Working Paper Series

#2023-042

Mobile internet and income improvement: Evidence from Vietnam

Trang Thi Pham

Published 23 November 2023

Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT)
email: **info@merit.unu.edu** | website: **http://www.merit.unu.edu**

Boschstraat 24, 6211 AX Maastricht, The Netherlands
Tel: (31) (43) 388 44 00

UNU-MERIT Working Papers
ISSN 1871-9872

Maastricht Economic and social Research Institute on Innovation and Technology
UNU-MERIT | Maastricht University

UNU-MERIT Working Papers intend to disseminate preliminary results of research carried out at UNU-MERIT to stimulate discussion on the issues raised.

WIDER Working Paper 2023/145

Mobile internet and income improvement

Evidence from Viet Nam

Trang Thi Pham*

December 2023

Abstract: New developments of existing technologies over time have led to emergent patterns of technology adoption and, accordingly, changing impacts on economy and society. Focusing on the arrival of mobile internet in the early 2010s in developing countries, this paper identifies significant positive effects on provinces' average household income in Viet Nam. The effect sizes are larger for lower-income quintiles and for rural areas, suggesting the more inclusive changing impact of the innovation over the last decade. Preliminary evidence of impact mechanisms via skilled employment rates and (formal) wages is also presented. The evidence from Viet Nam, a lower-middle-income country, can bring further understanding in terms of the extent of development impacts of second-generation mobile for development (M4D 2.0) in particular and information and communication technologies for development (ICT4D) in general.

Key words: household income, mobile internet, smartphone, technological change, developing countries, M4D, ICT4D

JEL classification: D31, O30, O53, R50

Acknowledgements: I would like to thank UNU-WIDER for the opportunity to participate in their Visiting PhD Fellowship.

Note: This study is published jointly with UNU-MERIT in the respective Working Paper Series.

---

* UNU-MERIT, Maastricht, Netherlands; phamthi@merit.unu.edu

This study has been prepared within the UNU-WIDER Visiting PhD Fellowship Programme.

Information and requests: publications@wider.unu.edu

ISSN 1798-7237 ISBN 978-92-9267-453-3

https://doi.org/10.35188/UNU-WIDER/2023/453-3

Typescript prepared by Luke Finley.

United Nations University World Institute for Development Economics Research provides economic analysis and policy advice with the aim of promoting sustainable and equitable development. The Institute began operations in 1985 in Helsinki, Finland, as the first research and training centre of the United Nations University. Today it is a unique blend of think tank, research institute, and UN agency—providing a range of services from policy advice to governments as well as freely available original research.

The Institute is funded through income from an endowment fund with additional contributions to its work programme from Finland and Sweden, as well as earmarked contributions for specific projects from a variety of donors.

Katajanokanlaituri 6 B, 00160 Helsinki, Finland

1 Introduction

Information and communication technologies (ICTs) have in the past decades offered multiplier effects on growth and productivity worldwide. The second decade of the twenty-first century has been characterized by the diffusion of mobile internet and smartphones in both developed and developing countries (see Øverby and Audestad (2021) for a timeline of ICT innovations). While, like other ICT innovations, mobile internet can provide near-zero marginal costs of information access and communications, the combination of internet and mobility characteristics can offer additional pathways to economic growth. In the past few years, the 'gig' or 'platform' economy initiated by mobile internet has created an additional service sector hiring significant numbers of software engineers for mobile applications (Arnold and Taş 2019; Mandel 2015). Mobility-based apps such as ride-hailing apps, for example, have also provided jobs for workers with diverse skill levels. Additionally, 'anytime, anywhere' connection has led to a further rise in e-commerce (Google et al. 2019). With affordable devices and data packages, mobile internet offers ubiquitous connection and communication via social media and messaging platforms and more timely accessibility to a wider range of information resources, as well as next-generation mobile banking and payment. These economic multifunctionalities can help to facilitate business transactions, as well as entrepreneurship, particularly for small or informal businesses (Caldarola et al. 2023). This is not to mention the potentially significant increase in social transfers and remittances thanks to lower transaction costs, more time efficiency, and other user-friendly utilities. Last but not least, there can be benefits as a result of other functionalities such as mapping services, calendar, and reminders, which help to reduce scheduling and travelling time, or improved access to health information and gaming and entertainment, which can help to improve social wellbeing and thus, possibly, individual productivity. These effects help to bring additional income sources for households, potentially in both the formal and the informal sectors. These benefits can be especially strong for less-advantaged groups (e.g., lower-income households) and regions (e.g., rural areas), particularly in developing countries that have historically been less connected to the regional and world economy.

In 2018, the world passed the threshold of 50 per cent of people using the internet, according to World Bank data, and the digital divide has moved from access or ownership to usage level in terms of time and quality or types of use. Viet Nam passed the 50 per cent threshold in 2015, while the average rate for lower-middle-income countries in 2020 was 45 per cent. Like many developing countries, Viet Nam has a large population, especially of low-income citizens and those in rural areas, who have skipped personal computers (PCs) and moved directly to smartphones to integrate into the digital world. Distinctively, Viet Nam is among the countries with the highest smartphone penetration rate in the world. The country is increasingly becoming a base for ICT outsourcing services for regional and international companies, producing products and services for the app economy (Arnold and Taş 2019). Human capital with universal literacy and primary education, and near-universal lower-secondary education, can help to facilitate and enhance this impact via better digital skills and use. In terms of cognitive skills, the PISA (Programme for International Student Assessment) test scores of the OECD (Organisation for Economic Co-operation and Development) in maths, English, and science for Viet Nam have been higher than those for Malaysia and Thailand (both upper-middle-income countries) and in the South-East Asia region are lower only than Singapore (a high-income country). Measuring the impacts of internet adoption and universal broadband policy using the case of Viet Nam can offer additional insights for both policy-making and academic research, since the internet has been advocated as a human right by the UN and other international organizations.

In this paper we add to the literature on the development impacts for developing countries of the diffusion of mobile internet, in particular on household income, using evidence from Viet Nam (Aker 2010; Bahia et al. 2020; Blumenstock et al. 2020; Dammert et al. 2013; Donati 2023; Hartje and Hübler 2017; Hübler and Hartjie 2016; Kaila and Tarp 2019; Muto and Yamano 2009; Roessler et al. 2020; Suri and Jack 2016). The rise of 3G coverage in the country in the last decade, in the context also of disparities between provinces and regions, can affect provincial average household income levels. Household income may have been improved through the creation of additional jobs at both high- and low-skilled levels, such as positions for software engineers, user interface designers, user experience analysts, and ride-hailing services, which are facilitated by the gig or app economy. Consequently, wages have increased, along with other income sources arising from self-employment, particularly for micro-, small, and medium-sized enterprises (MSMEs), whether formal or informal. Additionally, there has been a rise in remittances, both domestically and internationally, with the country maintaining its position as one of the top recipients of remittances globally. In this paper, we identify whether there are significant positive effects of improved mobile internet coverage on household income in Viet Nam, and the extent of these effects.

For our empirical analyses, to address the potential endogeneity between mobile internet coverage and income level, instrumental-variable and fixed-effects approaches are adopted. Following the extant literature and local context characteristics, we use elevation as the main instrument, which is shown to be relevant and reasonably exogenous, and we measure a significant positive effect of 3G coverage on provincial household average income. The unit of analysis is the province (meso level) due to availability of administrative and geo-referenced data from both the General Statistics Office of Vietnam (GSO) and international organizations.

The results are robust under a more restricted sample, and under alternative measurements of the main independent variable and units of analysis (gridded cell level of 0.5 degrees). The heterogeneity analysis provides evidence of more-inclusive or pro-poor effects, with stronger effect sizes for rural areas and for lower-income quintiles, while preliminary analysis of the mechanisms underlying the effects indicates improved effects on employment, i.e., skilled or trained employment rates and wages.

In what follows, we present case background and preliminary evidence in Section 2; then, Section 3 describes the data sources and descriptive analysis while Section 4 states our empirical strategy; our research results, including robustness tests and heterogeneity analyses, are shown in Section 5; followed by a brief discussion of impact mechanisms in Section 6; Section 7 concludes.

2 Background and preliminary evidence

In this section we provide background information about Viet Nam's development progress in the last decades, including broadband coverage, and preliminary evidence of positive effects on household income.

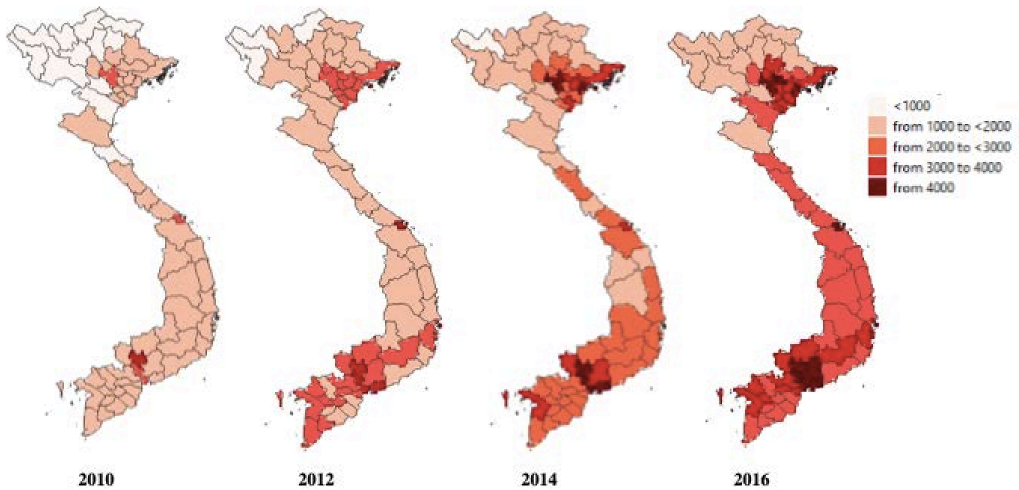
2.1 Viet Nam's development achievements since the 1980s

Aside from mass cheap access to the internet, Viet Nam has achieved notable success in poverty alleviation, universal electricity access, and universal primary education through 'small-scale and rural infrastructure development [as] a key feature of Vietnam's inclusive development' (Nguyen and Dapice 2009) over the past decades. The country reached the status of lower-middle-income country in 2010 with annual GDP per capita of US$1,673 (current value) (WDI data). The country's income level has risen significantly since then (see Figure A1 in the Appendix).

Since the reform (known as Doi Moi) towards a 'socialist-oriented market economy' in 1986, Viet Nam has liberalized the market and conducted multiple institutional reforms. The country became a member of the World Trade Organization (WTO) in 2007 and has participated in various bilateral and multilateral free trade agreements (FTAs) with regional partners, the US, and Europe (see Table A1 in the Appendix for more information on Viet Nam's FTAs since 1975). Viet Nam's recent growth has been based mainly on manufacturing, construction, tourism, and business services, with telecommunications equipment, textiles and garments, and computers, electronics, and integrated circuits the top three export sectors, providing millions of jobs and supplementing the traditional industries and exports of oil and mining, agriculture, and fisheries and aquaculture (Cameron and Pham 2018). Combined with a growing market of 95 million people in 2018, up from 60 million in 1986, Viet Nam has become South-East Asia's hub for foreign investment and manufacturing, notably being the largest clothing and the second-largest electronics exporter (after Singapore) in the region (WEF 2018; World Bank 2016). The social sector also plays an important role, with international non-governmental organizations (NGOs) providing around US$300 million annually (European Union 2014). Vietnamese citizens abroad also sent back over US$8 billion in remittances each year—approximately the same value as that of foreign direct investment (FDI) and twice of that of official development assistance (ODA) (European Union 2014).

Household income levels have increased over the years for all 63 provinces and centrally run cities[1] (henceforth provinces), though there remain some gaps between the north, central, and south regions and between provinces, as can be seen in Figure 1.

Figure 1: Regional disparities in provincial monthly real income per capita, 2010–2016 (in 1,000 VND)



Source: authors' illustration based on income data from GSO (2016a, 2020b).

Geographically, three-quarters of country's land is covered by mountains and plateaus (Nguyen 2010) (see Figure A2 in the Appendix). Spatial inequality between urban and rural areas and between mountainous or central highland areas and the rest of the country remains a concern (European Union 2014; Nguyen and Dapice 2009; World Bank 2019b).

[1] This includes 58 provinces and five centrally run cities (Ha Noi, Hai Phong, Da Nang, Ho Chi Minh City, and Can Tho).

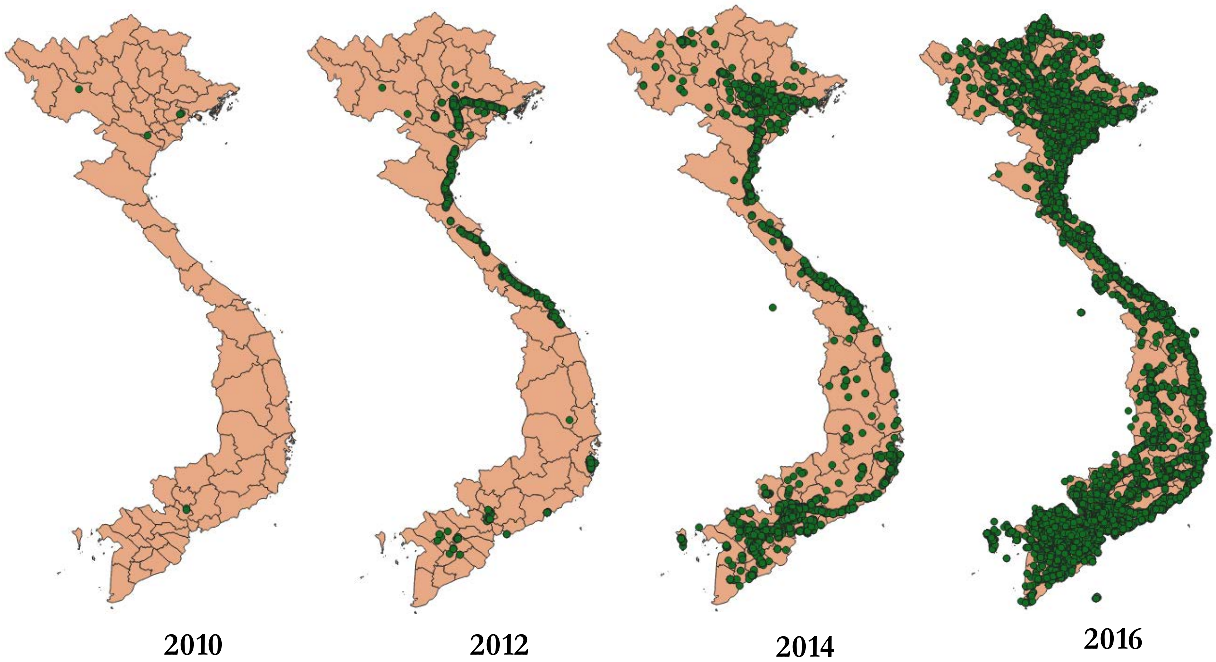
2.2 Mobile internet infrastructure and usage in Viet Nam, 2010–16

Viet Nam's smartphone penetration rates have been among the top ten in developing countries, reaching 71 per cent of the total population in 2017 (Appota 2018), following China and followed by Indonesia and Mexico (see Figure A3 in the Appendix). Percentages of individuals using the internet has surpassed the upper-middle-income country average since 2017 (WDI).

