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AN EMPIRICAL EVIDENCE AND PROPOSAL ON THE SPILLOVER EFFECTS OF INFORMATION AND COMMUNICATION TECHNOLOGY INFRASTRUCTURE IN INDIA

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In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

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Abstract

The COVID-19 pandemic highlights the importance of information and communications technology (ICT) not only for the economy but also for human well-being. However, the investment gap in ICT infrastructure has been growing and is expected to reach more than \$30 billion by 2040. We argue that one of the ways to attract private sector involvement in ICT infrastructure is by creating a steady stream of income for the investors. We quantify the spillover effects of mobile network on tax revenues, using annual state-level data for 2005 to 2016 from India across all states. Using simple Fixed Effect (FE) as well as Fixed Effect (FE) Two-Stage Least-Squares (2SLS) estimations, we show that the rise in the number of mobile network subscribers is associated with an increase in the amount of regional tax revenues. On average, an increase in the number of The Global System for Mobile Communications (GSM) subscribers per capita by 1 percentage point is expected to raise annual state tax revenues per capita by ₹134 (3% of average annual state tax revenue per capita in 2016). The number of GSM subscribers affect tax revenues through increased economic activities, as shown by our 2SLS estimation results. The results of this study justify our proposal to share the increased tax revenues with the investors to create a steady stream of income for investors. The findings of this study also support the increased support for the development of digital and physical infrastructure in the national budget of India for 2022–2023.

Keywords: infrastructure, spillover effect, information and communication technology, tax revenue, Difference-in-Difference (DiD) method, 2SLS

JEL Classification: H20, H54, O18, Q48

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1. INTRODUCTION

Information and communications technology (ICT) is an important growth driver and an indispensable part of the modern economy. ICT infrastructure, such as fixed-line telephones, mobile phones, internet, and broadband, is the foundation of economic activities and technological applications. The growth of ICT infrastructure has increased the effectiveness of resources allocations, reduced production costs, and boosted demand and investment in many economic sectors (Jorgenson and Stiroh 1999; Vu 2011; Lee et al. 2012; Grimes et al. 2012; Pradhan et al. 2015; Aseinov et al. 2022). Other than the economic impacts, the development of ICT infrastructure also improves access to information, which may contribute significantly to long-term sustainable development.

The current COVID-19 pandemic further emphasizes the importance of ICT infrastructure (Beirne, Morgan, and Sonobe 2021; Abdullaev et al. 2022). ICT has shown its strong contribution to overcoming difficulties during this devastating public health crisis by enabling people to connect, work, shop, and learn while maintaining restraints such as “staying at home” and physical distancing. Moreover, big data is used by many governments for pandemic control measures and impact measurement related to contact tracing, mobility, and health analysis. The use of the internet for healthcare and education during the COVID-19 pandemic has enabled patients to consult with healthcare professionals through online medical platforms and students to continue their learning activities despite school closures. These models of online/virtual healthcare and education services are expected to continue even after the pandemic ends. Similarly, COVID-19 may have also affected people’s willingness to commute to work post-pandemic.

Therefore, investment in access to and quality improvements of ICT infrastructure can be considered as an important factor, not only for human well-being, but also for economic development. It is no surprise that rapid growth of ICT services is occurring all over the world, including in developing countries.

However, the provision of ICT services is unable to keep up with its growing demand partly due to challenges in obtaining financing for investment in ICT infrastructure. Global Infrastructure Outlook (2021) shows that for telecommunication infrastructure, the projected investment needs for Asia in 2040 is expected to reach \$193 billion while the projected investment (using the current trend) for the year is only \$162 billion. This means that the investment gap for the telecommunications sector in Asia is expected to reach more than \$30 billion in 2040. The reason for this widening gap of ICT infrastructure investment is the same as that of other types of infrastructures, namely the inability of many governments, especially those of developing countries, to fully finance their infrastructure needs. Consequently, governments have been turning to the private sector for infrastructure investment. This has led to the use of partnerships between the public and the private sectors, commonly known as public–private partnership (PPP). The Asian Development Bank (2018) defines PPP as the

“contractual arrangement between public (national, state, provincial, or local) and private entities through which the skills, assets, and/or financial resources of each of the public and private sectors are allocated in a complementary manner, thereby sharing the risks and rewards, to seek to provide optimal service delivery and good value to citizens.”

While PPP has been adopted by many countries as a method to finance infrastructure investment, it also has its own set of challenges. First, the construction of physical infrastructure is risky. If construction takes more time than previously anticipated or if its costs exceed estimates, usually the private sector bears the burden. Second, even after the project is complete, failure can still occur if demand for the infrastructure turns out to be less than projected. PPP projects are usually implemented for public goods (such as roads, bridges, electricity, water, and ICT infrastructure) where users expect low fees. In contrast, the private sector is profit-oriented and may be in a position (by the PPP agreement) to raise fees in order to cover construction and operational costs. However, increasing fees, i.e., user charges, may lower the consumer demand. This mismatch in the needs of consumers and investors could lead to the failure of PPPs.

Therefore, to ensure the success of PPPs, it is important to guarantee the private sector that their involvement in infrastructure investment will not lead to losses. This paper points out that one way to create a steady stream of income for private sector investors without adding increased burden on the users (through imposing higher user charges or fees) is by sharing the increased tax revenues obtained by the local governments that benefitted from the newly built infrastructure. It is important to realize that infrastructure development creates spillover impacts in the region, meaning that the effects of infrastructure do not only benefit its direct users and investors, but also other parties that may be indirectly affected by the infrastructure. For example, building good quality infrastructure may lead to increased economic activities in the region, such as higher business growth and more employment, which leads to higher income, including that of the government, i.e., tax revenues. Yoshino and Thi Hoa (2020) show that the operation of the Noi Bai–Lao Cai and Ha Noi–Thai Nguyen expressways add more than D38.51 billion to the income tax revenues of the affected provinces compared to non-affected provinces. The authors argue that their results show that the operation of the new expressways increases the income of the people living in the provinces affected by creating new jobs and opportunities. Other studies show similar results of spillover effects of infrastructure development (Yoshino et al. 2021) on economic growth (Yoshino and Abidhadjaev 2015) and tax revenues (Yoshino and Pontines 2015; Yoshino and Abidhadjaev 2017).

