix Table A20 show a compositional change that is similar to that from the IV results: higher 3G coverage is associated with an increase in the shares of employers and employees, and declines in the shares of contributing family workers and own-account workers. The ANCOVA results therefore reinforce the idea that, in higher income contexts, 3G expansion appears more closely associated with a shift away from more vulnerable forms of employment and toward wage employment. Finally, in terms of sectoral composition of employment, the ANCOVA estimates show a strong and statistically significant decline in agriculture, a positive shift toward services, and no increase in industry.

5.2 Limitations

Several limitations should be kept in mind when interpreting the results. First, the analysis relies on an unbalanced panel of countries and subnational regions, with earlier start dates and more numerous observations for high-income and upper-middle-income countries than for lower-income settings. Countries belonging to different income groups also enter the sample at different points of the 3G diffusion process, and in high-income contexts only once baseline coverage is already relatively advanced. This may affect both comparability across contexts and identification, since later-entering countries may contribute less within-country variation in 3G expansion.

Furthermore, if the effect of 3G roll-out is non-linear along economic development or coverage rollout, the results for the full sample are likely to mask substantial heterogeneity in impacts at different points of the 3G expansion, as discussed in Section 4. While our analysis attempts to unpack such heterogeneity by splitting the sample across broad country-income groups and baseline 3G coverage levels, data limitations make the use of our instrumental variable approach challenging on smaller samples, which warrants caution in interpreting the results.

Second, our subnational units are larger administrative regions than those used in prior work (see, e.g., [Chiplunkar and Goldberg, 2022](#)). While this broader regional aggregation allows for substantially wider country coverage – as information on broad region of residence is available in more surveys – it may attenuate variation by averaging over within-region heterogeneity in both 3G network rollout and labour market adjustment, potentially weakening the first stage and reducing the precision of the estimates.

Third, while our cleaning of the 3G data ensured no artificially repeated observation was used for 3G coverage, measurement error in 3G access remains a concern. Coverage data are derived from provider-reported information that does not include all operators and is not always observed at regular annual intervals; in addition, technical coverage maps may not fully coincide with actual user access or effective service quality on the ground. To the extent that these sources of noise generate classical measurement error, they are likely to attenuate first-stage relationships and bias estimates toward zero.

Fourth, while rainfall controls and prior literature support the validity of the lightning-based instrument, we cannot fully rule out that lightning density correlates with agricultural conditions

or soil quality in ways not entirely captured by our controls, and results from the IV specifications should be interpreted with this caveat in mind.

Finally, there may be some measurement error in assigning households to subnational regions in the microdata due to mismatch between survey geography and administrative boundaries. This could further blur the correspondence between measured regional 3G exposure and observed labour market outcomes, again potentially introducing attenuation in the estimated effects.

► Conclusion

This paper has examined how the expansion of 3G mobile internet affected labour market outcomes across 52 countries between 2004 and 2023. Combining ILO harmonized labour force survey microdata with high-resolution regional 3G coverage maps, we study both overall labour market attachment and changes in employment composition, paying particular attention to heterogeneity by gender, country context, and individual characteristics. To address the non-random development of telecommunication infrastructure, we complement fixed-effects OLS estimates with an instrumental-variable strategy based on regional variation in lightning strike frequency.

Three main findings emerge. First, average effects in the pooled sample conceal substantial heterogeneity. In the full sample, OLS estimates suggest that 3G rollout is associated with little change in aggregate labour force participation, reflecting a small increase in employment that is broadly offset by a decline in unemployment. By contrast, the IV estimates point to more negative average effects, with additional 3G coverage reducing labour force participation and employment while increasing unemployment. However, these pooled estimates mask sharply different effects across contexts. In countries with low initial 3G coverage, additional rollout is associated with higher labour force participation and employment, with particularly strong gains for women. A similar pattern emerges in low- and lower-middle-income countries, where 3G expansion is associated with higher employment and lower unemployment. By contrast, in countries that entered the sample with already high 3G coverage, additional rollout is associated with weaker labour market attachment, and the IV results suggest that the overall negative average effects are driven primarily by these more advanced settings. Taken together, the evidence indicates that the labour market consequences of 3G expansion depend critically on countries' stage of digital diffusion and level of development.

Second, 3G rollout affects not only whether people participate in the labour force and work, but also the type of work they do. The compositional effects again differ across contexts. In lower-income settings, additional coverage is associated with a shift away from employee status and toward own-account work and, for women, also toward contributing family work, pointing to an increase in more vulnerable forms of employment. In upper-middle- and high-income countries, by contrast, the patterns are more consistent with increases in wage employment, lower shares of employment in agriculture, and higher shares of employment in services and industry. Evidence on firm size is more limited but suggests that in richer settings additional connectivity may support movement away from very small firms toward medium-sized firms, especially for women. Beyond employment composition, we also find that 3G expansion is not associated with significant changes in measures of job quality, for either gender, although we provide suggestive evidence that improved digital access may contribute to narrow gender gaps in earnings in lower-income contexts. These results suggest that digital expansion can reshape employment structures without necessarily improving job quality across the board, especially where structural transformation remains incomplete and formal employment opportunities are limited.

Third, the paper documents important heterogeneity by individual characteristics. The labour market effects of 3G differ markedly by age. While older individuals, especially those aged 55 and above, experience significant declines in participation and employment, younger individuals show more favourable participation responses. Heterogeneity also emerges by education: labour market gains are concentrated among workers with basic or intermediate education, whereas labour force participation and employment contract among those with advanced education. By marital status, the estimates suggest somewhat more favourable employment effects