Mobile internet users account for the majority of internet users in Viet Nam (Appota 2018), with 68 per cent of the population getting online via smartphone more often than via laptop or PC (Appota 2018).[2] In 2017, smartphone penetration rates were 84 per cent for key cities and 68 per cent for rural areas (Appota 2018), suggesting a small but real digital divide between urban and rural areas.

The numbers of towers providing 3G mobile internet signals have increased exponentially since 2010–16 (see Figure 2). The average number of 3G cell towers per province has risen from 0.11 in 2010 to 1,838 in 2018; or from near zero to 0.8 cell towers per 1,000 population per province over 2010–16. Coverage has become almost universal, with the exception of several areas in the north-east and north-west mountainous and central highlands regions. The prices for 3G and smartphone packages have reduced significantly. Telecoms companies, together with mobile virtual network operators (MVNOs) and retailers, have offered bundling services, driving down both smartphone and mobile internet prices (Google et al. 2019; momo.vn 2021; Q.P. Nguyen 2019).

Figure 2: Map of new 3G cell tower signals, 2010–16



Source: authors illustration based on data from OpenCellID (www.opencellid.org/downloads.php), a collaborative community project run by Unwired Labs, a geolocation service provider.

[2] With another 16% using smartphones and PC equally while 9% use PC/tablet more often than phone.

Smartphones users access the digital world mainly through apps, which can be classified into two main types: (1) general apps that are often available by default (apps that are built in by smartphone producers or telecoms providers and applicable to most demographics)[3] (DeFazio 2021; Roggio 2021); and (2) specialized apps for specific demographic user groups, which are often downloaded by the users themselves, such as those for education (e.g., online blackboard for formal education systems or Coursera/Udemy for specific skills or certificates), healthcare, and e-government, to name a few. These platforms can offer interactive 3D graphics and high-resolution videos that are downloadable for offline usage.

In Viet Nam, the activities that smartphone users engage in the most often on a weekly basis are (1) watching videos; (2) social networking; (3) using search engines; (4) playing games; (5) looking for product information; and (6) purchasing products and services (Appota 2018). For daily use, besides the aforementioned activities, people also check email, view maps, engage in e-banking, read books, and check health data (Appota 2018). Regarding online commerce, there were estimated to be over 35 million online shoppers in Viet Nam in 2017, with 72 per cent of total visits to e-commerce websites and 53 per cent of purchases being made using mobile phones (Appota 2018). Additionally, there is a growing trend for purchases to be made via social media: 83 per cent of mobile commerce in Viet Nam occurred on Facebook in 2017, up from 67 per cent in 2016 (Appota 2018; Google et al. 2021). Rural areas account for 39 per cent of e-commerce shoppers while Ho Chi Minh City (HCMC) alone contributes 38 per cent and Ha Noi 17 per cent (Appota 2018). There are still some issues in the app ecosystem, including trust, scamming, and content availability and quality (Appota 2018), but the market is growing nevertheless.

2.3 Preliminary evidence of improvements in household income and employment following mobile internet arrival

The app economy, or sharing economy (AlphaBeta 2021; IMF 2018; OECD 2020; Wang 2020), created 29,000 jobs in 2015 for app developers in Viet Nam, up from zero as of 2007 before the arrival of the iPhone (Mandel 2015). This rose to 42,500 jobs in 2017 (Arnold and Taş 2019). These numbers do not include additional jobs created for sales employees, project managers, or database analysts. The creation of these jobs comes from companies of different sizes that develop apps for clients or for themselves; foreign IT outsourcing companies with offices in Viet Nam; multinational companies setting up supply chains for app development in Viet Nam; companies developing apps for their consumers' use under their brands; and media, finance, and retail companies. The demand for new mobile apps is expected to continue to grow in the future (Mandel 2015), combined with the development of Internet of Things applications in almost all industries.[4]

The app economy has also led to the rise of ride-hailing services (transport, food delivery), e-commerce, and online travel (accommodation bookings, vacation rentals). This slowed down during COVID-19 but is recovering now, creating jobs for freelancers and increasing sales for small retailers (Google et al. 2019). The global freelance jobs-listing platform Upwork already has listings for Viet

[3] Such as maps that help consumers to locate places and businesses (as well as their opening hours and customer reviews) or suggest the best routes to destinations for riders/drivers; utility apps like calculator, video/voice recording, weather forecast; translation apps for cross-cultural communication and search; search engines like Google; and social media, e.g., Facebook in the context of Vietnam for both communication and information search, where more and more businesses (both formal and informal) have added their presence on the online platform for marketing and e-commerce purposes.

[4] From agriculture to healthcare and manufacture, where farmers, nurses and doctors, and managers will use applications to aid their production, manage patient care, control factories, and so on.

Nam-based positions or for Vietnamese,[5] and many other platforms, both local and international, also post information on both formal and freelance jobs (Sinicki 2021; Wang 2020).

In Viet Nam, the value of the internet economy reached US$12 billion in 2019—close to 5 per cent of the country total's GDP in 2019 (in current US$ values)—with e-commerce being one of the key drivers (Google et al. 2019). Home-grown online marketplaces (e.g., Tiki, Sendo) have grown and now compete with regional players (e.g., Lazada, Shopee) (Google et al. 2019). Ride-hailing and food delivery services (Grab, Grab Food, NOW, etc.) have created jobs for motorcycle or scooter riders and car drivers (Google et al. 2019), and have promoted sales for local small or micro-enterprises at the same time. With additional training, e.g. in internet use skills, the benefits can be further enhanced and extended (Thịnh 2020).[6] Rising funding and an increased number of startups, e.g., logistics startups that utilize optimization technologies, have also created additional jobs for both high- and low-education groups (Google et al. 2019).[7]

Following this suggestive evidence, we next provide quantitative analysis of income effects.

3 Data sources and descriptive statistics

We collected both open-source administrative and geo-referenced data for the period of 2010–16 for our main analysis and for 2004–08 for the pre-trend analysis tests. Our primary geographical unit of analysis is 63 provinces. This choice is driven mainly by the availability of income data from the open sources of the GSO. For robustness tests, we also aggregate data to a grid cell level of 0.5 × 0.5 degrees (or 55.55 × 55.55 km).

3.1 Vietnam Household Living Standard Survey, Population and Housing Census, and Statistical Yearbooks

Data on provinces' average household per capita income and employment rates are sourced from the reports of the Vietnam Household Living Standard Survey (VHLSS) published by the GSO (GSO 2016a for 2008–16, 2019a for 2004–14); and from the Population and Housing Census (PHC) reports for 2009 and 2019 (GSO 2010, 2020a). The VHLSS has been conducted biannually since the early 1990s and is designed to be representative at provincial, regional, and national levels, while the PHC is designed to be representative at the district level and above (Benjamin et al. 2017; Tarp 2017).[8] Data on formal wages are collected from GSO's Statistical Yearbooks (GSO 2016b, 2019b).

Provincial average household real income has risen significantly, from VND1,334,000 in 2010 to 2,816,000 in 2016, with the largest differences being between Lai Chau province, where income per

---

[5] Available at: www.upwork.com/freelance-jobs/vietnamese (accessed 15 March 2021).

[6] For example, farmers who participated in a training project conducted by Google and the Farmers' Association between 2017 and 2019, targeting government officials and association members, were trained in information access and internet skills to improve both their production and their daily lives. As a result, these farmers established fan pages on social media platforms such as Facebook and Zalo (the leading Vietnamese message app, comparable to WhatsApp) to promote and market their fruit and cattle products.

[7] Truck drivers, for example, can use a mapping service app on their phone for driving and a messenger app for communicating family during long-haul journeys.

[8] The administrative levels in Vietnam, in descending order, are national, regional, provincial, district, and commune. For before 2008, when Ha Tay province was merged into the capital Ha Noi, the data for Ha Tay and Ha Noi are calculated by averaging the two provinces' data.

capita increased from VND587,000 to 1,319,000, and Binh Duong province, where it increased from VND3,002,000 to 5,131,000, in the period 2010–16.

In terms of the components of income sources, wages accounted for the majority of household real income (41 per cent on average), followed by agriculture (27 per cent), and non-agriculture (22 per cent), though since 2014 non-agriculture sources have overtaken agriculture to become the second-largest component of income (see Figures A4 and A5 in the Appendix for trends in income sources and quintiles). Average formal wages increased from VND3,432,000 to 6,152,000 during 2010–16, approximately six times higher than average wages when both formal and informal are included.

Overall employment rates[9] averaged at 58.4 per cent, with Bac Kan province having the highest rate of 71.3 per cent in 2014. Da Nang city, the third-largest city after HCMC and Ha Noi in economic size, had the lowest employment rate among all provinces in 2010, at 47.3 per cent. Trained employment rates[10] (for employees who had formal education or on-the-job training) increased from 13 per cent to 18.2 per cent during 2010–18 (for a visualization, see Figure A6 in the Appendix).

3.2 Data on mobile internet

Data on mobile coverage is extracted from OpenCellID, a source which has been used for studies of the internet, mobile coverage, and socioeconomic development (Hodler and Raschky 2017; Viollaz and Winkler 2020)[11]. For Viet Nam, OpenCellID data cover three types of mobile technologies: 2G (GSM), 3G (UMTS, first data collected in 2010), and 4G (LTE, first in 2014). The databases offer information on cell towers' longitude and latitude[12] and date and time signal collected, which we then converted into province and year data (Viollaz and Winkler 2020). Due to limited 4G data collected, we use only 3G data.[13]

In September 2009, the licences to supply 3G services were offered to four companies: Vietnam Telecom Services Company (VinaPhone), Vietnam Mobile Telecom Services Company (MobiFone), Viettel Military Industry and Telecoms Group (Viettel), and Hanoi Telecoms Electricity Joint Stock

[9] Employment rates are calculated for surveyed individuals who are 15 years old or older and have done any (not illegal) job for at least an hour to produce goods or service during the time of the survey, including also paid trainees, internships, self-employed, students, and retirees. See www.gso.gov.vn/du-lieu-dac-ta/2019/12/htcttk-cap-tinh-so-lao-dong-co-viec-lam-trong-nen-kinh-te (accessed 18 January 2022).

[10] An employed person is considered a trained employee if they satisfy either of the following two conditions: 1) have trained at a formal school or centre under the national education system for at least three months and have graduated and received certificates/qualifications including vocational training, college, university, and postgraduates; (2) have not trained at a formal school but self-educated or have received on-the-job training, so that they have equivalent to those provided by the same formal training. See www.gso.gov.vn/du-lieu-dac-ta/2019/12/htcttk-cap-tinh-ty-le-lao-dong-da-qua-dao-tao (accessed 15 March 2021).

[11] The database was used instead of that of the Global System for Mobile Communications Association (GSMA) due to data availability for Viet Nam. The authors contacted a representative from Collins Bartholomew, the GSMA's partner for the mobile coverage database, but received the response that data for Viet Nam have been missing for many years, as local telecommunications companies do not submit their data.

[12] Averaged longitude and latitude were provided when more than one signal was received.

[13] For the 4G network, data from OpenCellID for Vietnam mostly cover urban areas only, either because current 4G users are from urban areas, or because contributors who send their signals to OpenCellID via cell tracking apps are in urban locations—but mostly the second case, because 4G signals have been provided across the country in both urban and rural areas by major service providers. The price difference between the two types of signal in the local market is negligible compared with the benefits (significantly faster speed, stable network, ranges of services: video calling), and most smartphones (as users frequently purchase or exchange their existing phones for new ones) can support the 4G signal.

Company. A total of 30,334 stations were built within 18 months, with over eight million 3G user accounts (Nhandan.vn 2011).

The coverage of 3G cell towers rose significantly between 2010 and 2016 (see Table A2 in the Appendix). Over this period, 3G stations covered almost the entire country, with an average of 504 towers per province, or 0.22 towers per 1,000 population, reaching the farthermost destinations from the north to south. Heterogeneity between provinces still exists, from almost zero for most provinces and cities in 2010 to 4.3 towers per 1,000 population for HCMC and 0.12 for Dien Bien and Bac Giang provinces in 2016. Distances to the nearest cell towers have been reduced significantly (see Figure A7 in the Appendix).

3.3 Other variables

Data on elevation are taken from the US Geological Survey (USGS) GTOPO30 mountain elevation (USGS 2018). The highest point in Viet Nam is the Fan Si Peak, with an elevation of 3,143m, located in Lao Cai province, while provinces along the coastlines are just above sea level. The national average elevation is 255.2 m; Lai Chau province has the highest provincial average elevation of 1,019 m and the Mekong Delta provinces have the lowest elevation of 1 m.

Terrain slope data at 0.5-degree resolution are obtained from Verdin et al. (2011). Geo-referenced data on terrain ruggedness at 1 × 1 km grid-square levels are provided by Carter (2018). Data on lightning strikes are collected from NASA's Global Hydrology Resource Center: their database provides a 0.1 × 0.1-degree[14] gridded composite of total lightning bulk production, expressed as a flash rate density (flash rate per square kilometres per year). More details on specific data sources and processing can be found in Table A3 in the Appendix.

A description of key variables in shown in Table 1. A scatterplot demonstrating the correlation between the dependent and the main independent variables can be seen in Figure A8 in the Appendix.

Table 1: Summary statistics for key variables

Variable	Obs	Mean	Std dev.	Min.	Max.
Real household income (1,000 VND)	252	2,147.207	926.689	586.638	5,131.138
Log real household income	252	7.580	0.433	6.374	8.543
3G cell towers	252	504.202	2,847.527	0	36,167
3G cell towers per 1,000 pop.	252	0.215	0.516	0	4.265
Log 3G cell towers per 1,000 pop.	252	0.145	0.275	0	1.661
Weighted 3G cell towers	252	17.578	68.910	0	823.723
Log weighted 3G cell towers	252	1.224	1.569	0	6.715
Distance to nearest 3G cell tower (metres)	252	60,950.79	96,732.8	34.065	531,947.8
Log distance to nearest 3G cell tower	252	9.827	1.801	3.528	13.184
Elevation × time trend	252	893.158	1,090.144	2	5,097.213
Employed ratio	252	58.437	3.778	47.3	71.3
Trained employment ratio	252	15.537	6.791	5.1	42.7

Source: authors' construction based on data sources described in Table A3 in the Appendix.

[14] 0.1 × 0.1 degrees is equivalent to 11.132 × 11.132 km. This smaller grid is used instead of 0.5 × 0.5 as in Manacorda and Tesei (2020) to fit the average area of communes in Vietnam.