In this paper, we highlight the lessons learnt from the COVID-19 pandemic on the importance of ICT infrastructure. We also discuss the continuity of the growing needs of ICT infrastructure post-COVID-19. Having illustrated the growing importance of ICT infrastructure, we quantify the “spillover effects” of ICT services on tax revenues using a large-scale ICT infrastructure development program in India as a case study. In order to quantify the spillover effects of mobile networks on tax revenues, we use annual state-level data for 2005 to 2016 from India across all states (some states are merged together—we will discuss this in further details in Section 5.2). The results of the fixed effects two-stage least squares (FE 2SLS) show that the rise in the number of mobile network subscribers is associated with an increase in tax revenues. Based on these results, we argue that in order to fill in the financing gap for the investment of infrastructure, the government should further incentivize participation from the private sector. Such support could not only be a massive one-time program, such as the Shared Mobile Infrastructure Scheme (SMIS) program covered in this paper, but could also be something continuous that could create a steady stream of income for the investors. We propose to mobilize private investments in ICT infrastructure through the sharing of the increased tax revenues with those private sectors that invested in the ICT infrastructure through an increased rate of return.

The remaining sections of this paper are structured as follows. In Section 2, we discuss the role of ICT during the COVID-19 pandemic. We provide a brief overview of the mobile phone coverage in India as well as the SMIS program in Section 3. In Section 4 provides an overview of taxation in Indian. Section 5 reviews literature on spillover effects of ICT infrastructure. Section 6 discusses the data and methodology used in this paper. Section 7 presents the results and discussion. Section 8 provides a policy proposal. Section 9 concludes and provides policy recommendations.

2. ROLE OF ICT DURING THE COVID-19 PANDEMIC

As previously discussed, the COVID-19 pandemic has shown us how the internet has become a critical aspect of our daily lives. Access to health-related information can reduce the spread of the coronavirus and save lives. ICT also enables us to work, study, shop, communicate, and access other important services despite restricted mobility. People are now able to perform numerous activities online in place of physical in-person activities, leading to the term “virtual mobility” (Mouratidis and Pappagiannakis 2021). This section discusses the role of the internet during this pandemic and how the current trends may continue post-COVID 19.

2.1 Telework

With the increasing restriction placed on in-person activities since the beginning of the COVID-19 outbreak, more and more people are shifting their work that can be done virtually online rather than in-person. A large-scale survey by Ono and Mori (2021) in eight countries including Japan, the People’s Republic of China (PRC), and the Republic of Korea found that there was a significant growth in the number of workers teleworking and that the growth was highly correlated with the respective national lockdown orders. As of July 2020, 75% of the respondents in urban PRC mentioned that they are working from home, with 35% of them having started teleworking before the pandemic began. On the other hand, in the same period, only 31% of the respondents in Japan said that they are teleworking and 22% have started teleworking after the pandemic.

It is important to note that teleworking is not free from challenges. Poor internet connection, which leads to difficulties in communicating with colleagues during online meetings, may hinder productivity, especially in East Asian countries, which tend towards collectivism and place importance on agreement with others Ono and Mori (2021). Similarly, although the use of ICT for teleworking has been on a growing trajectory, there are still disparities on who is able to access ICT services. In the study by Ono and Mori (2021) discussed above, the results of the survey in the PRC and Republic of Korea are only representative of the urban population because internet access is concentrated in urban areas for the two countries. Other studies have also shown the prevalence of digital inequality between countries, such as the significant difference between international bandwidth per internet user and the percentage of population connected to the internet between developed and developing countries. Similarly, digital inequality also holds within countries, such as between urban and rural regions and between people with higher and lower incomes (UNCTAD 2021).

2.2 E-Commerce

Although online shopping has already been growing since before the pandemic, COVID-19 has amplified the use in e-commerce and accelerated digital transformation. The share of e-commerce in global retail trade went up from 14% in 2019 to 17% in 2020 (UNCTAD 2021). The findings of the survey by UNCTAD (2021) show that the rise in e-commerce is occurring across regions, with consumers in emerging economies making the largest shift to online shopping. For example, online share of retail sales in the PRC jumped from 19.4% to 24.6% between August 2019 and August 2020. Similarly, Google, Temasek, and Bain & Company (2021) show that 80% of internet users in Southeast Asia have made at least one online purchase. Around 16% of digital consumers in Southeast Asia first started purchasing digital services from the beginning of the pandemic, with e-commerce, food delivery, and digital financial services being the most popular digital services. Just like teleworking that is expected to continue post-COVID, adoption of digital services by consumers is also expected to persist after the pandemic ends.

Sonobe et al. (2021) also shows that medium, small, and micro enterprises (MSMEs) in eight developing countries in South Asia, Southeast Asia, and Northeast Asia have begun resorting to online marketplaces and using mobile message services and social media to sell their products. Azhgaliyeva et al. (2021) show that broadband internet access significantly impacts small and medium-sized enterprises and large firms on total sales and exports, using an enterprise survey from nine Central Asia Regional Economic Cooperation (CAREC) member countries (Afghanistan, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, and Uzbekistan) in 2008, 2009, and 2013. Using an enterprise survey from four CAREC member countries—Azerbaijan, Georgia, Kazakhstan, and Mongolia—in 2020 and 2021, Aseinov et al. (2022) show that firms with their own website are more likely to have production adaptability due to the COVID-19 crisis .

It is important to highlight that the rise in digital services, including e-commerce and food delivery services, not only benefits consumers and large manufacturers, but also small merchants and casual workers, such as those in agriculture. With the emergence of e-commerce and other types of online marketplace, such as online marketing through social media, small businesses can reach customers that would not have been accessible without the help of the internet. Google, Temasek, and Bain & Company (2021) show that one third of digital merchants in Southeast Asia believe that they would not have survived COVID-19 if not for digital platforms.

The benefits of ICT for businesses are more than just for online marketing and sales. Jensen (2007) shows that in the span of his research period, 1997–2001, fishermen in Kerala India used mobile phones to obtain information on market prices. This resulted in lower price dispersion, increased profits for the fishermen, and a lower consumer price of the sardines being sold.

2.3 Online Educational Services

With the outbreak of COVID-19, many schools closed down and students were faced with no choice but to study from home. Fortunately, ICT has been helpful in aiding remote learning, enabling teachers and students to continue their learning activities despite school closures. The Asian Development Bank (ADB) (2021) shows that by April 2021, schools had been closed for at least 200 days since the pandemic began in 19 out of 46 economies in developing Asia. Most economies in developing Asia implemented partial closures, such as closing schools only in certain regions or for

some grade levels. In some instances, schools have adopted a hybrid learning method by combining reduced class time with remote learning. World Bank (2021) shows that 91% of countries delivered remote learning through online media and 70% of countries also delivered remote learning through mobile phones.