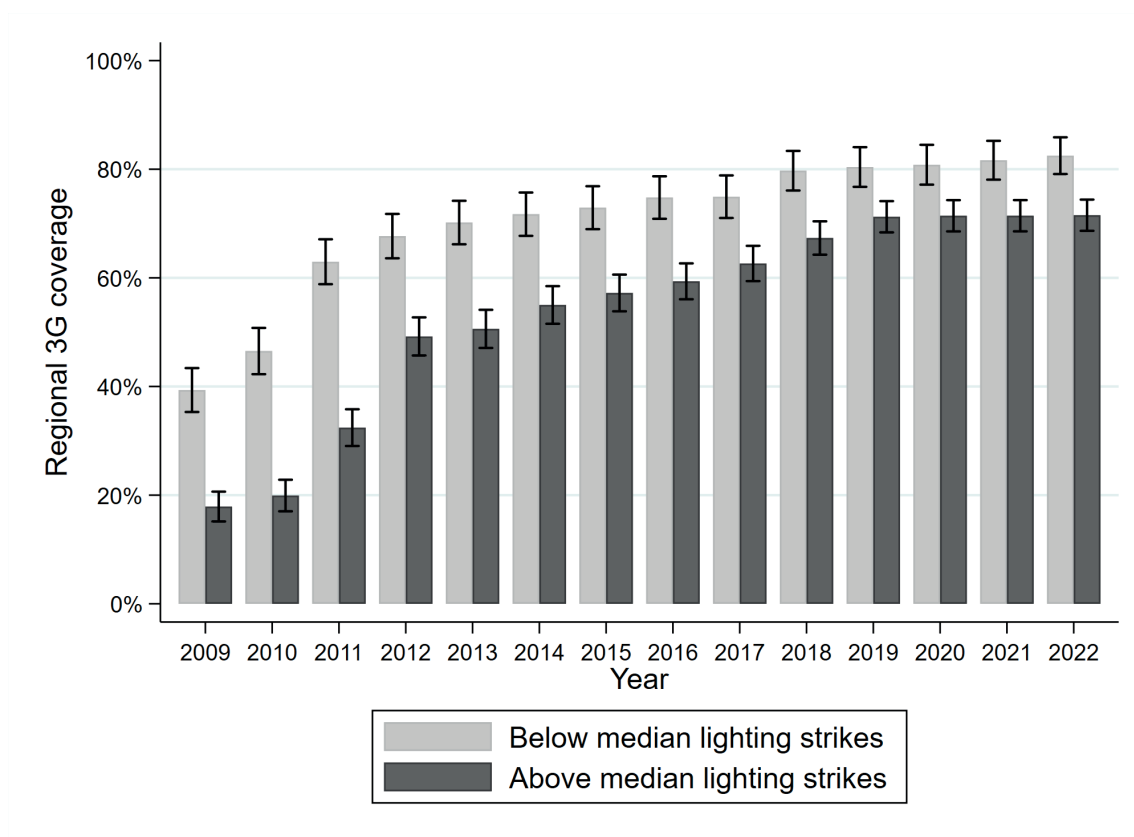
for married individuals, particularly married women. These patterns reinforce the broader conclusion that the labour market consequences of digital expansion depend not only on the technology itself, but also on which workers are exposed to it and in what economic environment. Finally, our analysis of female-to-male outcome ratios suggests that 3G expansion does not systematically narrow gender gaps in labour market outcomes, and cautions against assuming that digital expansion will automatically promote gender equality in labour markets.

Taken together, the results suggest that mobile internet expansion does not generate uniform labour market gains across contexts. Its effects are highly heterogeneous and depend critically on countries' stage of digital diffusion, level of development, labour market structure, and the characteristics of the workers exposed to the new technology. This has important policy implications. Expanding digital infrastructure remains essential, particularly in lower-income and low-coverage settings where the gains from improved connectivity appear strongest. However, digital infrastructure alone is unlikely to deliver inclusive labour market improvements. To translate connectivity into better and more equitable employment outcomes, rollout needs to be accompanied by complementary policies that strengthen digital skills, protect workers in vulnerable forms of employment, and address persistent gender gaps in access to devices, digital literacy, and labour market opportunities.

To conclude, we see our results as shedding light on the labour market effects of improved digital connectivity across the full distribution of digital infrastructure rollout and across a broader set of contexts than has typically been considered in the literature. In doing so, our findings also highlight key directions for future research, especially on impacts on earnings, earnings stability, and the interaction between successive generations of connectivity technologies. A better understanding of these dynamics will be crucial for designing digital policies that deliver not only broader access to employment, but also better and more secure jobs.