4 Empirical strategy

To identify the causal effects of mobile internet, it is required that 3G internet allocation is exogenous to the dependent variable over the period 2010–16. From the demand-side perspective, internet adoption or usage is more likely to be endogenous to household income (reverse causality of higher income leading to higher mobile broadband adoption) compared with coverage or availability from the supply side (Kolko 2012). Telecoms companies may decide to construct cell towers in places with more market potential, i.e., choosing to invest more in provinces with higher aggregate GDP, GNI, or per capital values. To address this endogeneity concern, following the contemporary literature, we use an instrumental variable (IV) approach combined with province fixed effects (FEIV) (Donati 2023; Ivus and Boland 2015; Manacorda and Tesei 2020; Ndubuisi et al. 2021; Tang et al. 2022; Wang 2020). Based on the extant literature and data availability, we identify that in Viet Nam, higher elevation results in lower coverage due to the higher costs of construction and maintenance of cell towers. This is because mountainous areas usually have narrow lanes built on cliffs, which leads to higher transportation costs; additionally, these areas more often experience unstable electricity supply and power outages more often,[15] as well as higher risks of flash flooding and landslides. We also use slope to test the robustness of the FEIV approach and identify similar results.

On the relevance requirement of the instrument, past literature has used elevation or terrain characteristics as instruments for cell tower coverage in developing countries, including Buys et al. (2009) and Klonner and Nolen (2010)) for 2G signal before 2010; and Donati (2023) and Tang et al. (2022) for 3G signal or broadband internet in the later period. For Viet Nam specifically, Yoon (2015) used terrain slope as an instrument for rural electrification to analyse its effects on household incomes during 2004–06. In their analysis, higher slope causes less electrification (proxied by nightlight intensity), with similar arguments relating to the higher installation costs of the transmission network due to greater cable length if the line has to pass through a mountain. Our instrument approach, adapted from Ivus and Boland (2015) and Manacorda and Tesei (2020) with local characteristics, can explain the differences in 3G coverage between provinces via elevation heterogeneity, while the linear time trend accounts for changes over time within provinces. The first-stage results with F-statistic significantly above 10 (presented in Section 5) corroborate the relevance condition.

For the exogeneity requirement, elevation can be used as an instrument under the assumption that its correlation with provinces' economic development is only indirect via mobile broadband coverage. In Sections 5.2 and 5.3 we present multiple tests in support of our identification assumptions. We show that the instrument is not correlated with income over the period 2004–08 (pre-treatment); and that leading values of income (placebo test) and the instrument are not associated.

[15] We also confirmed this with several engineers who had worked at local telecoms companies building cell towers.

4.1 Model specification

With the availability of socioeconomic panel data, the main equation used to estimate the effect of mobile internet on income is:

$$\ln(\bar{y}_{jt}) = \beta_0 + \beta_1 \ln(Cov_{jt}) + \beta_2 X_{jt} + f_j + f_t + \varepsilon_{jt} \quad (1)$$

where $\bar{y}_{jt}$ is average monthly household per capita income of province j in year t; Cov_{jt} is the mobile signal coverage of province j at year t (measured by logarithm of the number of 3G cells per 1,000 population per province); X_{jt} refers to a set of control variables measured at the province level (e.g. population density, FDI values); f_j to province fixed effects which can control for different trends in market outcomes across geographical units (e.g., distance to the nearest coastline, or local tradition/culture); f_t to time fixed effects (e.g., a general increase in tech-savvy culture); and ε_{jt} denotes the idiosyncratic error term.

Our first-stage estimation equation is:

$$\ln(Cov_{jt}) = \delta_0 + \delta_1 Z_{jt} + \beta_2 X_{jt} + f_j + f_t + \eta_{jt} \quad (2)$$

where $Z_{jt} = mount_j * t$, with $mount_j$ as the average elevation of province j; t captures the generalized increase in mobile phone coverage across the country during 2010–16;[16] f_j and f_t denote province and time fixed effects respectively, similarly to the second-stage equation; and η_{jt} is the idiosyncratic error term.

Our base models are FEIV without any time-variant control variables due to potential collinearity and measurement issues of these variables. We nevertheless tested models with several control variables, i.e., population density, FDI registered values, temperature, and rainfall, following the extant literature on factors influencing regional economic activities in Viet Nam and other countries with relatively similar socioeconomic characteristics (Driffield and Jones 2013; Nguyen and Nguyen 2007; Nguyen et al. 2021; H.H. Nguyen 2019; H.Q. Nguyen 2017; Vu et al. 2008; Yang et al. 2015; Zang 2019), and the results remain robust (see Section 5.1).

[16] With $t = 1, 2, 3, 4$ for the years 2010, 2012, 2014, 2016 respectively.

5 Empirical results

In this section we present our main regression results, tests of identification assumption, heterogeneity analyses, and a battery of robustness tests.

5.1 Main results

The main outcomes of different models are presented in Table 2. We adopted the multiple estimation methods of fixed effects (FE) and fixed effects-instrumental variable (FEIV) with different combinations of year and province fixed effects and weighting schemes. Columns 1 to 4 show the FE method, columns 5 to 6 the FEIV method. Columns 1 to 6 all have province FE, while columns 3 to 6 also have year FE. The even-numbered columns have province populations as weights while the odd-numbered columns do not. The dependent variable in all regressions is the log provincial average household per capita income; the main independent variable is log number of 3G cell towers per 1,000 population per province.

From Table 2 it can be seen that mobile broadband coverage has positive effects on household income across different estimation methods. The effect size from the FEIV estimation with weights in column 6 suggests that a 10 per cent increase in the number of 3G cell towers per 1,000 population per province will cause an increase of approximately 0.4 percentage points in household income per month, or 4.8 percentage points per year. In the IV models the first-stage results show that the effect of elevation on mobile internet coverage is negative and highly significant, with F-statistics satisfying the relevance requirement, being above 10. We also run models with time-variant controls and an alternative instrument, and the results remain robust in terms of effect sizes and significance levels for models with controls and qualitatively the same for models with the average slope of the terrain as the instrument (see Table A4 in the Appendix).

Table 2: Monthly household income and mobile broadband

Log household income	(1)	(2)	(3)	(4)		(5)		(6)
3G internet	0.152***	0.136***	0.0200**	0.0107	0.0449***		0.0387**	
	(0.00606)	(0.0140)	(0.00800)	(0.0110)	(0.0172)		(0.0165)	
1st stage						−0.000732***		−0.00105***
						(0.000136)		(0.000239)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes	No	No	Yes	Yes
F-stat.						29.213		19.565
N	252	252	252	252	252	252	252	252
R-sq.	0.581	0.614	0.967	0.969	0.985	0.899	0.985	0.884
Adjusted R-sq.	0.579	0.612	0.967	0.969	0.979	0.863	0.980	0.843
RMSE	0.187	0.183	0.0526	0.0521	0.0539	0.580	0.0551	0.742

Note: columns 1 to 4 show the adopted FE method, 5 and 6 the FEIV method; columns 1 to 6 all have province FE while columns 3 to 6 also have year FE; columns 5 and 6 use elevation × linear time trend as instrumental variable; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses; RMSE = root mean squared error; * $p<0.10$, ** $p<0.05$, *** $p<0.010$.

Source: author's construction based on data sources described in Table A3 in the Appendix.

In the next Section 5.2., we present tests of the identification assumptions for the instrument used in the FEIV models in Table 2.

5.2 Probing the instrument

We conduct multiple tests to examine the exogeneity of the instruments, as follows.

First, we run province and year FE models for the period 2004–08 to test if the instrument is correlated with the dependent variable. We find no statistically significant correlation at conventional levels (see Table A5 in the Appendix), suggesting the exogeneity of the instrument.

Second, we find that the (placebo) lead values of income do not correlate with the instrument in the province and year FE models, with or without time-variant control variables and with or without weights (see Table A6 in the Appendix).

As an additional check, we find that the instrument is not correlated with the residuals from the main regressions, with or without time-variant control variables, indicating the instrument's exogeneity with the dependent variable (see Table A7 in the Appendix).

5.3 Robustness tests

In this section, several robustness tests are carried out to corroborate the results of the main model.

We start by running the same models for a sample without Ha Noi, the capital, and HCMC, the largest economic centre, and find that the regression results remain robust across models, with effect sizes and statistical significance levels slightly increased (see Table A8 in the Appendix).

Next, we use distance to the nearest cell tower as the independent variable rather than cell tower count. As can be seen in Table A9 in the Appendix, distance to the nearest 3G cell tower has a statistically significant negative impact on income level, suggesting that the further away a household is from a 3G cell tower, the smaller the effect of mobile internet on household income.

Third, following Manacorda and Tesei (2020), we run the same models using 0.5 × 0.5 grid cells as the unit of analysis. This produces 62 units of analysis (the country's total land area is 310,070 km²) that have approximately the same average area as provinces. We detect similar positive significant results, as can be seen in Table A10 the Appendix.

Fourth, we use an event study approach, following Caldarola et al. (2022). As Figure A9 in the Appendix shows, there are positive results of mobile internet coverage treatment[17] with similar effect sizes in the first year of adoption. This is in line with our main regression results in Section 5.1. The results in the Appendix also demonstrate the increasing effect sizes over time, which are all statistically significant with the exception of the one-year lead effect in the weighted model. This result indicates the potential long-term impacts of mobile technologies, aligning with evidence from Bahia et al. (2020) and Caldarola et al. (2022). The pre-trend assumption is also confirmed by the insignificant effects on the (placebo) lags before treatment.

Fifth, we use the FEIV-Lewbel method, which exploits variation from the second moments of the error distribution of the first-stage regression (Equation 2) to create an instrument, following Deuflhard et al. (2019) and Ndubuisi et al. (2021), and identify similar significant results (see Table

[17] Under the threshold of 0.2 3G cells per 1,000 population, or one cell per 5,000 people.

A11 in the Appendix). The Hansen's J results are insignificant at the 5 per cent level, which fails to reject the null hypothesis of exogeneity of the generated instrument (Baum et al. 2012).

Finally, we also try a control function approach, following Pinzon (2020) and Wang et al. (2022), and identify similar results in models with or without controls and with or without weights (see Table A12 in the Appendix).

After providing multiple robustness tests for our main results, we now turn to examine the possibility of heterogeneous impacts of the technology.

5.4 Heterogeneity analyses

Previous literature has offered evidence that broadband technologies (including mobile broadband) have heterogeneous impacts on subgroups of the population in terms of both geography and socioeconomic conditions.

Rural areas, in particular, have received significant attention arising from the fact that internet technologies can help geographically isolated areas to access urban and international markets. Whitacre et al. (2014) identify positive significant increases in household income growth for rural areas in the US during 2001–10 following broadband adoption. Similarly, Ivus and Boland (2015) provide evidence of wage and employment growth for rural areas in Canada in 1997–2011 following broadband deployment, particularly for service industries (i.e., idea-producing industries like IT and finance) that have been able to overcome geographical barriers hampering rural growth. Zang (2019) provides some evidence not on broadband technologies specifically but of rural residents' increasing income over time thanks to computer penetration (using the government's village broadband connection programme as an instrument) in China during 200–13. In Viet Nam, Kaila and Tarp (2019) find that internet access (through a commune's internet access point) significantly promoted rural agricultural production during 2008–12 (6.8 per cent increase in total agricultural output), thanks to improved information about agriculture through government-run and private online information platforms, with effect sizes stronger for younger households and for less-developed northern provinces.

While mobile broadband is only a part of the broadband spectrum (including fixed broadband), its widespread adoption by individuals in both business and personal environments may offer additional and more-nuanced impacts for specific groups and regions. This section presents the heterogeneous analysis for urban–rural differences and for different income quintiles.

Urban–rural differences

GSO's statistical yearbooks have data about urban population for provinces in which urban population is 'the population of the territorial units which the State defines urban areas'. (GSO 2016b: 72).[18] The regression results (Table A13 in the Appendix) show stronger effect sizes for rural areas than for urban areas. This outcome may be indicative of the more-inclusive technological change impact of mobile internet compared with other technologies for (previously) disadvantaged regions such as rural or remote areas. The specific mechanisms behind the stronger effects for rural areas are discussed in Section 6. The insignificant results for urban areas may be due to the smaller number of observations and/or less variation in the independent variable.

[18] Urban classifications are decided by the prime minister, the minster of the Ministry of Construction, or the chair of the Provincial People's Committee based on regional and national urban development programmes.

Different effects between income quintiles

The VHLSS reports by Viet Nam's GSO provide information about provincial income distribution by quintile. Total monthly household per capita income is dissected into five quintiles. We conduct the same analyses using FEIV methods for each quintile for all provinces, resulting in five regressions for five quintile analyses.

As can be seen in Table A14 in the Appendix, mobile broadband offers the strongest positive effects for quintiles 2 and 3, followed by quintile 1. Quintiles 4 and 5 feel no significant effect.

For the second quintile, a 10 per cent increase in the number of 3G towers per 1,000 population per province will cause a rise of around 0.9 percentage points in household income per month, or 10.8 per cent per year, twice the average effect size for the whole population in the main regression result. For the third quintile, the effects are about two-thirds of the magnitude of those for the second quintile. For the poorest group, a 10 per cent increase in the number of 3G towers per 1,000 population per province will cause a 0.6 per cent rise in household income per month, or 7.2 per cent per year. This inclusive impact is also identified in developed-country contexts, such the US for example, according to Zuo's (2021) study, which finds significant effects of subsidized (in-home wireline) internet during 2012–15 for low-income groups using the triple difference-in-differences method (incorporating geographical, individual eligibility, and temporal differences). Wang (2020), in their research also for the US market, detect heterogeneous effects for different income groups: specifically, the largest earnings increase is for the 40th to the 50th percentile groups of the earnings distribution, followed by the 20th percentile group.

6 Mechanisms of impacts

The literature identifies multiple mechanisms through which mobile internet might affect income level. In Rwanda, Caldarola et al. (2023) identify positive effects on education (secondary and tertiary levels) for those aged 5–25 years and migration (to areas with internet coverage) for employment in skilled occupations and modern sectors (manufacturing, services); and increases in exports (for both manufacturing and services enterprises) and productivity (sales per employees, driven mainly by the services sector).

Arnold and Taş's (2019)'s qualitative and anecdotal evidence shows that Rich Interaction Apps (RIAs)[19] that offer 'full internet experience' (2019: 17) lower the entry barriers for entrepreneurs in Viet Nam, creating employment opportunities in retail, tourism, trade of goods, and services. Through the use of RIAs, MSMEs have been able to communicate with providers to get better information about products, to pay cashlessly, and to improve their business efficiency. There is also evidence that female entrepreneurs, including 'mumpreneurs', seem to benefit more (Hoang Anh et al. 2016; T.H. Nguyen 2017; Zhu et al. 2015).

Regarding education and labour market skills, emerging literature provides some evidence across countries of the effect of smartphone use on learners' (foreign) language skills; self-confidence; autonomy; skill knowledge and performance; and reinforcing learned knowledge thanks to personalized learning, demonstration videos e.g. for medical training, optimal two-way teacher-student communications, and anytime-anywhere learning, through literature review studies (Kacetl and Klímová 2019), qualitative interview s (Damuri et al. 2018; T.T.T. Nguyen and Yukawa 2019),

[19] Such as Facebook Messenger, Zalo, Mocha, iMessage, KakaoTalk, LINE, Signal, Skype, Snapchat, Threema, Viber, WeChat, and WhatsApp.

and randomized controlled trials (Chuang et al. 2018). The use of smartphones seems to offer additional benefits especially for learning in informal environments (outside school), and is considered complementary to formal schooling. Yet contemporary literature has found mixed results on educational achievements, and it remains to be seen whether and to what extent mobile device usage can effectively complement and/or replace aspects of formal education, and if so, which aspects. There are also other mechanisms such as increased revenue for tourism sectors (Le and Tran 2023) and increased efficiency in the health sector, as well as people's health more generally, thanks to more low-cost information and searching (Arnold and Taş 2019; Damuri et al. 2018).