Even before COVID-19, there was an already upward trend in the adoption of virtual education technology, such as language learning applications, virtual tutoring, video conferencing tools, and online learning software. However, the usage of education technology surged even more during COVID-19 (Li and Lalani 2020). The growth in the popularity of education technology is not only limited to students enrolled in schools, but also for adult or optional learning. For example, the Bank of Japan and Financial Services Agency began a financial education/financial literacy program in November 2021. This educational program is free of charge and can be accessed by anyone as long as they have internet connection. There is also an examination after the course and certificates are provided for students who have completed the course and examination.

Such types of free learning programs are also offered by other institutions, such as ADBI e-learning, which provides training courses on Asia and the Pacific Development and edX, which offers online courses on various topics from world-class universities, such as Massachusetts Institute of Technology and Harvard University. Online courses increase access of education to people who otherwise could not have attended such trainings/classes, such as those living far away from where the in-person training/courses are held or those who could not afford tuition/training fees. Therefore, it is clear that the availability of remote learning offers the opportunity for more people to increase their skills and enhances human capital.

However, besides increasing the access of remote learning, the COVID-19 pandemic also highlights the inequality of internet access and necessary equipment, such as computers or smartphones. ADB (2021) shows that while 86% of households in high-income economies have internet access, the number drops to 41% for lower-middle income economies. Within countries, as discussed previously, the number of households connected to the internet also varies between urban and rural regions.

The three points discussed above are examples of how ICT has proven to be critical in our daily lives, especially during the ongoing pandemic. Demand for telework, e-commerce, and online educational services is expected to continue post COVID-19. Especially for telework, a survey by Ernst and Young (EY; 2021) show that only 4% of employees in Asia and the Pacific prefer to go back to fully working from the office post-pandemic, while 19% and 42% prefer hybrid work and fully remote work, respectively.

Therefore, increasing access and quality of ICT services is of crucial importance, even after the pandemic ends. As previously discussed, unfortunately many countries are still faced with challenges in providing equal access to ICT for its citizens. In the upcoming section, we illustrate the effect of digital infrastructure, specifically mobile towers, on the amount of tax revenue collected by state governments in India. It is important to note that what we are estimating here is the short-term spillover effect of digital infrastructure. The long-term spillover effects, such as on human capital as illustrated by the e-learning point discussed above, is a subject for future research when data become available.

3. MOBILE PHONE COVERAGE AND SHARED MOBILE INFRASTRUCTURE SCHEME IN INDIA

Since the late 1990s, the development of telecommunications' infrastructure in India has been impressive. The robust growth in the ICT sector is primarily due to a progressive regulatory regime, a strong demand for telecommunication services, and robust economic growth. Overall telecom-density has increased from about 1% in 1994, when the telecommunications sector was first heard of in India, to about 90% as of June 2018 (IBEF 2018). With a subscriber base of 1.17 billion, India's telecom market is the world's second largest and contributes significantly towards GDP growth and job creation (IBEF 2018).

Nevertheless, the growth in rural areas has lagged behind that of urban areas. This is a common pattern, as the ICT infrastructure is often regarded as an industry driven by private capital with limited need for public sector participation (A4AI and World Wide Web Foundation 2018). Therefore, most of the development has primarily focused on the needs of the growing urban middle class, resulting in a widening digital divide between urban and rural areas. Extending access to connectivity in rural areas is a highly complex, multifaceted challenge. In addition to massive capital requirements for infrastructure investment, projects have extra layers of complexity tied to economics, government participation, and physical conditions, which may increase the hurdles, especially for rural areas (A4AI and World Wide Web Foundation 2018).

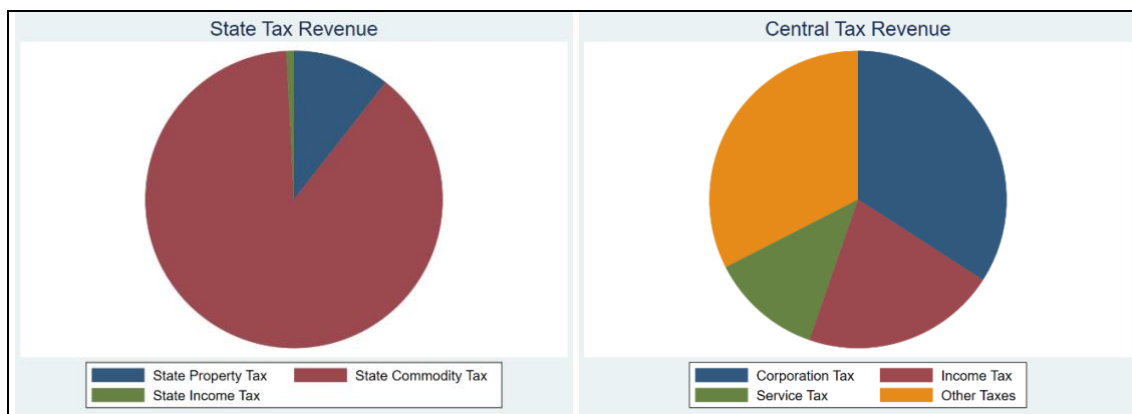
As a response to the lack of ICT infrastructure investment in rural areas, in 2007 the Indian government launched the Shared Mobile Infrastructure Scheme (SMIS) program. Under the program, from 2007 to 2013, more than 7,353 mobile towers were constructed in 500 districts, spread throughout 27 states (see figures Appendix C). The scheme prioritizes villages or clusters of villages not covered by mobile or wireless services and with a population more than 2,000 (Gupta et. al., 2021). These towers covered a total of 170,821 villages that were previously not covered by mobile services. By the end of 2011, the total number of villages not covered by mobile services in India fell to 56,399. The mobile towers constructed were to be shared by multiple service providers for the provision of mobile services. Construction of the mobile towers began in 2007 and ended in 2010. Most of the towers were built between the second half of 2008 and the first half of 2009. Telecommunication operators that received government subsidies were responsible for the installation and maintenance of the towers between 2007 and 2013.

4. TAXATION IN INDIA

In India, taxes are levied by state governments (state tax) and central governments (central tax). Taxes levied by state governments in India consist of sales and value added tax (VAT), property and capital gains tax, luxury tax, professional/employment tax, taxes on duties and electricity, etc. As shown in Figure 1, state tax revenues mainly consist of state tax on commodities and services, which consist of sales tax and VAT, vehicle tax, passenger tax, etc. The largest contributor of state tax on commodities and services are sales tax and VATs. On the other hand, tax levied by the central government are comprised of more types of taxes compared to those of state taxes, for example corporation tax, which is the largest contributor, income tax, service tax, customs, duties, and wealth tax, among others.