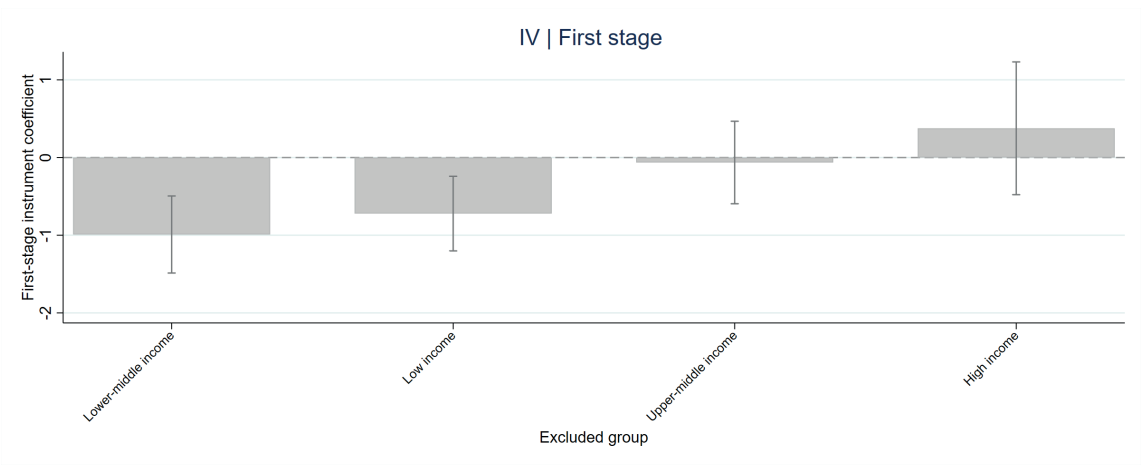
Annex

► Figure A1. Regional 3G coverage over time by frequency of lightning strikes



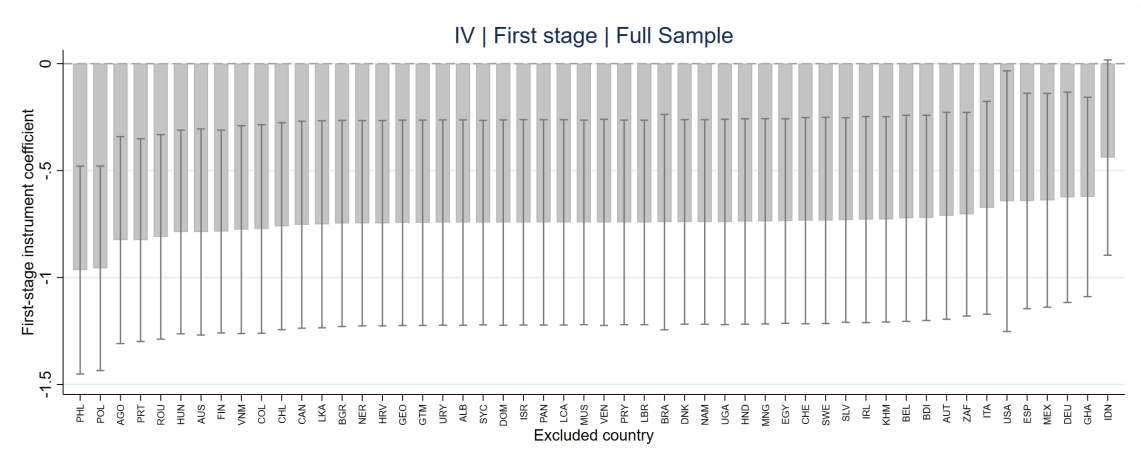
Note: The graph shows, for the years 2009 to 2022, the average regional 3G coverage, defined as the percentage of the local population that receives 3G signal, separately for regions with above- (dark grey) or below-median (light grey) lightning strike frequency. The time-invariant lightning strike frequency for each region is calculated from the average frequency over the years 2010-2023. The capped lines represent 95% confidence intervals on the mean.

► Figure A2. First-stage coefficients when excluding country-income groups



Note: The graph shows the leave-one-out coefficients of our instrument (lightning strike indicator times year fixed effects) on 3G coverage from first stage regressions run on restricted samples that exclude the group of countries defined by the bar labels on the x-axis. The capped lines represent 95% confidence intervals on the coefficients.

► Figure A3. First-stage coefficients when excluding individual countries



Note: The graph shows the leave-one-out coefficients of our instrument (lightning strike indicator times year fixed effects) on 3G coverage from first stage regressions run on restricted samples that exclude the country defined by the bar labels on the x-axis. The capped lines represent 95% confidence intervals on the coefficients.

► **Table A1. List of sample countries in the IV regression and their available regions and year observations.**

Country	Available subnational regions	Number of regions in sample	Number of years in sample	First year in sample	Last year in sample
Angola	18	10	2	2009	2021
Albania	12	12	4	2016	2022
Australia	10	8	8	2009	2020
Austria	9	9	7	2010	2020
Burundi	17	11	2	2014	2020
Belgium	11	11	9	2010	2022
Bulgaria	6	6	7	2011	2022
Brazil	27	27	8	2012	2020
Canada	13	10	14	2009	2022
Switzerland	26	26	8	2011	2022
Chile	16	16	5	2010	2022
Colombia	33	33	3	2017	2019
Germany	16	16	9	2006	2020
Denmark	5	5	4	2004	2015
Dominican Republic	32	31	4	2017	2020
Egypt	27	27	3	2008	2012
Spain	19	19	3	2009	2022
Finland	5	5	11	2009	2023
Georgia	12	10	3	2011	2019
Ghana	10	10	2	2006	2017
Guatemala	22	19	2	2014	2023
Honduras	18	13	3	2014	2020
Croatia	4	4	9	2008	2020
Hungary	8	8	9	2009	2022
Indonesia	33	33	3	2011	2019
Ireland	3	3	5	2009	2021
Israel	6	6	2	2012	2017
Italy	21	21	10	2009	2019
Cambodia	24	11	6	2011	2023
Liberia	15	7	2	2014	2017
Saint Lucia	11	9	3	2018	2022
Sri Lanka	25	25	7	2010	2019
Mexico	32	31	8	2009	2022
Mongolia	22	22	2	2010	2022
Mauritius	16	10	3	2017	2019

Namibia	13	13	2	2016	2018
Niger	8	8	3	2012	2017
Panama	12	12	7	2012	2023
Philippines	17	16	6	2007	2019
Poland	16	16	8	2010	2021
Portugal	7	7	6	2007	2017
Paraguay	18	6	2	2012	2013
Romania	8	8	6	2009	2019
El Salvador	14	14	4	2015	2020
Sweden	8	8	5	2011	2020
Seychelles	26	20	3	2015	2019
Uganda	112	13	3	2017	2021
Uruguay	19	19	2	2014	2019
United States	51	51	12	2009	2021
Venezuela, Bolivarian Republic of	25	24	3	2011	2016
Viet Nam	63	63	2	2014	2019
South Africa	9	9	8	2010	2019

► Table A2. OLS results for the impact of regional 3G coverage on labour market outcomes by age group

	LFPR	LFPR for 15-24	LFPR for 25-54	LFPR for 55 and above	EMP2POP	EMP2POP for 15-24	EMP2POP for 25-54	EMP2POP for 55 and above
<i>Panel A: Total</i>								
3G coverage (%)	0.01	0.02*	0.0	0.0	-0.01	-0.02	0.0	-0.02**
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.067	.087	.084	.095	.08	.081	.12	.101
<i>Panel B: Women</i>								
3G coverage (%)	0.0	0.01	0.0	0.0	-0.01	-0.02*	0.0	-0.02*
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.065	.058	.103	.122	.091	.079	.121	.131
<i>Panel C: Men</i>								
3G coverage (%)	0.01	0.02**	0.0	0.0	-0.01	-0.02	-0.01	-0.03*
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.109	.113	.052	.069	.08	.087	.11	.074
N	4007	4007	4007	4006	4035	4035	4035	4034
N. regions	831	831	831	831	811	811	811	811
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► **Table A3. OLS results for the impact of regional 3G coverage on labour market outcomes by age group – Upper-middle-income and high-income countries**