6.1 Employment and mobile internet

The Viet Nam GSO's online portal[20] provides data on employment and trained employment rate for provinces across years. By running the same FEIV regression models with employment rates as the dependent variable, we identify positive significant impacts on trained employment rates but not on overall employment rates (Table 3). Regarding trained employment, a 10 per cent increase in the number of 3G cell towers per 1,000 population per province will lead to a rise of approximately 0.127 percentage points in the trained employment rate.

Table 3: Employment rate/trained employment rate and mobile broadband

Employment	(1)	(2)	(3)	(4)
	Employed ratio		Trained employment ratio	
3G internet	−1.500***	−1.181***	1.269***	1.062**
	(0.422)	(0.321)	(0.473)	(0.431)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes
F-stat.	29.213	19.564	29.213	19.564
Observations	252	252	252	252
R-sq.	0.875	0.899	0.941	0.968
Adjusted R-sq.	0.830	0.863	0.920	0.957
RMSE	1.336	1.268	1.642	1.611

Note: all models adopt the FEIV method with elevation × linear time trend as instrumental variable, with both province and year FE; columns 1 and 2 have overall employment rates as dependent variable while columns 3 and 4 have trained employment rates as dependent variable; even-numbered columns have province populations as weights while odd columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author's construction based on data sources described in Table A3 in the Appendix.

This particular result can be understood through the increase in labour demand for skilled workers, including software engineers for the digital economy and sales or project management staff, thanks to stable flows of graduates (usually tertiary-level) who now have more job opportunities and are able to find jobs that better match their degrees or expertise—but not necessarily because of an increase in education attainment in the context of Viet Nam. There may be increases in enrolment and degree attainment for specific programmes e.g., for IT or business, but not for other programmes, and at national level but not a provincial level, as major changes in enrolment and

[20] See www.gso.gov.vn/lao-dong (accessed 15 March 2021).

graduation patterns are more likely to occur in major universities in Ha Noi, HCMC, and regional but not all provincial universities.

The negative effect signs of overall employment may be a result of data collection or measurement issues due to potentially significantly under-reported informal self-employment (GSO 2020b). On the other hand, they might be a result of the fact that the decrease in the number of low-skilled workers was not offset by the rise in the number of high-skilled workers.

6.2 Wages and mobile internet

Regarding the components of income sources, formal wages have the highest positive effect sizes with strong significance levels while self-employment from non-agricultural activities and other sources has no statistically significant signs (Table 4). Agriculture-based income sources have some positive effects though with only weak significance.

With regard to formal wages, the earlier section of preliminary evidence showed that the app economy has created a significant number of jobs for app developers and sales and project management staff, with these positions requiring formal education and training for high-skilled labour. This may also explain the significant effects for income quintile 3, as evidenced in the heterogeneity analysis.

Those in non-agriculture self-employment in Viet Nam are often in the high-income quintiles (quintiles 4 or 5) (UNDP and VASS 2016), and this justifies the insignificant effects for these quintiles.

Table 4: Income sources and mobile broadband

Log household income	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Wages		Formal wages		Agriculture		Non-agriculture		Others
3G internet	0.0250	0.0198	0.0944***	0.0662***	0.0583*	0.0688*	−0.0953*	−0.0511	−0.0953*	−0.0511
	(0.0234)	(0.0204)	(0.0281)	(0.0234)	(0.0313)	(0.0380)	(0.0525)	(0.0341)	(0.0525)	(0.0341)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
F-stat.	29.213	19.564	29.213	19.564	29.213	19.564	29.213	19.564	29.213	19.564
Observations	252	252	252	252	252	252	252	252	252	252
R-sq.	0.983	0.986	0.889	0.911	0.949	0.971	0.942	0.959	0.942	0.959
Adjusted R-sq.	0.976	0.981	0.849	0.879	0.931	0.961	0.922	0.944	0.922	0.944
RMSE	0.0718	0.0705	0.0983	0.0918	0.133	0.151	0.154	0.124	0.154	0.124

Note: all models adopt the FEIV method with elevation × time trend as the instrument; the dependent variables are log household income from wages, log household income from formal wages, log household income from agriculture, log household income from non-agricultural activities, and log household income from other sources, respectively from columns left to right; even-numbered columns have province populations as weights while odd columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author's construction based on data sources described in Table A3 in the Appendix.

Regarding agriculture-based income sources, while Kaila and Tarp (2019) find strong effect sizes of internet access on agricultural production in Viet Nam during 2008–12, the weakly significant effects we identify here may be due to (1) significantly smaller sample sizes and/or (2) stronger effect sizes for rural than for urban areas. Positive effects for agricultural income sources may nevertheless explain the strong effect sizes for income quintiles 1 and 2.

In sum, the stronger results for trained employment rates and formal wages indicate the structural change pattern towards formal sectors in the country. The stronger effect sizes for rural areas particularly may suggest (1) that new formal businesses have been established (potentially in both rural and urban areas) and/or household or informal businesses have been formalized, especially service-based ones ranging from retail to tourism (Arnold and Taş 2019) in rural area; and (2) the rising productivity of these sectors through increased sales and/or reduced business costs such as marketing and training. The insignificant effects of total employed rates and informal wages may be due to under-reported survey data issues, such as the VHLSS not being designed specifically for the informal sector (GSO 2020b).

Rural households, which typically have multiple income streams (World Bank 2019a),[21] may stand to benefit more from mobile digitalization. First, due to the lowered expenses associated with doing business at distance thanks to mobile communication, mobile banking, and online marketing, more businesses can be established in rural areas, possibly serving nationwide or urban markets. Second, business costs will also be reduced with the reduced cost and increased efficiency of transportation and logistics, while sales can be promoted. We identify positive significant outcomes of mobile internet and transportation volumes for both passenger and freight services (see Table A15 in the Appendix). Third, e-commerce platforms and social media can help rural citizens to market and sell their products online. Fourth, remittances and social transfers have been increased through more (im)migration (thanks to more information and cheap communication) and monetary flows (via mobile banking with lower fees and more user-friendly utilities).

We have no data on informal wages, self-employment and entrepreneurship, or (im)migration and remittances, and these areas need further study. These may benefit both rural and urban areas, though still with stronger effects for rural regions.

7 Concluding remarks

Our results offer evidence of the positive effects of mobile internet on household income over the decade following the arrival of the first smartphones in a developing-country context. In Viet Nam in the last decade, these technologies have produced more-inclusive impacts for lower-income groups and for those in rural areas. These groups in particular have skipped PCs and use smartphones as the only device through which they integrate into the digital world.

Our paper contributes further evidence for mobile for development (M4D) particularly for developing countries. Compared with Hübler and Hartjie (2016), we offer new evidence of stronger effect sizes and additional impact mechanisms of the new smartphone generations, which have better quality and more functionality with a growing app ecosystem. Compared with Bahia et

[21] Often three of out six: household farming, agricultural wages, non-agricultural wages, household business, remittances, and transfers.

al. (2020), we show that mobile internet can offer a pathway for improvement of livelihoods (income, employment) and productivity (wages), not only of welfare (consumption).

Future micro-data collection can be done to disentangle the heterogeneous effects for subgroups of the population, e.g., in terms of age (Caldarola et al. 2022; Kaila and Tarp 2019) or gender (Hoang Anh et al. 2016; T.H. Nguyen 2017; Zhu et al. 2015); and to dissect micro-mechanisms of impacts, including (1) information (about job search, migration or immigration); (2) communications (including social media platforms) that help to promote entrepreneurship, informal economy, e-commerce, and remittances (via social contact/groups) (Google et al. 2021); (3) digital/platform economy, including e-commerce (e.g., Shopee, Lazada, Tiki), the 'sharing economy' (Uber/Grab), e-banking (almost all banks), remittances, social transfers, and charities (Google et al. 2019); (4) learning, education, innovation e.g. mobile apps including videos, and augmented/virtual reality (AR/VR) with downloaded content (which requires no internet); and (5) 4G and 5G instead of 3G, as many 3G cell towers have been closed off since 2021 in many regions (Arnold and Taş 2019; Viettel 2022).

Future research can offer evidence on nuanced mechanisms regarding usage (quantity, quality, and skills) rather than just coverage or adoption, as well as regarding the emerging ecosystem with new content and functionalities that can offer further connectedness, engagement, and innovation.

References

Aker, J.C. (2010). 'Information from Markets Near and Far: Mobile Phones and Agricultural Markets in Niger'. *American Economic Journal: Applied Economics*, 2(3): 46–59. www.jstor.org/stable/25760219

AlphaBeta (2021). 'Unlocking Vietnam's Digital Potential: Harnessing the Economic Opportunities of Digital Transformation with Google's Contribution'. Available at: https://alphabeta.com/our-research/unlocking-vietnams-vnd1733-trillion-digital-potential (accessed 15 March 2021).

Appota (2018). 'Vietnam: Mobile Apps'. Available at: https://appota.com/uploads/report/Vietnam_mobile_app_market_Report_2018_EN.pdf (accessed 15 March 2021).

Arnold, R., and S. Taş (2019). *The Value of Rich Interaction Applications for Vietnam: Final Report*. Leibniz: Leibniz Information Centre for Economics. http://hdl.handle.net/10419/251547

Asia Business Consulting (2020). 'Free Trade Agreements in Vietnam'. 24 July. Available at: www.asiabizconsult.com/en/news-briefs/278-free-trade-agreements-in-vietnam (accessed 15 March 2021).

Bahia, K., X. Pedrós, C. Rodríguez-Castelán, H. Winkler, T. Pfutze, and C. Rodríguez-Castelán (2020). 'The Welfare Effects of Mobile Broadband Internet: Evidence from Nigeria'. Policy Research Working Paper 9230. Washington, DC: World Bank.

Baum, C.F., A. Lewbel, M.E. Schaffer, and O. Talavera (2012). 'Instrumental Variables Estimation using Heteroskedasticity-Based Instruments'. United Kingdom Stata User's Group Meeting, 7. https://EconPapers.repec.org/RePEc:boc:usug12:07

Benjamin, D., L. Brandt, and B. McCaig (2017). 'Growth with Equity: Income Inequality in Vietnam 2002–14. *The Journal of Economic Inequality*, 15(1): 25–46. https://doi.org/10.1007/s10888-016-9341-7

Blumenstock, J., N. Keleher, A. Rezaee, and E. Troland (2020). 'The Impact of Mobile Phones: Experimental Evidence from the Random Assignment of New Cell Towers'. Background paper. New Haven, CT: Innovations for Poverty Action.

Buys, P., S. Dasgupta, T.S. Thomas, and D. Wheeler (2009). 'Determinants of a Digital Divide in Sub-Saharan Africa: A Spatial Econometric Analysis of Cell Phone Coverage'. *World Development*, 37(9): 1494–505. https://doi.org/10.1016/j.worlddev.2009.01.011

Caldarola, B., M. Grazzi, M. Occelli, and M. Sanfilippo (2022). 'Mobile Internet, Skills and Structural Transformation in Rwanda'. Working Paper 60. Geneva: International Labour Organization.

Caldarola, B., M. Grazzi, M. Occelli, and M. Sanfilippo (2023). 'Mobile Internet, Skills and Structural Transformation in Rwanda'. *Research Policy*, 52(10): 104871. https://doi.org/10.1016/j.respol.2023.104871

Cameron, A., and T. Pham (2018). *Vietnam Today: First Report of the Vietnam's Future Digital Economy Project*. Canberra: Data61/CSIRO (Commonwealth Scientific and Industrial Research Organisation) and Ha Noi: Vietnam Ministry for Science and Technology. Available at: https://data61.csiro.au/en/Our-Research/Our-Work/Future-Cities/Planning-sustainable-infrastructure/Vietnam-Today (accessed 15 March 2021).

Carter, D. (2018). 'Terrain Ruggedness and Land Cover: Improved Data for Most Research Designs'. Harvard Dataverse, V1. https://doi.org/doi:10.7910/DVN/WXUZBN

Chuang, Y.-H., F.-C. Lai, C.-C. Chang, H.-T. and Wan (2018). 'Effects of a Skill Demonstration Video delivered by Smartphone on Facilitating Nursing Students' Skill Competencies and Self-Confidence: A Randomized Controlled Trial Study'. *Nurse Education Today*, 66: 63–68. https://doi.org/10.1016/j.nedt.2018.03.027

Dammert, A.C., J. Galdo, and V. Galdo (2013). 'Digital Labor-Market Intermediation and Job Expectations: Evidence from a Field Experiment'. *Economics Letters*, 120(1): 112–16. https://doi.org/https://doi.org/10.1016/j.econlet.2013.03.047

Damuri, Y.R., V.D. Perkasa, F.B. Hirawan, and D. Rafitrandi (2018). *Rich-Interactive-Applications (RIA) in Indonesia: Value to the Society and the Importance of an Enabling Regulatory Framework*. Jakarta: Centre for Strategic and International Studies (CSIS).

DeFazio, A. (2021). 'Facebook Ecommerce: The Complete Beginner's Guide'. Wordstream blog, 24 November. Available at: www.wordstream.com/blog/ws/2019/02/25/facebook-ecommerce (accessed 15 March 2021).

Deuflhard, F., D. Georgarakos, and R. Inderst (2019). 'Financial Literacy and Savings Account Returns'. *Journal of the European Economic Association*, 17(1): 131–64. https://doi.org/10.1093/jeea/jvy003

Donati, D. (2023). 'Mobile Internet Access and Political Outcomes: Evidence from South Africa'. *Journal of Development Economics*, 162: 103073. https://doi.org/10.1016/j.jdeveco.2023.103073Get rights and content

Driffield, N., and C. Jones (2013). 'Impact of FDI, ODA and Migrant Remittances on Economic Growth in Developing Countries: A Systems Approach'. *The European Journal of Development Research*, 25(2): 173–96. https://doi.org/10.1057/ejdr.2013.1

European Union (2014). *Development Finance for Sustainable Development Goals in Middle-Income Viet Nam. Financing Viet Nam's Development: Meeting the New Challenges.* Ha Noi: EU–Viet Nam Strategic Dialogue Facility.

GLOBE Task Team, D.A Hastings, P.K. Dunbar, G.M. Elphingstone, M. Bootz, H. Murakami, H. Masaharu, P. Holland, J. Payne, N.A. Bryant, T.L. Logan, J.-P. Muller, G. Schreier, and J.S. MacDonald (eds) (1999). 'The Global Land One-Kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0'. Boulder, CO: National Geophysical Data Center. Available at: www.ngdc.noaa.gov/mgg/topo/globe.html (accessed 15 March 2021).

Google, Temasek, and Bain. (2019). 'Southeast Asia Digital Economy'. Available at: https://economysea.withgoogle.com (accessed 15 March 2021).

Google, Temasek, and Bain. (2021). 'E-Conomy SEA 2021'. Available at: https://economysea.withgoogle.com (accessed 15 March 2021).