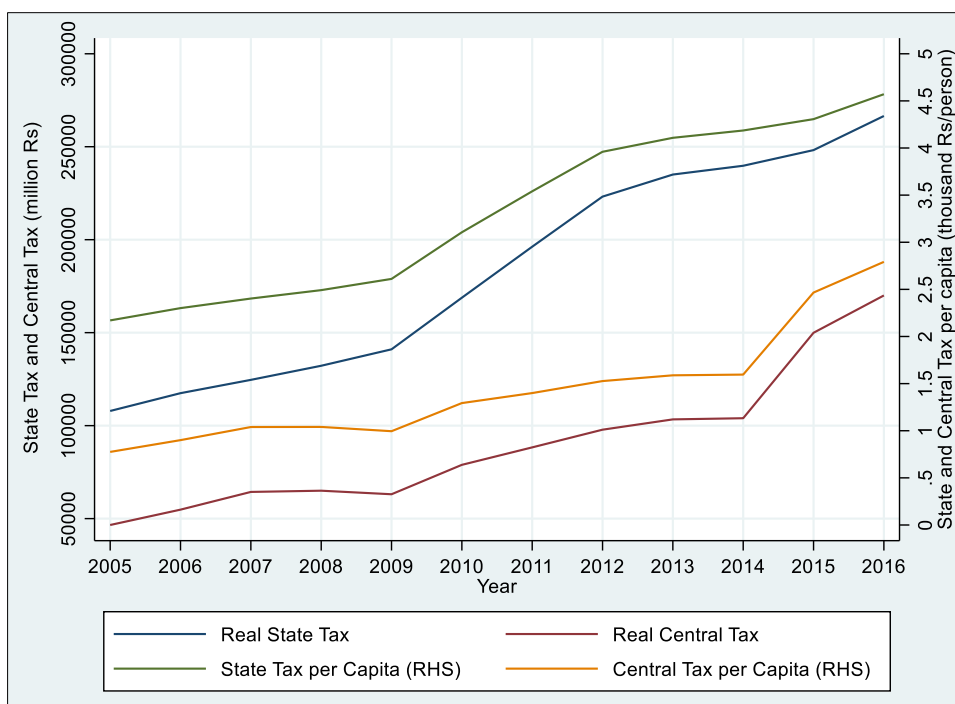
The amount of revenues received by the government from taxes are higher from state tax compared to that from central tax (Figure 2). In 2016, the average amount of state tax in 2004 prices collected by governments was ₹261.8 billion while for central tax the number was ₹170 billion. When taken by their per capita values, the average real state tax per capita in 2016 was ₹4.61 thousand while the average real central tax per capita was ₹2.8 thousand. Figure 2 also shows that both real state tax and real central tax revenues as well as their per capita values have upward trends, meaning that the Indian government has collected increasing tax revenues in 2005–2016.

Figure 1: State Tax Revenue and Central Tax Revenue Composition, 2005–2016



Source: Reserve Bank of India, State Finances: A Study of Budgets.

Figure 2: Real State Tax, Real Central Tax, Real State Tax per Capita, and Real Central Tax per Capita



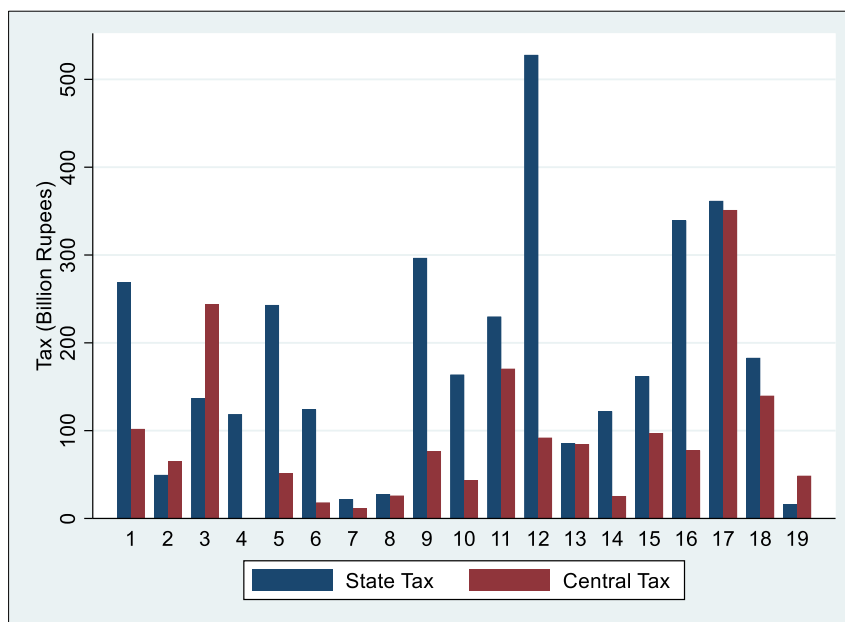
Note: Average tax revenues for all states in 2005–2016. All values are in constant 2004 prices.

Source: Reserve Bank of India, modified by authors.

When divided by states (Figure 3), it is clear that the highest and lowest earning states differ based on the type of tax revenues (state and central tax revenues). For example, the largest amount of state tax revenues collected was in the state of Maharashtra, Goa, Dadra and Nagar Haveli, and Daman and Diu (State ID 12), while the smallest is in the Northeastern Region (State ID 19). On the other hand, the states with the largest share of central tax revenues were Uttar Pradesh and Uttaranchal combined (State ID 17).

An important point to ensure that we obtain reliable estimates when using tax data is that the Indian tax structure did not undergo significant changes in the period of study. The consistency of the tax policy within our period of study is imperative for us to obtain reliable estimation results. Near our period of study, there were two major reforms that occurred in the Indian tax structure. The first was in 2005 when the government made a sales tax reform in the form of value added tax (VAT). The second occurred in 2017 when the government introduced the goods and services tax (GST) policy. No major reforms in the Indian taxation system occurred within our period of study of 2005–2016. However, many states adopted mandatory online tax filing in 2010-2014 which may have increased compliance and affected tax revenues. In order to control for this, we include year dummies as explained in Section 6 (Data and Methodology).