	LFPR	LFPR for 15-24	LFPR for 25-54	LFPR for 55 and above	EMP2POP	EMP2POP for 15-24	EMP2POP for 25-54	EMP2POP for 55 and above
<i>Panel A: Total</i>								
3G coverage (%)	0.01	0.03***	0.0	-0.03***	0.0	0.02	0.0	-0.03***
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.166	.186	.166	.256	.231	.147	.3	.284
<i>Panel B: Women</i>								
3G coverage (%)	0.0	0.02**	-0.01	-0.02*	0.0	0.02	-0.01	-0.02**
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.168	.119	.249	.303	.291	.155	.364	.323
<i>Panel C: Men</i>								
3G coverage (%)	0.01*	0.03***	0.0	-0.04***	0.01	0.02	0.0	-0.04***
	(.01)	(.01)	(.01)	(.01)	(.01)	(.02)	(.01)	(.01)
R2 (within)	.232	.203	.093	.167	.163	.113	.177	.191
N	3360	3360	3360	3360	3360	3360	3360	3360
N. regions	604	604	604	604	604	604	604	604
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample is restricted to countries with upper-middle or high income. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► **Table A4. OLS results for the impact of regional 3G coverage on labour market outcomes by age group – Low-income and lower-middle-income countries**

	LFPR	LFPR for 15-24	LFPR for 25-54	LFPR for 55 and above	EMP2POP	EMP2POP for 15-24	EMP2POP for 25-54	EMP2POP for 55 and above
<i>Panel A: Total</i>								
3G coverage (%)	0.02	-0.01	0.03	0.12***	0.06*	0.05	0.07**	0.13***
	(.03)	(.03)	(.03)	(.03)	(.03)	(.04)	(.03)	(.03)
R2 (within)	.233	.17	.243	.242	.237	.196	.225	.252
<i>Panel B: Women</i>								
3G coverage (%)	0.01	-0.09**	0.04	0.11***	0.04	-0.03	0.07*	0.11***
	(.03)	(.04)	(.04)	(.04)	(.03)	(.03)	(.04)	(.04)
R2 (within)	.245	.159	.232	.282	.258	.182	.22	.289
<i>Panel C: Men</i>								
3G coverage (%)	0.01	0.02	-0.01	0.13***	0.05*	0.09*	0.04**	0.14***
	(.02)	(.04)	(.01)	(.05)	(.03)	(.05)	(.02)	(.04)
R2 (within)	.224	.206	.263	.209	.215	.235	.27	.216
N	647	647	647	646	647	647	647	646
N. regions	227	227	227	227	227	227	227	227
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample is restricted to countries with lower-middle or low income. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

R2 (within)	.233	.145	.354	.255	.163	.108	.191	.168
N	3351	3351	3315	3349	3351	3351	3315	3349
N. regions	604	604	601	604	604	604	601	604
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample is restricted to countries with upper-middle or high income. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► **Table A7. OLS results for the impact of regional 3G coverage on labour market outcomes by educational attainment - Lower-middle-income and low-income countries**

	LFPR	LFPR basic education and lower	LFPR intermediary education	LFPR advanced education	EMP2POP	EMP2POP basic education and lower	EMP2POP intermediary education	EMP2POP advanced education
<i>Panel A: Total</i>								
3G coverage (%)	0.04	0.14***	0.01	-0.09	0.11**	0.17***	0.12**	-0.07
	(.04)	(.04)	(.05)	(.06)	(.04)	(.05)	(.06)	(.07)
R2 (within)	.144	.182	.288	.329	.165	.207	.197	.295
<i>Panel B: Women</i>								
3G coverage (%)	0.04	0.11*	0.03	-0.09	0.1*	0.14**	0.11*	-0.01
	(.06)	(.06)	(.07)	(.09)	(.05)	(.06)	(.06)	(.09)
R2 (within)	.123	.142	.223	.328	.149	.171	.138	.242
<i>Panel C: Men</i>								
3G coverage (%)	0.02	0.13***	-0.06	-0.07	0.09**	0.16***	0.08	-0.09
	(.03)	(.05)	(.05)	(.05)	(.04)	(.05)	(.06)	(.07)
R2 (within)	.175	.242	.347	.24	.175	.265	.189	.225
N	529	529	526	520	529	529	526	520
N. regions	200	200	200	200	200	200	200	200
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample is restricted to countries with lower-middle or low income. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► Table A8. IV results for the impact of regional 3G coverage on labour market outcomes by marital status

	LFPR	LFPR restricted sample	LFPR married	LFPR unmarried	EMP2POP	EMP2POP restricted sample	EMP2POP married	EMP2POP unmarried
First stage								
Lightning x Year	-0.74***	-1.1***	-1.1***	-1.1***	-0.74***	-1.1***	-1.1***	-1.1***
	(.24)	(.28)	(.28)	(.28)	(.24)	(.28)	(.28)	(.28)
F stat.	9.22	15.86	15.86	15.86	9.22	15.86	15.86	15.86
Panel A: Total								
3G coverage (%)	-0.13*	0.06**	0.1**	0.05	-0.27**	0.02	0.07*	0.01
	(.07)	(.03)	(.04)	(.04)	(.11)	(.05)	(.04)	(.07)
Panel B: Women								
3G coverage (%)	-0.17*	0.06	0.12**	0.01	-0.29**	0.03	0.08*	0.0
	(.09)	(.04)	(.05)	(.04)	(.12)	(.04)	(.05)	(.06)
Panel C: Men								
3G coverage (%)	-0.08	0.06*	0.07**	0.1**	-0.25**	0.02	0.04	0.05
	(.07)	(.03)	(.03)	(.05)	(.12)	(.06)	(.05)	(.08)
N	4007	2799	2799	2799	4007	2799	2799	2799
N. regions	831	655	655	655	831	655	655	655
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from IV regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage, 3G coverage is instrumented with an indicator for regional lightning frequency above the sample median interacted with year fixed effects. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

► Table A9. OLS results for the impact of regional 3G coverage on labour market outcomes by marital status

	LFPR	LFPR restricted sample	LFPR married	LFPR unmarried	EMP2POP	EMP2POP restricted sample	EMP2POP married	EMP2POP unmarried
Panel A: Total								
3G coverage (%)	0.02*	0.02*	0.01	0.02***	0.02**	0.03**	0.02*	0.02*
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.103	.116	.117	.108	.09	.174	.103	.116
Panel B: Women								
3G coverage (%)	0.02*	0.02*	0.01	0.03***	0.03**	0.02**	0.02*	0.02*
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.069	.081	.084	.093	.067	.17	.069	.081
Panel C: Men								
3G coverage (%)	0.01	0.01	0.01	0.02*	0.01	0.03**	0.01	0.01
	(.01)	(.01)	(.01)	(.01)	(.01)	(.02)	(.01)	(.01)
R2 (within)	.192	.274	.088	.135	.188	.175	.192	.274
N	2799	2799	2799	2799	2799	2799	2799	2799
N. regions	655	655	655	655	655	655	655	655
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