GSO (2010). *The 2009 Vietnam Population and Housing Census: Completed Results*. Ha Noi: General Statistics Office of Vietnam (GSO).

GSO (2016a). *Result of the Vietnam Household Living Standards Survey 2014*. Ha Noi: GSO.

GSO (2016b). *Statistical Yearbook of Vietnam 2015*. Ha Noi: GSO.

GSO (2019a). *Result of the Vietnam Household Living Standards Survey 2018*. Ha Noi: GSO.

GSO (2019b). *Statistical Yearbook of Vietnam 2019*. Ha Noi: GSO.

GSO (2020a). *Completed Results of the 2019 Vietnam Population and Housing Census*. Ha Noi: GSO.

GSO (2020b). *VHLSS 2020 Survey*. Ha Noi: GSO. Available at: www.niengiamthongke.net/kh%E1%BA%A3o-s%C3%A1t/vhlss-2020 (accessed 15 March 2021).

Hartje, R., and M. Hübler (2017). 'Smartphones Support Smart Labour'. *Applied Economics Letters*, 24(7): 467–71. https://doi.org/10.1080/13504851.2016.1203054

Hoang Anh, N., H.T. Giang, and H.B. Tram (2016). 'A Review of Women's Entrepreneurship in Vietnam Taking into Account Socio-Cultural Norms and the Institutional Ecosystem'. SECO (Secretariat for Economic Affairs of Switzerland)/WTI (World Trade Institute) Academic Cooperation Project Working Paper 2016/11. Bern: WTI. https://doi.org/10.2139/ssrn.2905163

Hodler, R., and P.A. Raschky (2017). 'Ethnic Politics and the Diffusion of Mobile Technology in Africa'. *Economics Letters*, 159: 78–81. https://doi.org/https://doi.org/10.1016/j.econlet.2017.07.011

Hübler, M., and R. Hartjie (2016). 'Are Smartphones Smart for Economic Development?' *Economic Letters*, 141: 130–33. https://doi.org/10.1016/j.econlet.2016.02.001

IMF (International Monetary Fund) (2018). 'Measuring the Digital Economy'. *Policy Papers*, 18(016). https://doi.org/10.5089/9781498307369.007

Ivus, O., and M. Boland (2015). 'The Employment and Wage Impact of Broadband Deployment in Canada'. *Canadian Journal of Economics/Revue Canadienne d'économique*, 48(5): 1803–30. https://doi.org/10.1111/caje.12180

Kacetl, J., and B. Klímová (2019). 'Use of Smartphone Applications in English Language Learning: A Challenge for Foreign Language Education'. *Education Sciences*, 9(3): 179. https://doi.org/10.3390/educsci9030179

Kaila, H., and F. Tarp (2019). 'Can the Internet Improve Agricultural Production? Evidence from Viet Nam'. *Agricultural Economics*, 50(6): 675–91. https://doi.org/https://doi.org/10.1111/agec.12517

Klonner, S., and P.J. Nolen (2010). 'Cell Phones and Rural Labor Markets: Evidence from South Africa'. *Proceedings of the German Development Economics Conference*, 56.

Kolko, J. (2012). 'Broadband and Local Growth'. *Journal of Urban Economics*, 71(1): 100–13. https://doi.org/10.1016/j.jue.2011.07.004

Laricchia, F. (2023). 'Smartphone Users by Country Worldwide 2022'. Statista, 4 May. Available at: www.statista.com/statistics/748053/worldwide-top-countries-smartphone-users (accessed 11 December 2023).

Le, D. van, and T.Q. Tran (2023). 'Heterogenous Effects of ICT Application on Local Tourism Development: A Quantile Regression Approach'. *Journal of Policy Research in Tourism, Leisure and Events*, online (3 April): 1–23. https://doi.org/10.1080/19407963.2023.2196727

Manacorda, M., and A. Tesei (2020). 'Liberation Technology: Mobile Phones and Political Mobilization in Africa'. *Econometrica*, 88(2): 533–67. https://doi.org/10.3982/ecta14392

Mandel, M. (2015). 'Vietnam and the App Economy'. Policy brief, September. Washington, DC: Progressive Policy Institute (PPI). Available at: www.progressivepolicy.org/wp-content/uploads/2015/09/2015.09-Mandel_Vietnam-and-the-App-Economy.pdf (accessed 15 March 2021).

Momo.vn (2021). 'Popular 4G Data Packages by Viettel, Mobifone, and Vinaphone'. Available at: https://momo.vn/blog/tong-hop-cac-goi-cuoc-3g-4g-cua-nha-mang-viettel-mobifone-va-vinaphone-c102dt146 (accessed 15 March 2021).

Muto, M., and T. Yamano (2009). 'The Impact of Mobile Phone Coverage Expansion on Market Participation: Panel Data Evidence from Uganda'. *World Development*, 37(12): 1887–96. https://doi.org/10.1016/j.worlddev.2009.05.004

Ndubuisi, G., C. Otioma, and G.K. Tetteh (2021). 'Digital Infrastructure and Employment in Services: Evidence from Sub-Saharan African Countries'. *Telecommunications Policy*, 45(8): 102153. https://doi.org/10.1016/j.telpol.2021.102153

Nguyen, A.N., and T. Nguyen (2007). 'Foreign Direct Investment in Vietnam: An Overview and Analysis the Determinants of Spatial Distribution Across Provinces'. *SSRN Electronic Journal*, July. https://doi.org/10.2139/ssrn.999550

Nguyen, C.V., L.T. Giang, A.N. Tran, and H.T. Do (2021). 'Do Good Governance and Public Administration Improve Economic Growth and Poverty Reduction? The Case of Vietnam'. *International Public Management Journal*, 24(1): 131–61. https://doi.org/10.1080/10967494.2019.1592793

Nguyen, D.M. (2010). 'An Overview of Spatial Policy in Asian and European Countries: Vietnam'. Tokyo: Ministry of Land, Infrastructure, Transport and Tourism, Japan. Available at: https://www.mlit.go.jp/kokudokeikaku/international/spw/general/vietnam/index_e.html (accessed 15 March 2021).

Nguyen, H.H. (2019). 'Regional Welfare Disparities and Regional Economic Growth in Vietnam'. PhD thesis, Wageningen University. Available at: https://edepot.wur.nl/2542 (accessed 15 March 2021).

Nguyen, H.Q. (2017). 'The Role of Public Expenditures in Economic Growth at Provincial Level: Empirical Study in Vietnam'. *Journal of Politics and Law*, 10(2): 88–96. https://doi.org/10.5539/jpl.v10n2p88

Nguyen, M.N. (2022). 'Smartphone Market in Vietnam: Statistics and Facts'. Statista, 17 March. Available at: www.statista.com/topics/9168/smartphone-market-in-vietnam/#topicOverview (accessed 11 December 2021).

Nguyen, Q.P. (2019). 'Comparative Evaluation Should Install the Best Wifi Optical Cable Internet Today—using FPT, Viettel or VNPT?' Tinhte, 28 January. Available at: https://tinhte.vn/thread/danh-gia-so-sanh-nen-lap-internet-cap-quang-wifi-nao-tot-nhat-hien-nay-dung-fpt-viettel-hay-vnpt.2763525 (accessed 15 March 2021).

Nguyen, T.H. (2017). 'Vietnamese Mumpreneurs? Middle-Class Mothers Negotiating Motherhood and Work in Northern Vietnam'. Lund: Centre for East and South-East Asian Studies, Lund University.

Nguyen, T.T.T., and T. Yukawa (2019). 'Kahoot with Smartphones in Testing and Assessment of Language Teaching and Learning: The Need of Training on Mobile Devices for Vietnamese Teachers and Students'. *International Journal of Information and Education Technology*, 9(4): 286–96. https://doi.org/10.18178/ijiet.2019.9.4.1214

Nguyen, X.T., and D. Dapice (2009). 'Vietnam's Infrastructure Constraints'. Harvard-UNDP Policy Dialogue Paper 3. Ha Noi: UNDP (UN Development Programme).

NhanDan (2011). 'Utilize 3G Technologies Effectively'. NhanDan, 7 August. Available at: https://nhandan.vn/khai-thac-hieu-qua-cong-nghe-3g-post550842.html (accessed 15 March 2021).

OECD (2020). A Roadmap towards a Common Framework for Measuring the Digital Economy: Report for the G20 Digital Economy Task Force. Paris: OEC. Available at: www.oecd.org/sti/roadmap-toward-a-common-framework-for-measuring-the-digital-economy.pdf (accessed 15 March 2021).

Øverby, H., and J. A. Audestad (2021). *Introduction to Digital Economics: Foundations, Business Models and Case Studies*. Cham: Springer. https://doi.org/10.1007/978-3-030-78237-5

Pinzon, E. (2020). 'A GMM Recipe to Get Standard Errors for Control Function and Other Two-Step Estimators'. London Stata Conference 2020, 12.

Roessler, P., P.P. Carroll, F. Myamba, C. Jahari, B. Kilama, and D.L. Nielson (2020). *An Experimental Analysis of Mobile Phone Ownership on Poverty Reduction*. Available at: http://danielnielson.com/wp-content/uploads/2020/02/Roessler-et-al.2020.Experimental-Analysis-of-Mobile-Phones-on-Poverty.Ms_.pdf (accessed 15 March 2021).

Roggio, A. (2021). 'Facebook Could Dominate Ecommerce'. PracticalEcommerce, 4 October. Available at: www.practicalecommerce.com/facebook-could-dominate-ecommerce (accessed 15 March 2021).

Sinicki, A. (2021). 'What Is UpWork? Your Guide to the Biggest Freelancing Platform'. Android Authority, 1 April. Available at: www.androidauthority.com/what-is-upwork-1189973 (accessed 15 March 2021).

Sun, S. (2023). 'Smartphone Penetration Rate in India 2009–2040'. Statista, 18 July. Available at: www.statista.com/statistics/1229799/india-smartphone-penetration-rate (accessed 11 December 2023).

Suri, T., and W. Jack (2016). 'The Long-Run Poverty and Gender Impacts of Mobile Money'. *Science*, 354(6317): 1288–92. https://doi.org/10.1126/science.aah5309

Tang, C., Y. Xue, H. Wu, M. Irfan, and Y. Hao (2022). 'How Does Telecommunications Infrastructure affect Eco-Efficiency? Evidence from a Quasi-Natural Experiment in China'. *Technology in Society*, 69: 101963. https://doi.org/10.1016/j.techsoc.2022.101963

Tarp, F. (2017). *Growth, Structural Change and Development in Rural Vietnam*. Oxford: Oxford University Press.

Thịnh, Đ. (2020). 'Google Project: Farmers Use Computer Fast, Learn Useful Things'. Danviet, 19 January. Available at: https://danviet.vn/du-an-google-nha-nong-dung-may-tinh-nhoay-nhoay-hoc-dieu-hay-77771051462.htm (accessed 15 March 2021).

UNDP and VASS (Vietnam Academy of Social Science) (2016). *Growth That Works for All: Viet Nam Human Development Report 2015 on Inclusive Growth*. New York: UNDP.

USGS (2018). 'USGS EROS Archive – Digital Elevation – Global 30 Arc-Second Elevation (GTOPO30)'. Earth Resources Observation and Science (EROS) Center, 11 July. https://doi.org//10.5066/F7DF6PQS

Vanham, P. (2018). 'The Story of Viet Nam's Economic Miracle'. ASEAN, 11 September. Available at: www.weforum.org/agenda/2018/09/how-vietnam-became-an-economic-miracle (accessed 15 March 2021).

Verdin, K.L., F.G. Hall, G.J. Collatz, B.W. Meeson, S.O. Los, E.B. De Colstoun, and D.R. Landis (2011). 'ISLSCP II HYDRO1k Elevation-Derived Products'. Oak Ridge, TN: ORNL DAAC (Oak Ridge National Laboratory Distributed Active Archive Center). https://doi.org/https://doi.org/10.3334/ORNLDAAC/1007

Viettel (2022). 'Viettel Turned Off 3G Stations in 6 Provinces, Cities from 1 Mar 2022'. 1 March. Available at: https://tongdaiviettelecom.vn/hot-viettel-tat-tram-3g-tai-6-tinh-thanh-pho-tu-ngay-1-3-2022 (accessed 15 March 2021).

Viollaz, M., and H. Winkler (2020). 'Does the Internet Reduce Gender Gaps? The Case of Jordan'. Policy Research Working Paper 9183. Washington, DC: World Bank.

Vu, K.N. (2013). 'Viet Nam's Participation in Free Trade Agreements: History and the Way Forward'. Asia Regional Integration Center, 2 September. Available at: https://aric.adb.org/blog/viet_nams_participation_in_free_trade_agreements_history_and_the_way_forward (accessed 15 March 2021).

Vu, T.B., B. Gangnes, and I. Noy (2008). 'Is Foreign Direct Investment Good for Growth? Evidence from Sectoral Analysis of China and Vietnam'. *Journal of the Asia Pacific Economy*, 13(4): 542–62. https://doi.org/10.1080/13547860802364976

Wang, J., X. Yu, K. Lyu, and J.-H. Feil (2022). 'The Impact of Mobile Finance Use on Livelihoods of Farmers in Rural China'. *Emerging Markets Finance and Trade*, 58(10): 2867–79. https://doi.org/10.1080/1540496X.2021.2013195

Wang, P. (2020). The Causal Effect of Mobile Broadband on Earnings Inequality and Employment'. SSRN Electronic Journal, 1 November. https://doi.org/10.2139/ssrn.3725699

WEF (World Economic Forum) (2018). 'The Story of Viet Nam's Economic Miracle'. WEF, 11 September. Available at: https://www.weforum.org/agenda/2018/09/how-vietnam-became-an-economic-miracle (accessed 15 March 2021).

Whitacre, B., R. Gallardo, and S. Strover (2014). 'Broadband's Contribution to Economic Growth in Rural Areas: Moving towards a Causal Relationship'. *Telecommunications Policy*, 38(11): 1011–23. https://doi.org/10.1016/j.telpol.2014.05.005

World Bank (2016). 'Sustaining Success. Priorities for Inclusive and Sustainable Growth'. Vietnam Systematic Country Diagnostic 2016. Washington, DC: World Bank.

World Bank (2019a). *Better Opportunities for All : Vietnam Poverty and Shared Prosperity Update*. Washington, DC: World Bank.

World Bank (2019b). *Vietnam Development Report 2019: Connecting Vietnam for Growth and Shared Prosperity*. Washington, DC: World Bank.

World Bank (2021). 'GDP per Capita (Current US$): Viet Nam, Lower Middle Income'. Available at: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?end=2018&locations=VN-XN&start=2008 (accessed 15 March 2021).