Figure 3: State and Central Tax Revenues, Average 2005–2016 (Constant Price 2004)



Note: 1: Andhra Pradesh and Telangana; 2: Assam; 3: Bihar and Jharkhand; 4: National Capital Territory of Delhi; 5: Gujarat; 6: Haryana; 7: Himachal Pradesh; 8: Northern region; 9: Karnataka; 10: Kerala; 11: Madhya Pradesh and Chhattisgarh; 12: Maharashtra, Goa, Dadra and Nagar Haveli, and Daman and Diu; 13: Odisha;^a 14: Punjab; 15: Rajasthan; 16: Tamil Nadu and Puducherry; 17: Uttar Pradesh and Uttaranchal; 18: West Bengal and Sikkim; 19: North Eastern region (including Manipur, Meghalaya, Mizoram, Nagaland, Tripura, and other). Note that the capital territory of Delhi has no central tax revenue.

Source: Authors' calculations using data from Reserve Bank of India.

5. LITERATURE REVIEW: ICT INFRASTRUCTURE SPILLOVER EFFECTS

Numerous studies have examined the effects of ICT infrastructure on the economy of various countries. Several studies examining cross-country comparisons between European countries (Madden and Savage 1998) and among OECD countries (Roller and Waverman 2001; Datta and Agarwal 2004) concluded that investment in telecommunication infrastructure is associated with higher economic growth. As for the case of India, Erumban and Das (2016) show the increasing role of investment in the ICT sector in driving aggregate economic growth in India, although the growth is largely limited to the service sector. For the mechanism, Sarangi and Pradhan (2020) show that ICT infrastructure can lead to a decrease in the costs of transactions, enrich market information, accelerate knowledge diffusion, enhance quality of decision-making, and augment productivity, all eventually increasing economic growth.

As for the spillover effects of infrastructure on tax revenues, many have focused on non-ICT infrastructure. Yoshino and Abidhadjaev (2017) estimated the effects of the construction and operation of the Kyushu high-speed rail line on total tax revenue and personal income tax revenue. The findings show that prefectures that are affected by the Kyushu high-speed railway have higher tax revenues (both total and personal income tax) compared to prefectures that are not affected by the high-speed railway. Once the Kyushu high-speed railway was connected to another existing high-speed railway line, thereby increasing access to other prefectures, tax revenues in the region where the rail line was located and in adjacent prefectures as well as prefectures along the connected high-speed railway line increased significantly compared to nonaffected regions. The spillover effects from railways, airports and roads in Central Asia are provided in Yoshino, Huang, Azhgaliyeva, and Abbas (2021).

This paper fills the gap in the literature by estimating the spillover effects of ICT infrastructure on tax revenue. It is important to provide evidence for ICT infrastructure because spillover effects vary by type of infrastructure (Azhgaliyeva and Kalyuzhnova 2021).

6. DATA AND METHODOLOGY

6.1 Theoretical Model of Spillover Effects Created by ICT Infrastructure

Based on the literature review presented in section 5, it is clear that infrastructure, including ICT infrastructure, not only has a direct effect on its users and providers but also an indirect effect on other aspects of the economy, such as GDP growth and tax revenue. Due to lack of data on central tax revenues, in this study we only focus on state tax per capita.

We argue that a plausible way for ICT infrastructure to affect state tax revenues is through increased economic activities in the state, which may result in increased consumption. This will eventually push up tax revenues collected by the state government. As previously mentioned, the largest contributors of state tax revenues are sales tax and VATs. Thus, higher economic activities, such as increased sales of goods and services in a region may lead to increased state tax revenues.

The hypothesis on the effects of ICT infrastructure on increased economic activities is supported by other studies that found similar effects. Fabritz (2013) find an overall positive relationship between local employment and local broadband infrastructure in Germany. The effects are larger in rural municipalities. Falck et. al. (2016) also finds evidence of the positive effect of broadband infrastructure on the number of startup establishments, especially in rural areas, indicating that ICT infrastructure affects job growth. Another study shows that increased broadband infrastructure is associated with a significant increase in annual sales turnover and an increase in value-added (Canzian et al. 2015).

6.2 Data

In order to estimate the effects of ICT infrastructure on tax revenues, we use annual state-level data from 2005 to 2016 from India. India has 28 states and 8 union territories. However, due to data limitation especially on the number of GSM subscribers, we merged some smaller and/or newer states with originating states, resulting in a total number of states of 19 (see Table A1 for details of the states and union territories used in this paper).

The data used in this paper are collected from the following sources. Data on tax revenues were downloaded from the Reserve Bank of India. To take into account the effects of inflation, we use tax data at constant 2004 prices. We also consider population growth to be a factor that may cause the rise in tax revenue, RDP, and GSM subscribers, so this paper consistently uses per capita terms. Data on regional domestic product (RDP) were collected from the Indian Central Statistics Office. Similar to tax data, we also use RDP per capita at constant 2004 prices. while data on the number of GSM subscribers were collected from the Cellular Operators Association of India (COAI)¹. We also control for capital per capita and the number of persons engaged in industry work as these variables may affect RDP and tax revenues. For our main variable of interest, the number of GSM subscribers, the data were obtained from the Cellular Operators Association of India. We divided the number of GSM subscribers per state by the number of population in that state to obtain per capita values. For simplicity, we will refer to this as GSM penetration rate.

Table 1 provides the definitions of each variable used in this study. Table 2 presents the summary statistics of the data. Note that data on the breakdown of central taxes, namely corporation tax, income tax, and service tax, are only available from 2006. Therefore, the number of observations differ between state tax revenues and central tax revenues. It is also important to note that data on the actual tax revenues for 2016 are not published on the Reserve Bank of India's webpage. Therefore, instead of the actual tax revenues, we use the revised estimates for 2016.

¹ Because the SMIS program focused on rural areas, a more appropriate variable would have been the number of GSM subscribers in rural areas instead of the total number of GSM subscribers (in rural and urban areas). However, we were unable to find data on the number of GSM subscribers in rural areas broken down by states prior to 2008.

Table 1: Data Source and Definition of Variables

Variable	Data Source	Definition
State tax revenue (total) per capita	Reserve Bank of India	Revenues collected by the state governments from taxes divided by state population
State tax revenue on Property and Capital Transactions per capita	Reserve Bank of India	Revenues collected by the state governments from tax on property and capital transaction divided by state population. This includes property tax, stamps and registration fees, etc.
State tax revenue on Commodities and Services per capita	Reserve Bank of India	Revenues collected by the state governments from tax on commodities and services divided by state population. This includes sales tax/VAT, taxes on vehicles, taxes on electricity, etc.
GSM subscribers per capita	Cellular Operators Association of India (COAI)	Number of GSM subscribers divided by state population.
RDP per capita	Indian Central of Statistics Office	Regional (state) domestic product at current prices divided by state population
Population	Office of the Registrar General and Census Commissioner, India	2001 and 2011 population census and population projection
Productive capital per capita	Reserve Bank of India	total of fixed capital and working capital divided by state population
Persons engaged in industry	Reserve Bank of India	employees and workers (who are paid and unpaid) who are actively engaged in work in industry divided by state population
Time fixed effects	–	Time fixed effects used to control for year-specific characteristics
State fixed effects	–	Fixed effects used to control for state-specific characteristics

GSM = Global System for Mobile Communications, RDP = regional domestic product.