3G coverage (%)	0.01***	-0.01***	-0.04***	0.04***	0.01	-0.06***	0.04***
	(.0)	(.0)	(.01)	(.01)	(.01)	(.01)	(.01)
R2 (within)	.061	.255	.218	.281	.262	.308	.166
N	3360	3360	3360	3360	3360	3360	3360
N. regions	604	604	604	604	604	604	604
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample is restricted to countries with upper-middle or high income. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► **Table A12. OLS results for the impact of regional 3G coverage on employment status and sectoral composition – Lower-middle-income and low-income countries**

	Employers rate	Contributing family workers rate	Own account workers rate	Employees rate	Share services	Share agri-culture	Share industry
<i>Panel A: Total</i>							
3G coverage (%)	0.03	0.03	0.11***	-0.17***	-0.18**	0.2*	-0.02
	(.03)	(.04)	(.03)	(.05)	(.08)	(.11)	(.06)
R2 (within)	.159	.392	.382	.349	.27	.346	.342
<i>Panel B: Women</i>							
3G coverage (%)	0.02	0.11	0.11***	-0.24**	-0.23	0.25	-0.02
	(.01)	(.1)	(.04)	(.11)	(.17)	(.17)	(.03)
R2 (within)	.211	.265	.365	.213	.202	.271	.337
<i>Panel C: Men</i>							
3G coverage (%)	0.04	0.02	0.1***	-0.16***	-0.17**	0.2*	-0.03
	(.04)	(.03)	(.04)	(.05)	(.08)	(.12)	(.06)
R2 (within)	.207	.393	.35	.372	.274	.368	.359
N	647	647	647	647	586	586	586
N. regions	227	227	227	227	227	227	227
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample is restricted to countries with lower-middle or low income. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► **Table A13. OLS results for the impact of regional 3G coverage on employment by firm size – Upper-middle-income and high-income countries**

	EMP2POP	% firms with 1 to 4 workers	% firms with 5 to 49 workers	% firms with more than 50 workers
<i>Panel A: Total</i>				
3G coverage (%)	0.01	-0.01	0.01	0.01
	(.01)	(.01)	(.01)	(.01)
R2 (within)	.352	.143	.199	.136
<i>Panel B: Women</i>				
3G coverage (%)	0.01	-0.03***	0.02**	0.01
	(.01)	(.01)	(.01)	(.01)
R2 (within)	.317	.233	.198	.146
<i>Panel C: Men</i>				
3G coverage (%)	0.01	0.0	0.0	0.01
	(.01)	(.01)	(.01)	(.01)
R2 (within)	.345	.096	.15	.129
N	1177	1177	1177	1177
N. regions	301	301	301	301
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample is restricted to countries with upper-middle or high income. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► **Table A14. OLS results for the impact of regional 3G coverage on employment by firm size – Low-income and lower-middle-income countries**

	EMP2POP	% firms with 1 to 4 workers	% firms with 5 to 49 workers	% firms with more than 50 workers
<i>Panel A: Total</i>				
3G coverage (%)	0.11*	0.09	-0.09	0.0
	(.06)	(.09)	(.12)	(.15)
R2	.343	.56	.356	.077
<i>Panel B: Women</i>				
3G coverage (%)	0.11	-0.1	-0.14	0.24
	(.08)	(.12)	(.23)	(.3)
R2 (within)	.151	.59	.201	.167
<i>Panel C: Men</i>				
3G coverage (%)	0.13**	0.13	-0.08	-0.05
	(.06)	(.1)	(.1)	(.14)
R2 (within)	.517	.525	.398	.055
N	318	318	318	318

N. regions	99	99	99	99
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample is restricted to countries with lower-middle or low income. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

► Table A15. OLS results for the impact of regional 3G coverage on gender ratios in labour market outcomes

	EMP2POP	UNE2POP	NEET	% Agriculture	% Services	% Industry	% Employees	% Contributing family workers	% Own account workers	% Employers
<i>Panel A: Full sample</i>										
3G coverage (%)	0.0	-0.03	0.24*	0.02	0.05	-0.01	0.0	-0.38	-0.08	0.09
	(.01)	(.07)	(.13)	(.06)	(.03)	(.03)	(.03)	(.32)	(.08)	(.06)
R2 (within)	.09	.064	.132	.052	.044	.01	.024	.024	.045	.044
<i>Panel B: Upper-middle- and high-income countries</i>										
3G coverage (%)	-0.01	-0.07	0.13	-0.05	0.04**	-0.05**	0.01	-0.14	-0.01	0.01
	(.01)	(.06)	(.13)	(.05)	(.02)	(.02)	(.02)	(.33)	(.04)	(.06)
R2 (within)	.229	.08	.133	.061	.103	.078	.035	.02	.12	.036
<i>Panel C: Low- and lower-middle-income countries</i>										
3G coverage (%)	0.05	0.45	1.41**	0.68	0.17	0.22	-0.11	1.33	0.16	-0.03
	(.04)	(.39)	(.69)	(.51)	(.37)	(.24)	(.18)	(1.4)	(.35)	(.08)
R2 (within)	.204	.136	.208	.096	.131	.046	.099	.162	.059	.215
N	647	647	621	579	586	565	643	619	640	538
N. regions	227	227	226	224	227	225	227	225	225	214

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► **Table A16. OLS and IV results for the impact of regional 3G coverage on labour force participation and status on the population of individuals aged 15-64**