Yang, C.-H., E.D. Ramstetter, J.-R. Tsaur, and M. Ngoc Phan (2015). 'Openness, Ownership, and Regional Economic Growth in Vietnam'. *Emerging Markets Finance and Trade*, 51(sup1): S224–33. https://doi.org/10.1080/1540496X.2014.998886

Yoon, S. (2015). 'Essays on Development Economics and Energy Access'. PhD paper, Columbia University. https://doi.org/https://doi.org/10.7916/D8H1314C

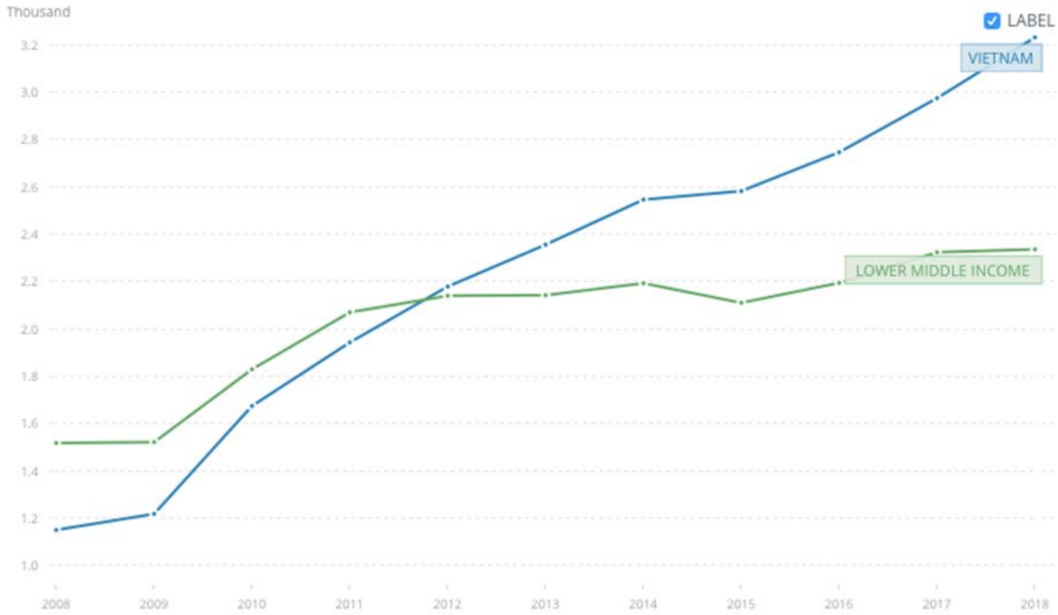
Zang, L. (2019). 'Does Computer Penetration Increase Farmers' Income? An Empirical Study from China'. In *Re-understanding of Contemporary Chinese Political Development*. Singapore: Springer. https://doi.org/10.1007/978-981-13-1250-2_6

Zhu, L., O. Kara, H.M. Chu, and A. Chu (2015). 'Female Entrepreneurship: Evidence from Vietnam'. *Journal of Business and Entrepreneurship*, 26(3): 103.

Zuo, G.W. (2021). 'Wired and Hired: Employment Effects of Subsidized Broadband Internet for Low-Income Americans'. *American Economic Journal: Economic Policy*, 13(3): 447–82. https://doi.org/10.1257/pol.20190648.

Appendix

Figure A1: GDP per capita, Viet Nam, lower-middle income (in current US$)



Source: World Bank (2021), licensed under Creative Commons Attribution 4.0 International licence (CC-BY 4.0).

Table A1: Viet Nam's economic achievements since 1975

Timeline	Event
1975	Reunification of North and South following the end of Viet Nam–US war
1986	The beginning of reform process towards 'socialist-oriented market economy' (Doi Moi)
1995	ASEAN FTA, WTO application
2000	Viet Nam–US FTA
2004	ASEAN–PRC FTA
2006	ASEAN–South Korea FTA
2007	WTO accession
2008	ASEAN–Japan FTA; Viet Nam–Japan EPA
2009	ASEAN–India FTA; ASEAN–Australia –New Zealand (AANZ) FTA
2012	Viet Nam–Chile FTA (commenced in January 2014)
2014	ASEAN–Hong Kong FTA negotiation started
2015	Europe–Viet Nam FTA (EVFTA) negotiation completed; Viet Nam–Israel FTA negotiation started
2018	CPTPP signed
2019	CPTPP came into effect
2020	EVFTA came into effect

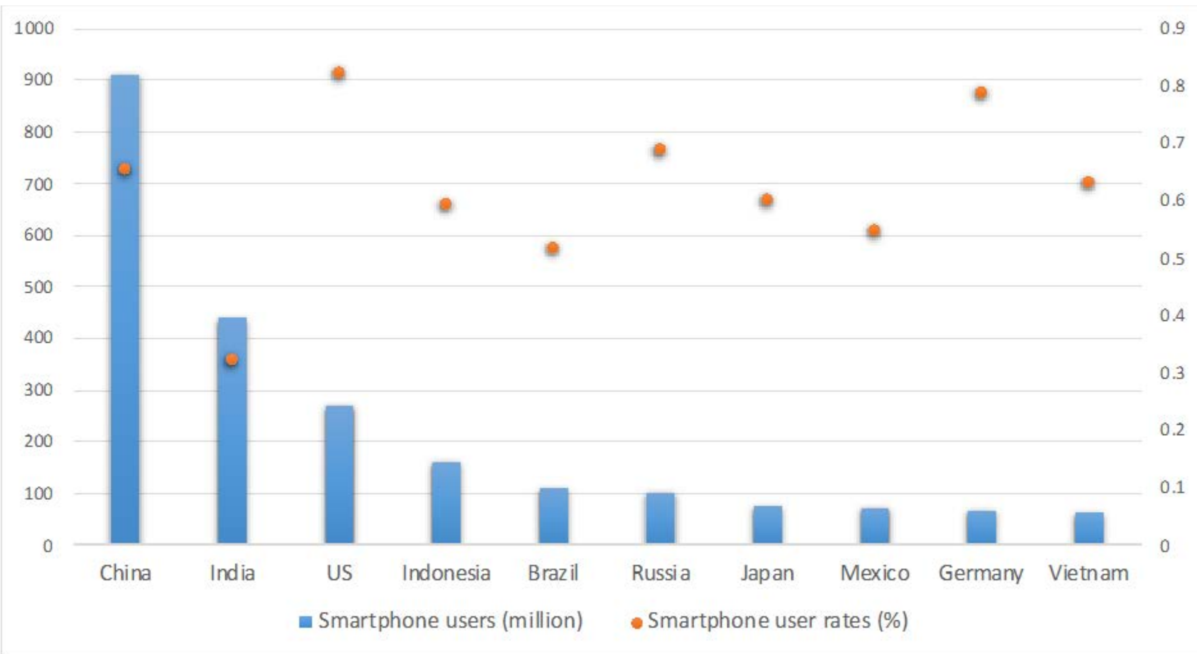
Note: ASEAN = Association of Southeast Asian Nations; PRC = People's Republic of China;
CPTPP = Comprehensive and Progressive Agreement for Trans-Pacific Partnership.

Source: authors' construction based on Asia Business Consulting (2020); Vanham (2018); Vu (2013).

Figure A2: Viet Nam’s topography

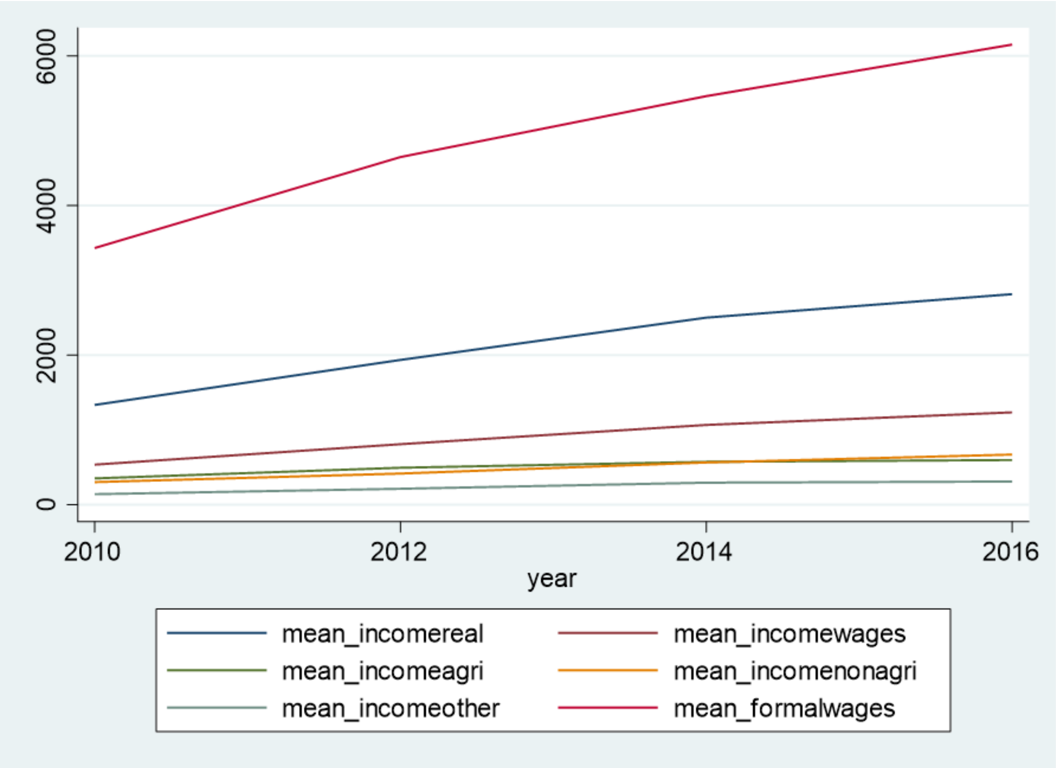
Source: author’s illustration using data from GLOBE Task Team et al. (1999).

Figure A3: Smartphone users and penetration rates for several countries, May 2021



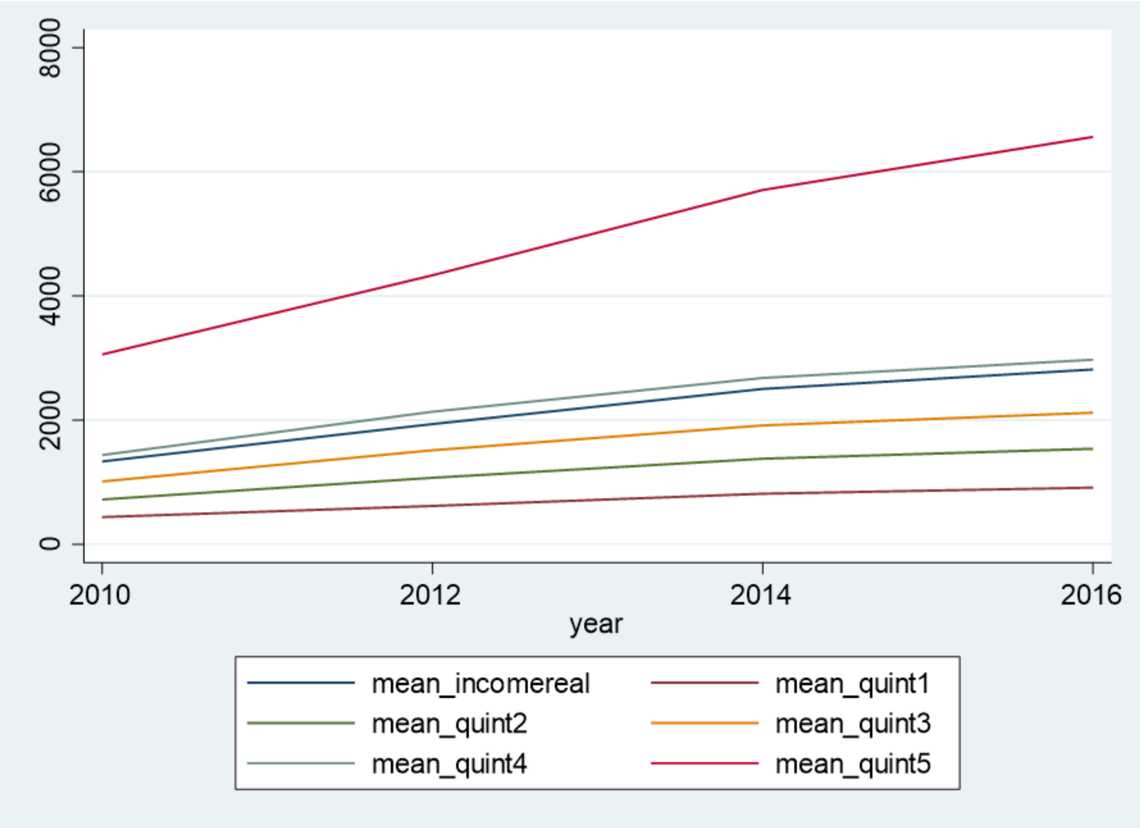
Source: author’s illustration based on data from Laricchia (2023); Nguyen (2022); Sun (2023).

Figure A4: Household income components, 2010–16 (in 1,000 VND)



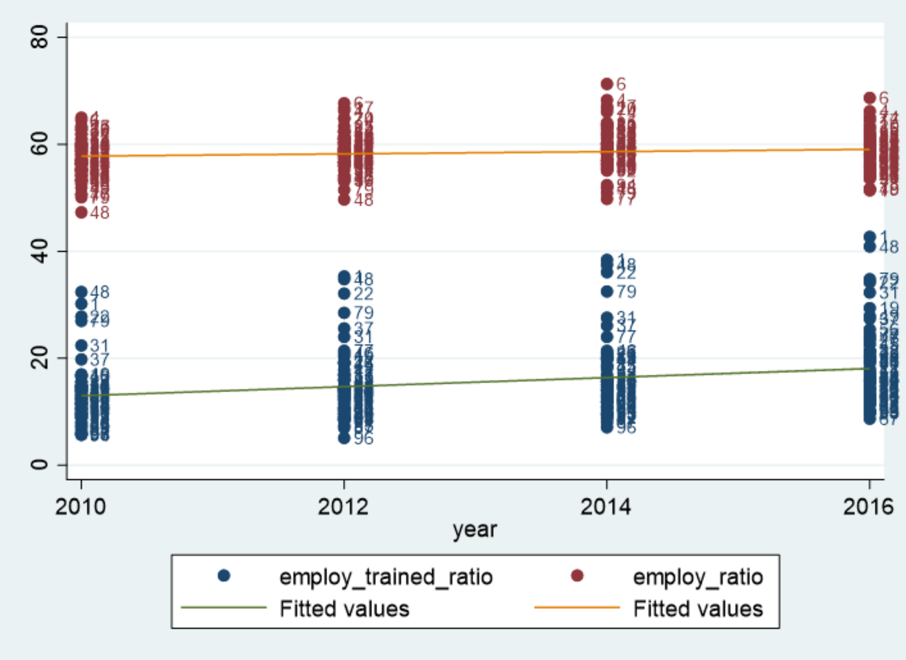
Source: author's illustration based on GSO (2016a, 2019a).

Figure A5: Income quintiles, 2010–16 (in 1,000 VND)



Source: author's illustration based on GSO (2016a, 2019a).