Table 2: Summary Statistics

Variable (Annual, State-level)	Units	Obs.	Mean	Std. Dev.	Min	Max
GSM subscribers per capita		228	0.454	0.325	0.015	1.997
Real Regional domestic product (RDP) per capita	Thousand Rupees	228	46.989	23.253	11.372	137.393
State tax revenue						
Real Total state tax revenue per capita	Thousand Rupees	228	3.180	1.798	0.512	8.314
Real State tax on property and capital gains per capita	Thousand Rupees	228	0.349	0.251	0.025	1.101
Real State tax on commodities and services per capita	Thousand Rupees	228	2.800	1.599	0.456	7.358
Productive capital per capita	Thousand Rupees	228	20.903	20.465	0.584	101.241
Persons engaged in industry	Thousand people	228	652.272	592.092	28.385	2,455.010

6.3 Estimation Strategy

We would prefer to conduct a difference-in-difference (DID) analysis with the construction of new mobile towers as the region treatment group to estimate the causal effects of a certain policy or program, however it is not feasible with our data set. The DID method has been employed in numerous studies investigating the effects of infrastructure investment (Yoshino and Thi Hoa 2020, Yoshino and Abidhadjaev 2017, Yoshino et al. 2021 and Yoshino and Pontines 2015). However, because the smallest administrative (geographical) unit for tax revenues is “states,” and all states in India

already had mobile towers at the beginning of the period of this study, we are unable to identify “treatment and control groups” for this study (because all states have received treatment). Therefore, we employ another approach to estimate the effects of GSM subscribers on tax revenues. Our estimation method is as follows.

First, we calculate the actual growth in the number of GSM subscribers per capita and tax revenues per capita throughout our period of study. For the purpose of illustration, in Figure 4, we use total state tax revenue per capita. However, for the actual calculation, we will estimate the effects of the number of GSM subscribers per capita on different types of taxes, as broken down in Table 2. In Figure 4, the number of GSM subscribers per capita is shown by the solid blue line while total state tax revenue per capita is shown by the solid red line. Second, we estimate what the number of GSM subscribers per capita (dashed blue line) and total state tax revenues per capita (dashed red line) would have been if the number of GSM subscribers per capita and tax revenues per capita did not increase substantially due to the introduction of the SMIS program. In other words, we estimate the number of GSM subscribers per capita and the amount of state tax revenues per capita collected for 2007–2015 using the slope obtained from the estimation for 2005–2007. Third, we calculate the difference in the number of GSM subscribers per capita from the predicted value (ΔGSM) and the difference in the actual state tax revenues per capita collected by the government from its predicted value (ΔTax). Finally, we estimate whether ΔGSM has a significant effect on ΔTax . As previously mentioned, we also included capital per capita and the number of persons engaged in industry.

Specifically, the model that we estimate is as follows:

$$\begin{aligned} \Delta\text{Tax per capita}_{it} = & \alpha_0 + \alpha_1 \Delta\text{Subscribers per capita}_{it} + \\ & \alpha_2 \Delta\text{Productive Capital per capita}_{it} + \alpha_3 \Delta\text{Persons engaged in industry}_{it} + \\ & v_i + \delta_t + u_{it}, \end{aligned} \quad (1)$$

Where:

*Tax per capita*_{it} = the amount of tax revenue per capita in state *i* at time *t*,

*Subscribers per capita*_{it} = the number of subscribers per capita at state *i* and time *t*,

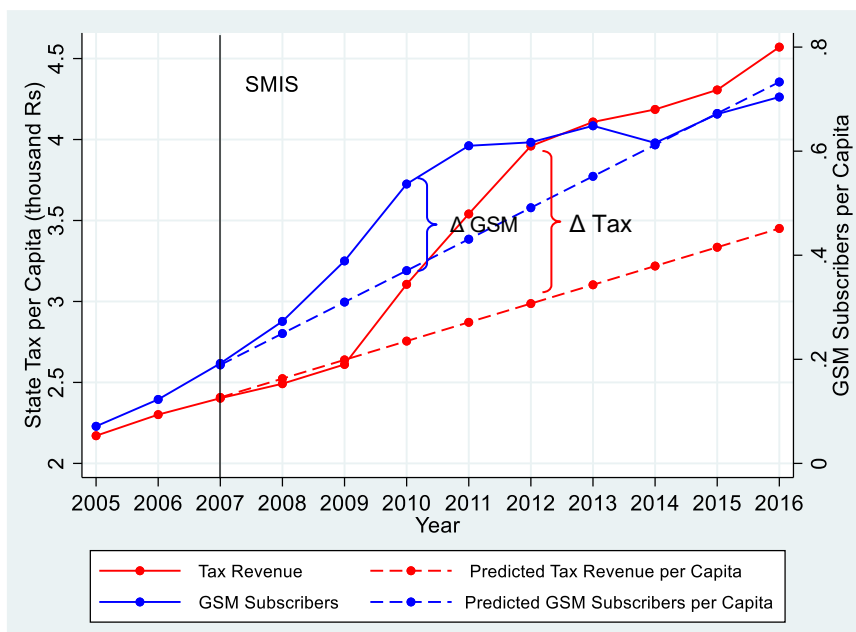
Productive Capital per capita = total of fixed capital and working capital per capita

*Persons engaged in industry*_{it} = employees and workers (who are paid and unpaid) who are actively engaged in industry work in state *i* and time *t*

v_i and *δ_t* = a set of state and time fixed effects.

Therefore, we are essentially estimating the effect of increase in the number of subscribers on the increase in tax revenues while controlling for capital, labor, time fixed effects and state fixed effects. We first analyze Equation 1 through a simple fixed effects estimator.

Figure 4: Actual and Predicted Values of GSM subscribers and Total State Tax Revenue



GSM = Global System for Mobile Communications, SMIS = Shared Mobile Infrastructure Scheme.

Note: The figures above are averages of all states for each year. State tax revenue per capita is in thousand rupees and is shown by the left axis. GSM subscribers per capita are shown by the right axis. The data for this figure are given in Table A2.