	OLS results			IV results		
	LFPR 15-64	EMP2POP 15-64	UNE2POP 15-64	LFPR 15-64	EMP2POP 15-64	UNE2POP 15-64
<i>First stage</i>						
Lightning x Year				-0.74***	-0.74***	-0.74***
				(.24)	(.24)	(.24)
First-stage F-statistic				9.22	9.22	9.22
<i>Panel A: Total</i>						
3G coverage (%)	0.0	-0.01	0.01	-0.03	-0.2*	0.17**
	(.01)	(.01)	(.01)	(.06)	(.1)	(.07)
R2 (within)	.06	.075	.241			
<i>Panel B: Women</i>						
3G coverage (%)	0.0	-0.01	0.01	-0.07	-0.21**	0.14**
	(.01)	(.01)	(.00)	(.07)	(.1)	(.06)
R2 (within)	.061	.089	.194			
<i>Panel C: Men</i>						
3G coverage (%)	0.0	-0.01	0.01	0.01	-0.19*	0.19**
	(.01)	(.01)	(.01)	(.06)	(.11)	(.08)
R2 (within)	.097	.067	.253			
N	4313	4313	4313	4007	4007	4007
N. regions	1099	1099	1099	831	831	831
Controls	Yes	Yes	Yes			
Fixed effects	Yes	Yes	Yes			

Note: The table shows results from OLS and IV regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. In the first stage of the IV regressions, 3G coverage is instrumented with an indicator for regional lightning frequency above median, interacted with year fixed effects. The outcome variables are calculated for the population of individuals aged 15-64. P-values are denoted as follows: * p < 0.10, ** p < 0.05, *** p < 0.01.

► **Table A17. OLS results for the impact of regional 3G coverage on labour force participation and status, removing high-income countries from the sample**

	LFPR	EMP2POP	UNE2POP	NEET rate
<i>Panel A: Total</i>				
3G coverage (%)	0.01	0.03**	-0.02***	0.03
	(.01)	(.01)	(.01)	(.04)
R2 (within)	.135	.162	.274	.128
<i>Panel B: Women</i>				
3G coverage (%)	0.01	0.03*	-0.02***	0.05
	(.02)	(.01)	(.01)	(.04)

R2 (within)	.147	.161	.188	.126
<i>Panel C: Men</i>				
3G coverage (%)	0.01	0.02*	-0.02**	0.02
	(.01)	(.01)	(.01)	(.03)
R2 (within)	.142	.192	.299	.15
N	1758	1758	1758	1758
N. regions	517	517	517	517
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample excludes high-income countries. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

► **Table A18. OLS results for the impact of regional 3G coverage on labour force participation and status, removing countries with baseline coverage above 80 per cent**

	LFPR	EMP2POP	UNE2POP	NEET rate
<i>Panel A: Total</i>				
3G coverage (%)	0.01	0.01	0.0	0.04
	(.01)	(.01)	(.00)	(.02)
R2 (within)	.108	.141	.309	.142
<i>Panel B: Women</i>				
3G coverage (%)	0.01	0.01	0.0	0.04
	(.01)	(.01)	(.00)	(.03)
R2 (within)	.082	.138	.238	.144
<i>Panel C: Men</i>				
3G coverage (%)	0.01*	0.0	0.01*	0.04
	(.01)	(.01)	(.01)	(.02)
R2 (within)	.18	.133	.335	.142
N	2960	2960	2960	2960
N. regions	579	579	579	579
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from OLS regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for region and year fixed effects and region-specific controls. The sample excludes countries with baseline coverage above 80 per cent at the national level. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

► **Table A19. Comparison of ANCOVA sample and full analysis sample**

	ANCOVA sample			Full sample		
	No. of countries	% of group population	% of group labour force	No. of countries	% of group population	% of group labour force
Low-income countries	1	4	4	4	13	15
Lower-middle-income countries	5	7	8	8	15	15
Upper-middle-income countries	8	26	25	16	29	28
High-income countries	22	55	54	24	56	55

Note: The table compares the country coverage for the ANCOVA analysis sample to the country coverage for the main sample used throughout the paper.

► **Table A20. ANCOVA results for the impact of regional 3G coverage on labour force participation and status**

	LFPR	EMP2POP	UNE2POP	NEET rate
<i>Panel A: Total</i>				
3G coverage (%)	0.03	0.02	0.02**	-0.04**
	(.02)	(.02)	(.01)	(.02)
R2 (within)	.789	.829	.842	.853
<i>Panel B: Women</i>				
3G coverage (%)	0.03	0.02	0.02*	-0.07***
	(.03)	(.02)	(.01)	(.02)
R2 (within)	.827	.854	.861	.889
<i>Panel C: Men</i>				
3G coverage (%)	0.03	0.01	0.02***	0.0
	(.02)	(.02)	(.01)	(.02)
R2 (within)	.853	.86	.794	.766
N	2219	2219	2219	2219
N. regions	517	517	517	517
Controls	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes

Note: The table shows results from OLS ANCOVA regressions of the outcome variables reported in the column headings on regional 3G coverage (0-100), controlling for year fixed effects, the baseline level of the outcome variable and region-specific controls. The sample is restricted to countries with at least one observation in or before 2012, and one observation after 2012. P-values are denoted as follows: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