Figure A6: Employment and trained employment ratio, 2010–16



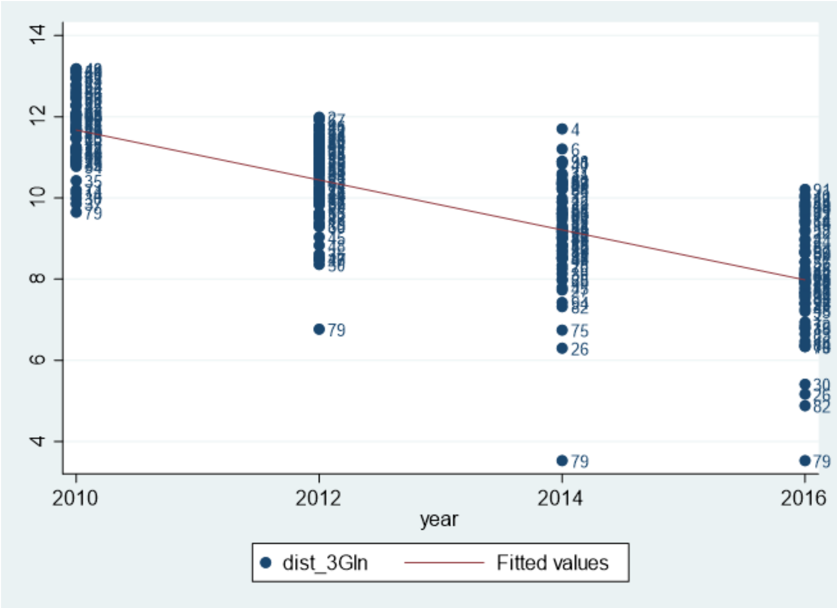
Source: author's illustration based on GSO (2016a, 2019a).

Table A2: 3G cell tower signals, 2008–20

Year	GSM/2G	UMTS/3G	LTE/4G	Total	Accumulation
2008	87	0	0	87	89
2009	1,135	0	0	1,135	1,224
2010	38	7	0	45	1,269
2011	29	49	0	78	1,347
2012	551	1,346	0	1,897	3,244
2013	1,187	3,022	0	4,209	7,453
2014	9,576	5,520	1	15,097	22,550
2015	12,278	34,858	2	47,138	69,688
2016	33,557	71,817	118	105,492	175,180
2017	6,053	26,685	4,985	37,723	212,903
2018	16	346	701	1,063	213,966
2019	796	3,204	985	4,985	218,951
2020	4,838	355	83	5,277	224,228
Total	70,141	147,211	6,875	224,228	

Source: author's construction based on data from OpenCellID (www.opencellid.org/downloads.php).

Figure A7: Distance from province's centroid to nearest 3G station



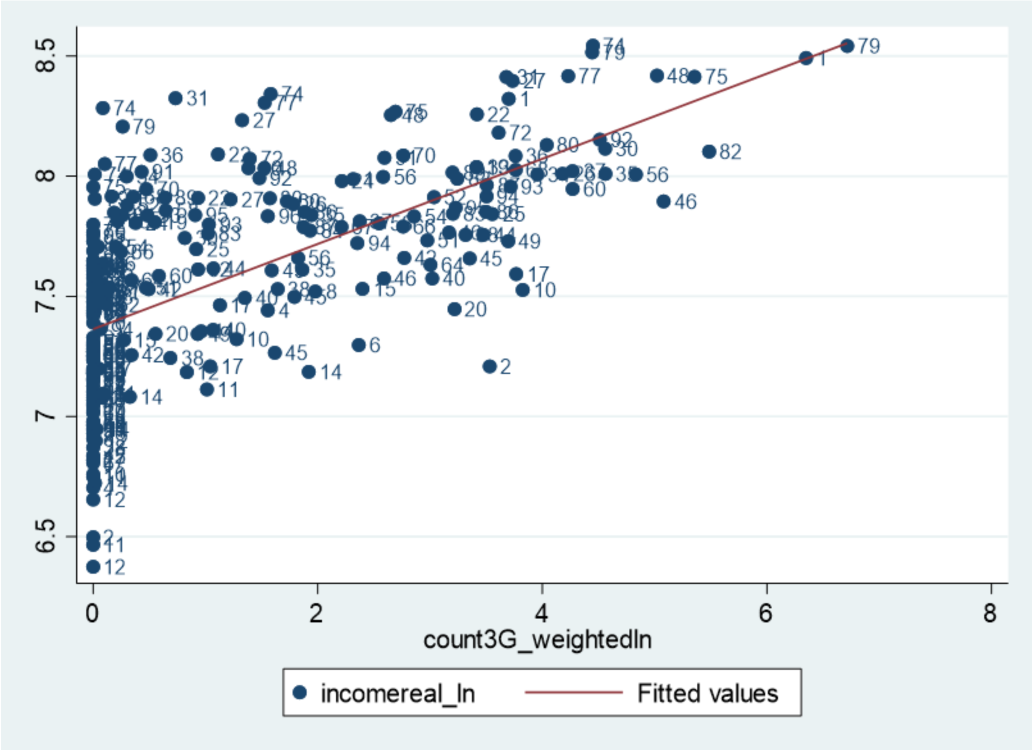
Source: author's illustration based on data from OpenCellID (www.opencellid.org/downloads.php).

Table A3: Specific data sources and interpolation

Variable	Content	Unit	Data source
Income per capita	Province's average monthly household income	1,000 VND	GSO (2016a, 2019a)
Mean school years	Average number of school years	School years	
Area	Province's total area	Square km	
Pop.	Province's total population	1,000	
Employed rate	Employment ratio (of those aged 15 and older) % total pop.	%	GSO (2016b, 2019b)
Trained employment rate	Trained employed (of 15yo older) % population	%	
GDP	Regional GDP of each province	Billion VND current price	GSO (2016a, 2019a)
GDP sectors	% share of agriculture, industry, and service	%	
Public spending	Public expenditure on education, training, and vocational training, social securities	Billion VND	
Public investment		Billion VND	
Private investment		Billion VND	
Internet sub.	Number of internet subscribers	1,000	
FDI capital	Accumulated registered values of province's FDI projects	Million US$	GSO (2016b, 2019b)
3G BTS coverage	Accumulated number of 3G BTSs (base transceiver stations) per 1,000 population	BTS	OpenCellID
2G BTS coverage	Accumulated number of 2G BTSs per 1,000 population	BTS	
Distance to Ha Noi/HCMC	Distance from province's centroid to Ha Noi or HCMC		
Elevation	Mountain elevation	Metres	USGS (2018)

Source: author's construction.

Figure A8: Scatterplot between the dependent and the main independent variable



Source: author’s illustration based on data from OpenCellID (www.opencellid.org/downloads.php).

Table A4: Models with time-variant control variables and alternative instrument

Log household income	(1)	(2)	(3)	(4)		(5)		(6)		(7)		(8)
3G internet	0.139***	0.128***	0.0150*	0.0114	0.0407**		0.0442***		0.0423*		0.0343*	
	(0.00855)	(0.0111)	(0.00802)	(0.0109)	(0.0175)		(0.0167)		(0.0216)		(0.0183)	
1st stage						−0.000739***		−0.0009***		−0.0959***		−0.145***
						(0.00013)		(0.000162)		(0.0182)		(0.033)
Log pop. density	0.277	0.205	0.215	0.0175	0.140	2.933*	−0.234	6.816***				
	(0.554)	(0.422)	(0.159)	(0.267)	(0.132)	(1.527)	(0.228)	(2.632)				
Log FDI	0.130***	0.162***	0.0145	0.0206*	0.0143	−0.128	0.0263***	−0.309***				
	(0.0329)	(0.0364)	(0.0120)	(0.0112)	(0.00962)	(0.082)	(0.00929)	(0.117)				
Rainfall	−0.000268***	−0.000280***	−0.0000312*	−0.0000322*	−0.0000325**	−0.000033	−0.0000467***	0.000238				
	(0.0000456)	(0.0000446)	(0.0000159)	(0.0000172)	(0.0000128)	(0.000155)	(0.0000164)	(0.000211)				
Temperature	−0.103***	−0.135***	0.0123	0.00796	0.000967	0.332***	−0.0168	0.622***				
	(0.0365)	(0.0445)	(0.0144)	(0.0168)	(0.0139)		(0.0190)	(0.221)				
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes	No	No	Yes	Yes	No	No	Yes	Yes
F-stat.						31.341		31.561		27.93		19.495
Observations	252	252	252	252	252	252	252	252	252	252	252	252
R-sq.	0.686	0.731	0.969	0.970	0.985	0.909	0.986	0.913	0.985	0.895	0.986	0.883
Adjusted R-sq.	0.680	0.726	0.968	0.969	0.980	0.874	0.980	0.880	0.979	0.858	0.981	0.841
RMSE	0.163	0.154	0.0514	0.0515	0.0522	0.557	0.0541	0.649	0.0535	0.591	0.0541	0.746

Note: columns 1 to 4 show the adopted FE method, 5 to 8 the FEIV method; columns 1 to 6 have control variables; columns 5 and 6 use elevation as instrumental variable, columns 7 and 8 use slope, both interacted with linear time trend; columns 1 to 8 all have province FE while columns 3 to 8 also have year FE; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author's construction based on data sources described in Table A3.

Table A5: Correlation of instrument (elevation) and household income during 2004–08

	(1)	(2)	(3)	(4)
Elevation × time trend	0.0000317	0.0000539*	0.0000348	0.0000577*
	(0.0000326)	(0.0000321)	(0.0000381)	(0.0000324)
Log pop. density			−0.00716	−0.346
			(0.455)	(0.490)
Log FDI			0.00428	0.00776
			(0.0101)	(0.0124)
Constant	5.999***	6.142***	6.019**	8.181***
	(0.0137)	(0.00758)	(2.534)	(2.953)
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	189	189	189	189
R-sq.	0.976	0.975	0.976	0.976
Adjusted R-sq.	0.975	0.974	0.975	0.975
RMSE	0.0468	0.0463	0.0470	0.0456

Note: all models include province and year fixed effects; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses;
* p<0.10, ** p<0.05, *** p<0.010.

Source: author’s construction based on data sources described in Table A3.

Table A6: Placebo test—correlation of instrument (elevation) and lead values of income

Log household income	(1)	(2)	(3)	(4)
Elevation × time trend	−0.0000115	−0.0000365	−0.00000986	−0.0000283
	(0.0000235)	(0.0000272)	(0.0000240)	(0.0000264)
Log pop. density			0.182***	0.122
			(0.0646)	(0.161)
Rainfall			0.0000224	0.0000325*
			(0.0000151)	(0.0000180)
Temperature			−0.01000	−0.0220
			(0.0126)	(0.0155)
Constant	7.522***	7.659***	10.22***	14.00***
	(0.0140)	(0.0120)	(3.814)	(4.742)
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	189	189	189	189
R-sq.	0.914	0.923	0.917	0.927
Adjusted R-sq.	0.913	0.922	0.914	0.925
RMSE	0.0481	0.0469	0.0475	0.0459

Note: all models include province and year fixed effects; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses;
* p<0.10, ** p<0.05, *** p<0.010.

Source: author’s construction based on data sources described in Table A3.

Table A7: Correlations of instrument (elevation) and the residuals of the main regressions

Residuals	(1)	(2)	(3)	(4)
Elevation × time trend	−0.0000182	−0.0000294	−0.0000221	−0.0000331
	(0.0000161)	(0.0000230)	(0.0000162)	(0.0000225)
Constant	0.00931	0.0106	0.0113	0.0119
	(0.0105)	(0.00932)	(0.0100)	(0.00894)
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Observations	252	252	252	252
R-sq.	0.013	0.023	0.019	0.030
Adjusted R-sq.	−0.003	0.007	0.003	0.014
RMSE	0.0523	0.0515	0.0509	0.0509

Note: all models include province and year fixed effects; residuals in columns 1 and 2 are from the main regression models without any controls, those in columns 3 and 4 from models with the control variables population density, rainfall, and temperature; even-numbered columns have province populations as weights while odd columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author’s construction based on data sources described in Table A3.

Table A8: Main regression results without Ha Noi and HCMC

Log household income	(1)	(2)	(3)	(4)		(5)	(6)	
3G internet	0.158***	0.156***	0.0230***	0.0198**	0.0509**		0.0754***	
	(32.86)	(24.25)	(2.75)	(2.08)	(2.53)		(3.16)	
1st stage						−0.000638***		−0.000561***
						(0.000131)		(0.000135)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes	No	No	Yes	Yes
F-stat.						24.095		17.372
Observations	244	244	244	244	244	244	244	244
R-sq.	0.578	0.595	0.967	0.969	0.984	0.909	0.980	0.911
Adjusted R-sq.	0.577	0.593	0.967	0.968	0.978	0.877	0.973	0.879
RMSE	0.187	0.187	0.0526	0.0523	0.0539	0.523	0.0583	0.532

Note: columns 1 to 4 show the adopted FE method, 5 and 6 the FEIV method; columns 1 to 6 all have province FE while columns 3 to 6 also have year FE; columns 5 and 6 use elevation × linear time trend as instrumental variable; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author’s construction based on data sources described in Table A3.

Table A9: Distance to nearest BTS as independent variable

Log household income	(1)	(2)	(3)	(4)		(5)		(6)
Distance to cell	−0.162***	−0.156***	−0.00488	−0.000758	−0.0775**		−0.0611**	
	(0.00740)	(0.0140)	(0.00697)	(0.00774)	(0.0337)		(0.0301)	
1st stage						0.000424***		0.000666***
						(0.000156)		
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes	No	No	Yes	Yes
F-stat.						7.102		8.154
Observations	252	252	252	252	252	252	252	252
R-sq.	0.749	0.741	0.966	0.968	0.971	0.857	0.977	0.881
Adjusted R-sq.	0.748	0.740	0.965	0.968	0.961	0.806	0.968	0.838
RMSE	0.145	0.150	0.0537	0.0527	0.0731	0.792	0.0690	0.848

Note: columns 1 to 4 show the adopted FE method, 5 and 6 the FEIV method; columns 1 to 6 all have province FE while columns 3 to 6 also have year FE; columns 5 and 6 use elevation × linear time trend as instrumental variable; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author’s construction based on data sources described in Table A3.