However, as discussed in Section 6.1, the process in which the number of mobile network subscribers affect tax revenue may be through increases in economic activity which are reflected in regional GDP (RDP). Therefore, we also analyze a two-stage-least squares model (Equation 2 and Equation 3). Furthermore, because RDP is possibly endogenously determined with tax revenues, instrumenting it is necessary. We use subscribers per capita, productive capital per capita, and the number of persons engaged in industry as the instruments. We test for the exogeneity of RDP through an augmented regression test (Durbin–Wu–Hausman test) as outlined in Wooldridge (2010) and find that we could reject the null hypothesis of exogeneity (Appendix B.1). We also test whether RDP and Subscribers are endogenous and found evidence of exogeneity at the 10% significance level (Appendix B.2)

First stage:

$$\Delta GDP \text{ per capita}_{it} = \beta_0 + \beta_1 \Delta \text{Subscribers per capita}_{it} + \beta_2 \Delta \text{Productive Capital per capita}_{it} + \beta_3 \Delta \text{Persons engaged in industry}_{it} + v_i + \delta_t + u_{it} \tag{2}$$

Second stage:

$$\Delta Tax \text{ per capita}_{it} = \alpha_0 + \alpha_1 \widehat{\Delta GDP \text{ per capita}_{it}} + v_i + \delta_t + u_{it} \tag{3}$$

In selecting whether to use the random effects model or the fixed effects model, we use the Mundlak approach outlined in Wooldridge (2010) and found that the FE 2SLS is preferred for state tax revenue per capita equation. Results of this diagnostic test are presented in Appendix B.3 and Appendix B.4.

To be able to infer that the increase in tax revenues is a result of the implementation of the SMIS program, we have to verify that the rise in the number of GSM subscribers is due to the construction and operation of mobile towers during the years of the SMIS program rollout. Therefore, we regressed the number of GSM subscribers on a set of fixed effects while also controlling for RDP per capita and population, all of which could contribute to the number of GSM subscribers in a state. Based on the results (Appendix B.5), we find that the number of GSM subscribers increased in the years 2008–2012, with the largest increase in 2009, which is when the greatest number of towers were built (Apoorv et al. 2021). This suggests that the SMIS program was a significant factor in the rise of mobile (GSM) users in 2008–2012.

7. RESULTS AND DISCUSSION

In this section we discuss the estimation results of Equations 1 to 3. The discussion is divided into two parts based on the type of taxes: state tax revenues and central tax revenues. We estimate the effects of the number of GSM subscribers on different types of taxes to see whether the effects are similar or different across sectors.

7.1 Fixed Effects Estimation Results

Table 3 shows the results of our simple fixed effects estimation. The results show that the number of GSM subscribers per capita has a positive and significant effect on tax revenues per capita: on total state tax revenues per capita, state property tax revenue per capita and state commodity tax revenue per capita.

Table 3: Fixed Effects Estimation Results, State Tax Revenue per Capita

	State Tax per Capita	State Property Tax per Capita	State Commodity Tax per Capita
GSM Subscribers per capita	1.340*** (0.280)	0.391*** (0.0527)	0.949*** (0.261)
Productive capital per capita	0.013** (0.006)	0.001 (0.001)	0.0124* (0.006)
Number of persons engaged in industry	0.001 (0.001)	0.0003** (0.0001)	0.0006 (0.001)
Constant	-0.012 (0.071)	-0.003 (0.016)	-0.033 (0.072)
Observations	190	190	190
R-squared (within)	0.358	0.68	0.365

GSM = Global System for Mobile Communications.

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are in parentheses and are clustered at the state level. State fixed effects and time fixed effects are included in the estimation.

The estimates show that an increase in the number of GSM subscribers per capita by 10 percentage point is expected to raise total state tax revenue per capita by ₹134 (approximately USD 2 at the time of writing this article or 3% of the average state tax per capita in 2016). When divided by the type of taxes, that amount comprises of a raise of ₹39 in state commodity tax per capita, ₹95 in state property tax per capita.

The mechanism on how the number of GSM subscribers may affect tax revenues is further explained by the 2SLS regression estimation results in section 7.2.

7.2 2SLS Estimation Results

The estimation results are given in Table 4 (first stage) and Table 5 (second stage). In the first stage, we find that a state's RDP per capita is significantly affected by the number of GSM subscribers per capita in that state. The estimate can be interpreted as follows. An increase in GSM subscribers penetration rate by one percentage point is expected to increase RDP per capita by ₹306.18 or 0.5% of the average RDP per capita in 2016. The positive effect of the number of GSM subscribers on RDP is in line with the findings of other studies, such as International Telecommunication Union (ITU) (2019) which found that in the Asia and the Pacific region, an increase in the penetration rate of mobile broadband subscribers of 10% is expected to raise GDP per capita by 0.51%.

Table 4: Estimation Results, State Tax Revenue – First Stage

	RDP per Capita
GSM subscribers per capita	30.618*** (4.993)
Productive capital per capita	0.127 (0.089)
Number of persons engaged in industry	0.004 (0.007)
Constant	-0.095 (0.761)
Observations	190

GSM = Global System for Mobile Communications, RDP = regional domestic product.

Note: ***: p-value<0.01, **: p-value<0.05, *: p-value<0.1. Standard errors are in parentheses and are clustered at the state level. State fixed effects and time fixed effects are included in the estimation.

Results from the second stage, which is our main estimation result of interest, show that the increase in RDP that is attributed to the effects of the rise in the number of GSM subscribers, is positively associated with the change in state tax revenues. This result is significant at the 1% level of statistical significance (strongly significant) (Table 5). The coefficient of 0.0502 means that, on average, an increase in the number of RDP per capita by ₹10 thousand is expected to raise total state tax per capita by ₹502 or 12.5% of the average state tax per capita in 2016. When broken down by the type of taxes, this increase in total state tax revenue is comprised of a ₹132 increase in state commodity tax per capita, an ₹370 increase in state property tax per capita, and the remaining as an increase in state income tax per capita.

Table 5: Estimation Results, State Tax Revenue – Second Stage

	State Tax (Total) per Capita	State Property Tax per Capita	State Commodity Tax per Capita
RDP per capita	0.0502*** (0.0138)	0.0132*** (0.00230)	0.0370*** (0.0132)
Constant	-0.0133 (0.0743)	-0.00351 (0.0235)	-0.0332 (0.0672)
Observations	190	190	190

RDP = regional domestic product.

Note: ***: p-value<0.01, **: p-value<0.05, *: p-value<0.1. Standard errors are in parentheses and are clustered at the state level. State fixed effects and time fixed effects are included in the estimation.