References

- Adema, Joop Age Harm, Cevat Giray Aksoy, and Panu Poutvaara. 2022. "Mobile Internet Access and the Desire to Emigrate." CESifo Working Paper No. 9758. Munich: CESifo. https://www.ifo.de/DocDL/cesifo1_wp9758.pdf
- Aguiar, Mark, Mark Bils, Kerwin Kofi Charles, and Erik Hurst. 2021. "Leisure luxuries and the labor supply of young men." *Journal of Political Economy* 129, no. 2 (2021): 337-382. <https://www.journals.uchicago.edu/doi/abs/10.1086/711916>
- Aker, Jenny C. "Information from Markets Near and Far: Mobile Phones and Agricultural Markets in Niger." *American Economic Journal: Applied Economics* 2, no. 3 (July 2010): 46-59. <https://doi.org/10.1257/app.2.3.46>.
- Aker, Jenny C., and Marcel Fafchamps. 2015. "Mobile Phone Coverage and Producer Markets: Evidence from West Africa." *The World Bank Economic Review* 29 (2): 262-292. <https://doi.org/10.1093/wber/lhu006>
- Bahia, K., Castells, P., Cruz, G., Masaki, T., Pedrós, X., Pfutze, T., Rodríguez-Castelán, C., & Winkler, H. 2024. "The welfare effects of mobile broadband internet: Evidence from Nigeria." *Journal of Development Economics*, 170, 103314. <https://doi.org/10.1016/j.jdeveco.2024.103314>
- Bahia, Kalvin, Pau Castells, Genaro Cruz, Takaaki Masaki, Carlos Rodríguez-Castelán, and Viviane Sanfelice. 2023. "Mobile Broadband, Poverty, and Labor Outcomes in Tanzania." *The World Bank Economic Review* 37 (2): 235-256. <https://doi.org/10.1093/wber/lhad003>
- Barboni, Giorgia, Anwesha Bhatta, Erica Field, Rohini Pande and Natalia Rigol. 2024. "Hold the phone: The short- and long-run impacts of connecting Indian women to digital technology." EGC Discussion Papers, No. 1109, Yale University, Economic Growth Center, New Haven. <https://www.econstor.eu/bitstream/10419/305496/1/1905843488.pdf>
- Begazo, Tania, Moussa P. Blimpo, and Mark A. Dutz. 2023. "Digital Africa: Technological Transformation for Jobs. Overview Booklet." World Bank, Washington, DC, 2023. <https://www.worldbank.org/en/region/afr/publication/digital-africa>
- Bhuller, Manudeep, Andreas Ravndal Kostøl, and Trond Christian Vigtel. 2020. "How broadband internet affects labor market matching." No. 12895. IZA Discussion Papers, 2020. <https://www.econstor.eu/handle/10419/215291>
- Bhuller, Manudeep, Domenico Ferraro, Andreas R. Kostøl, and Trond C. Vigtel. "The Internet, Search Frictions and Aggregate Unemployment." NBER Working Paper No. 30911. Cambridge, MA: National Bureau of Economic Research, February 2023. <https://www.nber.org/papers/w30911>.
- Breen, Casey F., Masoomali Fatehkia, Jiani Yan, Xinyi Zhao, Douglas R. Leasure, Ingmar Weber, and Ridhi Kashyap. "Mapping Subnational Gender Gaps in Internet and Mobile Adoption Using Social Media Data." *Proceedings of the National Academy of Sciences* 122, no. 42 (2025): e2416624122. <https://doi.org/10.1073/pnas.2416624122>.

Briglauer, Wolfgang, Jan Krämer, and Nicole Palan. 2024. "Socioeconomic benefits of high-speed broadband availability and service adoption: A survey." *Telecommunications Policy* 48.7 (2024): 102808. <https://www.sciencedirect.com/science/article/pii/S0308596124001058>

Caldarola, Bernardo. "Mobile Internet Adoption and Inclusive Structural Change: Evidence from Nigerian Non-Farming Enterprises." STEG Working Paper No. 29. September 2022. <https://ssrn.com/abstract=4233182>.

Chiplunkar, Gaurav, and Pinelopi Koujianou Goldberg. "The Employment Effects of Mobile Internet in Developing Countries." NBER Working Paper No. 30741. Cambridge, MA: National Bureau of Economic Research, December 2022. <https://doi.org/10.3386/w30741>.

Dettling, Lisa J. 2017. "Broadband in the labor market: The impact of residential high-speed internet on married women's labor force participation." *Ilr Review* 70.2 (2017): 451-482. <https://journals.sagepub.com/doi/full/10.1177/0019793916644721>

Efobi, Uchenna R., Belmondo V. Tanankem, and Simplice A. Asongu. 2018. "Female economic participation with information and communication technology advancement: evidence from Sub-Saharan Africa." *South African Journal of Economics* 86, no. 2 (2018): 231-246. <https://onlinelibrary.wiley.com/doi/abs/10.1111/saje.12194>

Fabritz, Nadine. 2013. "The impact of broadband on economic activity in rural areas: evidence from German municipalities." No. 166. Ifo Working Paper, 2013. <https://www.ifo.de/DocDL/IfoWorkingPaper-166.pdf>

Falck, Oliver & Mazat, Andreas & Stockinger, Bastian, 2015. "Broadband Infrastructure and Entrepreneurship: Evidence from German Municipalities," 26th European Regional ITS Conference, Madrid 2015 127136, International Telecommunications Society (ITS). [Broadband Infrastructure and Entrepreneurship: Evidence from German Municipalities](#)

Falck, Oliver. 2017. "Does broadband infrastructure boost employment?." *IZA World of Labor* (2017). <https://wol.iza.org/articles/does-broadband-infrastructure-boost-employment/long>

Fang, Bingxu, Sterling Huang, Sugata Roychowdhury, and Ewa Sletten. "Mobile Internet and Analyst Forecast Performance." Working paper, November 2023. <https://abfer.org/media/abfer-events-2024/annual-conference/papers-accounting/AC24P5017-Mobile-Internet-and-Analyst-Forecast-Performance.pdf>.

GSMA. *The Mobile Gender Gap Report 2025*. London: GSMA, 2025. <https://www.gsma.com/wp-content/uploads/2025/12/The-Mobile-Gender-Gap-Report-2025.pdf>.

Guriev, Sergei, Nikita Melnikov, and Ekaterina Zhuravskaya. "3G Internet and Confidence in Government." *Quarterly Journal of Economics* 136, no. 4 (2021): 2533-2613. <https://doi.org/10.1093/qje/qjab013>.

Henderson, Savanna, Daniela Graney, and Elizabeth Koshy Kalarikad. "Leveraging Digital Tools for Women's Skills Development and Economic Empowerment: Evidence from Low- and Middle-Income Countries." Evidence Review. Washington, DC: Innovations for Poverty Action, March 2026. https://poverty-action.org/sites/default/files/2026-03/IPA-EvidenceReview-LeveragingDigitalTools_WomensEconomicEmpowerment%20FINAL.pdf.

Hjort, Jonas, and Jonas Poulsen. 2019. "The Arrival of Fast Internet and Employment in Africa." *American Economic Review* 109 (3): 1032–1079. <https://doi.org/10.1257/aer.20161385>

International Labour Organization. "ILO modelled estimates database" ILOSTAT. Accessed 16-05-2026. <https://ilostat.ilo.org/data/>.

International Telecommunication Union. 2023. "Measuring Digital Development: Facts and Figures 2023". Geneva: International Telecommunication Union. <https://www.itu.int/itu-d/reports/statistics/wp-content/uploads/sites/5/2023/11/Measuring-digital-development-Facts-and-figures-2023-E.pdf>

Jain, Ronak, and Samuel Stemper. 2026. "Growing Up Online: Global Evidence on (3G) Mobile Internet and Adolescent Learning." Working paper, March 10, 2026. https://ronak-jain.com/3G_Internet_and_PISA.pdf

Jensen, Robert. "The Digital Divide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector." *Quarterly Journal of Economics* 122, no. 3 (August 2007): 879–924. <https://www.jstor.org/stable/25098864>.