Table A10: Household income and mobile broadband with grids as unit of analysis

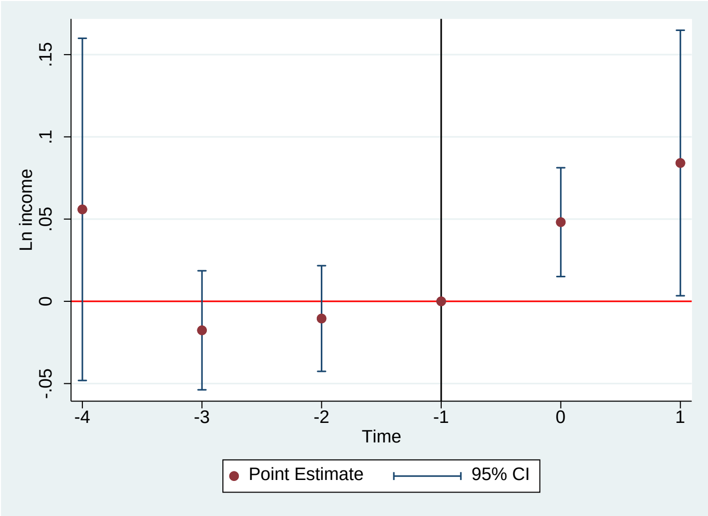
Log household income	(1)	(2)	(3)	(4)		(5)		(6)
3G internet	0.105***	0.0988***	0.00436	0.00907**	0.0383***		0.0235***	
	(0.00298)	(0.00546)	(0.00358)	(0.00375)	(0.0122)		(0.00740)	
1st stage						−0.001139***		−0.000658***
						(0.000242)		(0.000185)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes	No	No	Yes	Yes
F-stat.						22.825		12.981
Observations	236	236	236	236	236	236	236	236
R-sq.	0.638	0.768	0.980	0.985	0.981	0.903	0.990	0.843
Adjusted R-sq.	0.637	0.767	0.980	0.984	0.974	0.869	0.986	0.787
RMSE	0.181	0.145	0.0425	0.0374	0.0570	1.139	0.0403	1.261

Note: columns 1 to 4 show the adopted FE method, 5 and 6 the FEIV method; columns 1 to 6 all have province FE while columns 3 to 6 also have year FE; columns 5 and 6 use elevation × linear time trend as instrumental variable; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

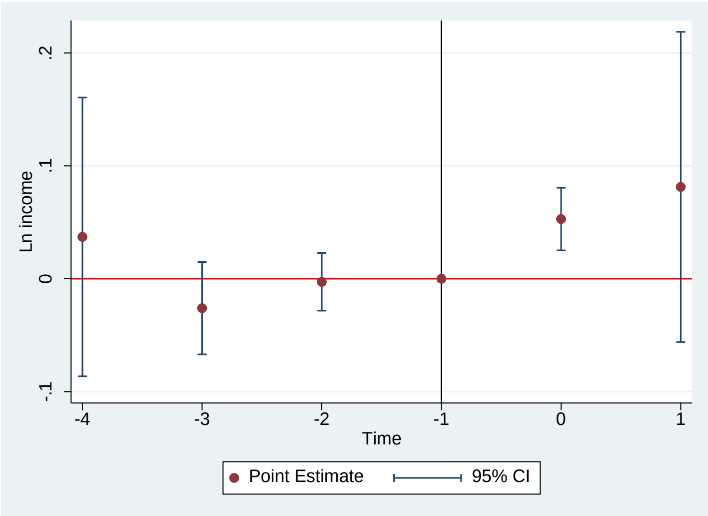
Source: author's construction based on data sources described in Table A3.

Figure A9: Event study approach

Unweighted model



Weighted model



Note: the event study design uses the first year in which a province hits 0.2 cells per 1,000 population, or one cell per 5,000 people, as treatment, corresponding to time 0 in the horizontal axis; the coefficients reported in the figure come from a model based on Equation 1, including province and year fixed effects; standard errors are clustered at the province level; regression coefficients are reported together with their 95% confidence interval.

Source: author's illustration using STATA command eventdd.

Table A11: FEIV-Lewbel results

Log household income	(1)	(2)
3G internet	0.0382*	0.0361**
	(0.0201)	(0.0167)
Log pop. density	0.00109	−0.0186
	(0.0164)	(0.0163)
Mean schooling years	−0.00259	−0.0351
	(0.0295)	(0.0275)
FDI	0.0149	0.0261**
	(0.0113)	(0.0110)
Rainfall	−0.0000332**	−0.0000436**
	(0.0000147)	(0.0000187)
Temperature	0.00246	−0.00958
	(0.0162)	(0.0217)
Hansen J test	3.536	3.976
Hansen J p-value	0.8964	0.8593
Weights	No	Yes
Observations	252	252
R-sq.	0.967	0.968
Adjusted R-sq.	0.954	0.955
RMSE	0.0602	0.0605

Note: the table reports IV estimates from regressions using both sets of generated instruments under the Lewbel method and external instruments (elevation × time trend); column 2 has province populations as weights while column 1 does not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author's construction based on data sources described in Table A3.

Table A12: Control function approach

Log household income	(1)	(2)	(3)	(4)
3G internet	0.0449**	0.0387*	0.0480**	0.0558**
	(0.0221)	(0.0217)	(0.0233)	(0.0256)
Residuals	−0.0304	−0.0334*	−0.0399	−0.0517**
	(0.0235)	(0.0199)	(0.0251)	(0.0257)
Pop. density			0.129	−0.334
			(0.163)	(0.282)
Temperature			−0.00116	−0.0246
			(0.0147)	(0.0215)
Rainfall			−0.0000278*	−0.0000446***
			(0.0000154)	(0.0000166)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes
Observations	252	252	252	252
R-sq.	0.968	0.970	0.970	0.971
Adjusted R-sq.	0.967	0.969	0.969	0.970
RMSE	0.0523	0.0515	0.0512	0.0511

Note: columns 1 and 2 are models without control variables while columns 3 and 4 are models with control variables; residuals are from the first-stage regressions of the endogenous variable and the instrument; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author’s construction based on data sources described in Table A3.

Table A13: Urban–rural difference and 3G mobile internet

Log household income		(1)		(2)		(3)		(4)
				Rural				Urban
3G internet	0.0530**		0.0887***		0.0362*		0.0174	
	(0.0267)		(0.0301)		(0.0216)		(0.0183)	
1st stage		−0.000625***		−0.000604***		−0.000798***		−0.00131***
		(0.000158)		(0.000160)		(0.000299)		(0.000421)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	No	Yes	Yes	No	No	Yes	Yes
F-stat.		16.046		14.554		7.303		9.967
Observations	143	143	143	143	109	109	109	109
R-sq.	0.983	0.902	0.977	0.905	0.980	0.905	0.983	0.897
Adjusted R-sq.	0.976	0.861	0.967	0.866	0.971	0.864	0.975	0.852
RMSE	0.0517	0.502	0.0579	0.505	0.0547	0.653	0.0523	0.823

Note: All models adopt THE FEIV method with elevation × time trend as the instrument; province population is divided into urban and rural population based on the threshold of percentage of people living in urban communities (i.e. ward, not commune); even-NUMBERED columns have province populations as weights while odd-NUMBERED columns do not; Standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author's construction based on data sources described in Table A3.

Table A14: Income quintiles and 3G BTS

Log household income quintile	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Quintile 1		Quintile 2		Quintile 3		Quintile 4		Quintile 5
3G internet	0.0652***	0.0598***	0.119***	0.0930***	0.0996***	0.0691***	0.0217	0.0222	0.0234	0.0233
	(0.0204)	(0.0186)	(0.0272)	(0.0244)	(0.0269)	(0.0241)	(0.0272)	(0.0199)	(0.0168)	(0.0157)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
F-stat.	29.213	19.564	29.213	19.564	29.213	19.564	29.213	19.564	29.213	19.564
Observations	252	252	252	252	252	252	252	252	252	252
R-sq.	0.976	0.979	0.971	0.973	0.971	0.973	0.979	0.980	0.980	0.983
Adjusted R-sq.	0.968	0.971	0.961	0.963	0.961	0.963	0.971	0.973	0.973	0.976
RMSE	0.0675	0.0687	0.0800	0.0800	0.0781	0.0746	0.0620	0.0585	0.0610	0.0620

Note: all models adopt the FEIV method with elevation × time trend as the instrument; quintiles 1 to 5 are the income quintiles of each province during 2010–16; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses; * $p<0.10$, ** $p<0.05$, *** $p<0.010$.

Source: author's construction based on data sources described in Table A3.

Table A15: Transportation volumes and 3G BTS

Volumes	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Passengers carried		Passengers × distance		Freight carried		Freight × distance	
3G internet	0.0420**	0.0380***	1.405**	0.625***	19.88*	2.671	2.576*	1.114**
	(0.0202)	(0.00854)	(0.668)	(0.201)	(11.00)	(2.447)	(1.509)	(0.503)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	Yes	No	Yes	No	Yes	No	Yes
Observations	252	252	252	252	252	252	252	252
R-sq.	0.937	0.975	0.858	0.922	0.796	0.911	0.864	0.930
Adjusted R-sq.	0.915	0.966	0.808	0.894	0.724	0.879	0.815	0.905
RMSE	0.00598	0.00577	0.254	0.189	3.507	2.156	0.425	0.333

Note: all models adopt the FEIV method with elevation × linear time trend as instrumental variable, with both province and year FE; the dependent variables are number of passengers carried per capita per province for columns 1 and 2, number of passengers × travel distance per capita per province for columns 3 and 4, number of freights carried per capita per province for columns 5 and 6; and number of freights × travel distance per capita per province for columns 7 and 8; even-numbered columns have province populations as weights while odd-numbered columns do not; standard errors clustered at province level in parentheses; * p<0.10, ** p<0.05, *** p<0.010.

Source: author's construction based on data sources described in Table A3.

The UNU-MERIT WORKING Paper Series

2023-01 *Can international mobility shape students' attitudes toward inequality? The Brazilian case* by Cintia Denise Granja, Fabiana Visentin and Ana Maria Carneiro

2023-02 *Demand-led industrialisation policy in a dual-sector small open economy* by Önder Nomaler, Danilo Spinola and Bart Verspagen

2023-03 *Reshoring, nearshoring and developing countries: Readiness and implications for Latin America* by Carlo Pietrobelli and Cecilia Seri

2023-04 *The role of product digitization for productivity: Evidence from web-scraping European high-tech company websites* by Torben Schubert, Sajad Ashouri, Matthias Deschryvere, Angela Jäger, Fabiana Visentin, Scott Cunningham, Arash Hajikhani, Lukas Pukelis and Arho Suominen

2023-05 *More than a feeling: A global economic valuation of subjective wellbeing damages resulting from rising temperatures* by Stephan Dietrich and Stafford Nichols

2023-06 *Was Robert Gibrat right? A test based on the graphical model methodology* by Marco Guerzoni, Luigi Riso and Marco Vivarelli

2023-07 *Predicting social assistance beneficiaries: On the social welfare damage of data biases* by Stephan Dietrich, Daniele Malerba and Franziska Gassmann

2023-08 *Related or unrelated diversification: What is smart specialization?* By Önder Nomaler and Bart Verspagen

2023-09 *Breach of academic values and digital deviant behaviour: The case of Sci-Hub* by Giulia Rossello and Arianna Martinelli

2023-10 *The effect of lobbies' narratives on academics' perceptions of scientific publishing: An information provision experiment* by Giulia Rossello and Arianna Martinelli

2023-11 *Making impact with agricultural development projects: The use of innovative machine learning methodology to understand the development aid field* by Lindsey Moore, Mindel van de Laar, Pui Hang Wong and Cathal O'Donoghue

2023-12 *Green windows of opportunity in the Global South* by Rasmus Lema and Roberta Rabellotti

2023-13 *The green and digital transition in manufacturing global value chains in latecomer countries* by Rasmus Lema and Roberta Rabellotti

2023-14 *Impact of prestigious-STEM Education of corporate board members on innovation effort: Evidence from India* by Rituparna Kaushik, Sourabh Bikas Paul and Danilo Spinola

2023-15 *Reducing environmental impact through shared ownership: A model of consumer behaviour* by Francesco Pasimeni and Tommaso Ciarli

2023-16 *Welfare losses, preferences for redistribution, and political participation: Evidence from the United Kingdom's age of austerity* by Patricia Justino, Bruno Martorano and Laura Metzger

2023-17 *Inequality, social mobility and redistributive preferences* by Isabel Günther and Bruno Martorano

2023-18 *Automation-induced reshoring and potential implications for developing economies* by Hubert Nii-Aponsah, Bart Verspagen and Pierre Mohnen

2023-19 *Ethnic spatial dispersion and immigrant identity* by Amelie F. Constant, Simone Schüller and Klaus F. Zimmermann

2023-20 *Public R&D and Growth: A dynamic Panel VECM Data Analysis for 14 OECD Countries* by Thomas H.W. Zieseme by r

2023-21 *Innovation and the labor market: Theory, evidence and challenges* by Nicoletta Corrocher, Daniele Moschella, Jacopo Staccioli and Marco Vivarelli

2023-22 *Revisiting Schumpeter in Europe: Place-based innovation and transformative industrial policy* by Luc Soete and Johan Stierna

2023-23 *Identification of Fourth Industrial Revolution technologies using PATSTAT data* by María de las Mercedes Menéndez, Önder Nomaler and Bart Verspagen

2023-24 *Expectations and the stability of stock-flow consistent models* by Huub Meijers, Joan Muysken and Giulia Piccillo

2023-25 *Critical minerals and countries' mining competitiveness: An estimate through economic complexity techniques* by Jorge Valverde Carbonell, María de las Mercedes Menéndez, and Carlo Pietrobelli

2023-26 *Internal rates of return for public R&D from VECM estimates for 17 OECD countries* by Thomas H.W. Ziesemer

2023-27 *Does moral transgression promote anti-social behavior? Evidence from lab-in-the-field experiments* by Halefom Yigzaw Nigus, Eleonora Nillesen, Pierre Mohnen and Salvatore Di Falco

2023-28 *Does exposure to markets promote investment behavior? Evidence from rural Ethiopia* by Halefom Yigzaw Nigus, Pierre Mohnen and Eleonora Nillesen

2023-29 *The virtuous loop of quality of government (QoG) and institutional trust in OECD countries, 2006-2021 and culture* by Ahmed Hussain and Jo Ritzen

2023-30 *Alternative related variety, macroeconomic factors and diversification: Extractive vs. non-extractive products* by Beatriz Calzada Olvera

2023-31 The effect of government cuts of doctoral scholarships on science by Giulia Rossello

2023-32 *Spatial inequality during the COVID-19 pandemic in Africa using night-time lights data* by Bruno Martorano, Elena Perra and Marco Tiberti

2023-33 *How humanitarian are Germans towards refugees?* By Tobias Hillenbrand, Bruno Martorano, Laura Metzger and Melissa Siegel

2023-34 *The gender inequality effects of the COVID-19 pandemic on the Nigerian labor market* by Ana Karen Diaz Mendez and Bruno Martorano

2023-35 *Lost in aggregation? On the importance of local food price data for food poverty estimates* by Stephan Dietrich, Valerio Giuffrida, Bruno Martorano, Georg Schmerzeck and Marco Tiberti

2023-36 *Technologies fly on the wings of science: Exploring the role of science in technologies' spatial evolution* by Michele Pezzoni, Reinhilde Veugelers and Fabiana Visentin

2023-37 *Co-evolutionary patterns of GVC-trade and knowledge flows in the mining industry: Evidence from Latin America* by Fabrizio Fusillo, Silvia Nenci, Carlo Pietrobelli and Francesco Quatraro

2023-38 *Forced displacement and occupational mobility: a skills-based approach* by Antonio Martins-Neto, Renata Mayer Gukovas and Didier Fouarge

2023-39 *Are social inequalities being transmitted through higher education? A propensity-score matching analysis of private versus public university graduates using machine learning models* by Andrea Visentin and Louis Volante

2023-40 *Navigating challenges: STI policies for sustainable and inclusive development in Latin America* by Pietrobelli C., Anlló G., Barletta F., Bianchi C., Dutrénit G., Menéndez M., Puchet M., Rocha F., Ruiz K., Segura Bonilla O., Szapiro M.

2023-41 Why do we still measure state fragility? *by Gulzhan Asylbek kyzy, Gary Milante, Zina Nimeh and Kaj Thomsson*

2023-42 *Mobile internet and income improvement: Evidence from Vietnam* by Trang Thi Pham