Kashyap, Ridhi, Masoomali Fatehkia, Reham Al Tamime, and Ingmar Weber. "Monitoring Global Digital Gender Inequality Using the Online Populations of Facebook and Google." *Demographic Research* 43 (2020): 779–816. <https://www.jstor.org/stable/26967824>.

Klonner, Stefan, and Patrick J. Nolen. 2010. "Cell Phones and Rural Labor Markets: Evidence from South Africa." Paper presented at the German Development Economics Conference, Hannover, Verein für Socialpolitik, Göttingen. https://www.econstor.eu/bitstream/10419/39968/1/354_klonner.pdf

Kolko, Jed. 2012. "Broadband and Local Growth." *Journal of Urban Economics* 71 (1): 100–113. <https://doi.org/10.1016/j.jue.2011.07.004>

Kopytov, Alexandr, Nikolai Roussanov, and Mathieu Taschereau-Dumouchel. 2023. "Cheap thrills: the price of leisure and the global decline in work hours." *Journal of Political Economy Macroeconomics* 1, no. 1 (2023): 80–118. <https://www.journals.uchicago.edu/doi/abs/10.1086/723717>

Kuhn, Peter, and Hani Mansour. 2014. "Is Internet Job Search Still Ineffective?" *The Economic Journal* 124 (581): 1213–1233. <https://doi.org/10.1111/ecoj.12119>.

Kusumawardhani, Niken, Rezanti Putri Pramana, Nurmala Selly Saputri, and Daniel Suryadarma. 2023. "Heterogeneous Impact of Internet Availability on Female Labor Market Outcomes in an Emerging Economy: Evidence from Indonesia." *World Development* 164 (2023): 106182. <https://doi.org/10.1016/j.worlddev.2022.106182>.

Li, Wentao, and Yun Chen. 2025. "The Digital Economy and Gender Disparities in Rural Non-Agricultural Employment: Challenges or Opportunities for Sustainable Development?." *Sustainability* 17, no. 9 (2025): 3911. <https://www.mdpi.com/2071-1050/17/9/3911>

Manacorda, Marco, and Andrea Tesei. "Liberation Technology: Mobile Phones and Political Mobilization in Africa." *Econometrica* 88, no. 2 (2020): 533–567. <https://doi.org/10.3982/ECTA14392>.

Mang, Constantin. 2012. "Online job search and matching quality". No. 147. Ifo Working Paper, 2012. <https://www.ifo.de/DocDL/IfoWorkingPaper-147.pdf>

McKenzie, David. 2012. "Beyond baseline and follow-up: The case for more T in experiments," *Journal of development Economics*, 2012, 99 (2), 210–221. <https://documents1.worldbank.org/curated/en/333121468147852171/pdf/WPS5639.pdf>

Ngoa, Gaston Brice Nkoumou, and Jacques Simon Song. 2021. "Female participation in African labor markets: The role of information and communication technologies." *Telecommunications Policy* 45, no. 9 (2021): 102174. <https://www.sciencedirect.com/science/article/pii/S0308596121000781>

Rezki, Jahan F. "Does the Mobile Phone Affect Social Development? Evidence from Indonesian Villages." *Telecommunications Policy* 47, no. 3 (2023). <https://doi.org/10.1016/j.telpol.2023.102490>.

Rotondi, Valentina, Ridhi Kashyap, Luca Maria Pesando, Simone Spinelli, and Francesco C. Billari. 2020. "Leveraging mobile phones to attain sustainable development." *Proceedings of the National Academy of Sciences* 117, no. 24 (2020): 13413–13420. <https://www.pnas.org/doi/abs/10.1073/pnas.1909326117>

Stork, Christoph, Enrico Calandro, and Alison Gillwald. "Internet Going Mobile: Internet Access and Use in 11 African Countries." *Digital Policy, Regulation and Governance* 15, no. 5 (August 2, 2013): 34–51. <https://doi.org/10.1108/info-05-2013-0026>.

Viollaz, Mariana, Hernan Winkler. 2021. "Does the Internet Reduce Gender Gaps? The Case of Jordan." *Journal of Development Studies* September 2021; 58 (3): 436–453. <https://doi.org/10.1080/00220388.2021.1965127>

Wang, Wei, and Shengbo Zhang. 2022. "The Impact of Internet Use on Rural Women's Off-Farm Work Participation: Empirical Evidence from China." *Sustainability* 14 (24): 16972. <https://doi.org/10.3390/su142416972>

Zahidi, Saadia. 2018. "Fifty million rising: The new generation of working women transforming the Muslim world." Hachette UK.

Acknowledgements

This research paper was produced as part of a partnership with the Gates Foundation. We are particularly grateful to Steven Kapsos for his valuable guidance and thoughtful feedback throughout the project. We also thank Caroline Fredrickson, Director of the Research and Statistics Department, and Sumana Hussain of the Gates Foundation for their careful review of the paper and insightful comments. We are also grateful to Ridhi Kashyap of the University of Oxford for generously sharing her team's insights on cleaning and processing the Collins Bartholomew Mobile Coverage Explorer data, including a technical report on mapping mobile coverage prepared by Till Koebe. Finally, this work would not have been possible without the contributions of the microdata team in the Data Production and Analysis Unit of the Statistics Branch: Hamidreza Bakhtiarizadeh, Vipasana Karkee, Donika Limani, Sandra Mora Caballero, and Yves Perardel.

► Advancing social justice, promoting decent work

The International Labour Organization is the United Nations agency for the world of work. We bring together governments, employers and workers to improve the working lives of all people, driving a human-centred approach to the future of work through employment creation, rights at work, social protection and social dialogue.

Contact details

Research and Statistics Department (RESTAT) Data Production and Analysis Unit (DPAU)

International Labour Organization
Route des Morillons 4
1211 Geneva 22
Switzerland
T +41 22 799 8631
statistics@ilo.org
www.ilo.org/stat



I S B N 9789220437452



9 789220 437452