The results of the first and second stages of the 2SLS estimation combined indicate the presence of spillover effects from the number of subscribers on the amount of state tax revenues collected through increases in RDP. This indicates that RDP, which is positively affected by increased access to mobile services brought by the SMIS program, has a positive effect on the determinants of state tax collection: consumption/sales of goods; land and buildings; and employment, among others.

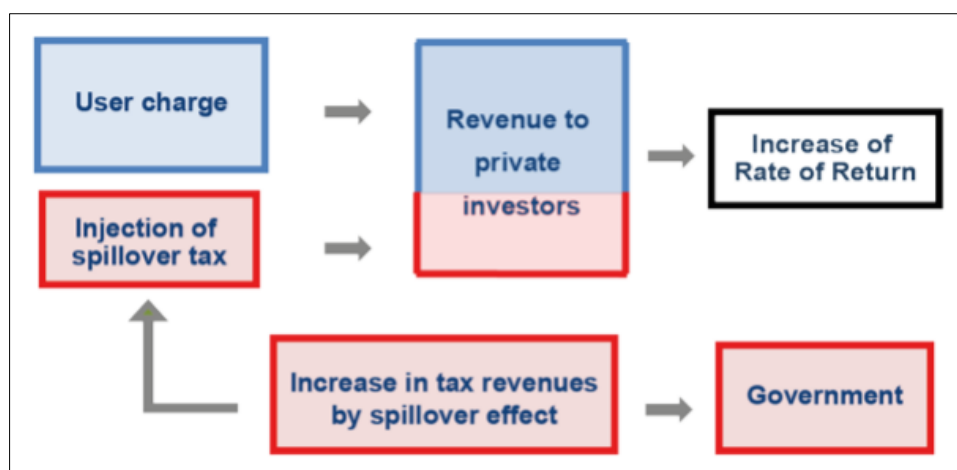
8. PROPOSAL

Going back to our main argument, which is to propose a method of financing ICT infrastructure, our results suggest that state governments have an increased revenue due to the development of such infrastructure. More specifically, an increase in the number of mobile (GSM) penetration rate by 10 percentage points is expected to raise state tax revenue per capita by ₹134. The mechanism in how the number of GSM subscribers affect tax revenues is through increases in economic activities, as reflected in its positive and significant effect on RDP (as shown by our 2SLS estimation results).

One way to ensure that the private sector remains attracted to infrastructure development is to provide a steady stream of income for them. We argue that that could be achieved by sharing the spillover effects of ICT infrastructure on taxes obtained by the government with the investors/operators of the infrastructure. Figure 5 illustrates this scheme.

The red “increase in tax revenues by spillover effect” box shows the increased tax revenues resulting from the spillover effects of infrastructure that was previously only absorbed by the government. However, if the government shares the increased tax revenues with the investors, the revenues of the investors will increase from only user charges (blue box) to user charges and injection of spillover tax (as shown by the “revenue to private investors” box in blue and red), thus increasing the rate of return to investors.

Figure 1: Spillover Tax Revenues Increase the Rate of Return of Investors



Note: State tax per capita: ₹134 (3% average state tax per capita in 2016) (assuming 10 pts additional GSM penetration rate).

Source: Yoshino et. al. (2019).

9. CONCLUSION AND POLICY RECOMMENDATIONS

In this paper, we argue that the ongoing COVID-19 pandemic highlights the importance of ICT infrastructure, not only for the economy, but also for human welfare, such as through better health and education services. However, the development of ICT infrastructure has been facing hurdles, mostly due to the widening investment gap for its construction. Moreover, rural and less developed areas have also been disproportionately affected, as ICT infrastructure has mostly been developed by the private sector. This leads the development of ICT infrastructure to be mostly concentrated in urban areas where it is more profitable for the investors compared to rural areas.

An important way to fill in the investment gap is to ensure the private sector remains attracted to infrastructure projects by guaranteeing that these projects will be profitable. This paper proposes sharing the tax revenues collected by the government as a result of the infrastructure development in the area with the private sector.

We quantify the spillover effects of mobile network to tax revenues, using annual state-level data for 2005 to 2016 from India across all states. We show that for the case of India, a large-scale mobile tower construction program has increased the number of mobile network subscribers. Using a simple FE estimation and an FE 2SLS estimation, we show that the rise in the number of mobile network subscribers is associated with the increase in the amount of regional tax revenues collected by state governments. On average, an increase in the number of GSM subscribers by 10 percentage point is expected to raise regional state revenues by ₹134 or roughly 3% of the average state tax per capita in 2016. The results indicate that the development of mobile towers, as reflected in the rise in the number of GSM subscribers, increases tax revenues. The results support our proposal to create a steady stream of income for investors by sharing the spillover tax revenues with the investors, thus making infrastructure projects more attractive for investments. Moreover, the findings of this paper also support the national budget of India for 2022–2023, which places emphasis on the investment of both digital and physical infrastructure.

Although the findings of this study are important, there are certain limitations to it. First, the amount of data collected is relatively small. Despite doing this to maintain consistency in the measurement and determinants of tax (we wish to avoid years where tax policies had undergone changes), the results would have been more robust if we could have collected more data, perhaps by not merging some states due to limited data, as we have done in this paper.

Second, as previously mentioned, a more suitable variable to be used in our estimation would have been the number of GSM subscribers in rural areas. This is because the SMIS program specifically built mobile towers in rural areas where there was no prior mobile connection. However, we were unable to obtain data on the number of GSM subscribers in rural areas. Similarly, a more viable approach to test the spillover effects of the SMIS program would have been to compare areas where the towers were built with those where there were no new towers built. This is especially important because the building of the towers occurred at different times depending on each location. Unfortunately, again, the lack of data available made it difficult for us to conduct such estimations.

Third, in this paper, we argue that the mechanism of how the number of GSM subscribers affect tax revenue is through increased economic activity. Although we believe that this is true, “economic activities” as presented in this study by RDP, is somewhat vague. More interesting results could have been obtained if we use more concrete variables to represent “economic activities,” such as number of business establishments, but the data were unavailable.

Finally, it is also important to note that what we are showing here is the short-term spillover effects of ICT infrastructure. We also expect there to be long-term spillover effects, such as on human capital (brought about by increased access to education and information). However, this is the subject for future research.

APPENDIX A: DATA

Table A.1: State IDs and State Names

State ID	States and Territories
1	Andhra Pradesh and Telangana
2	Assam
3	Bihar and Jharkhand
4	Delhi
5	Gujarat
6	Haryana
7	Himachal Pradesh
8	Northern India (union territory)
te9	Karnataka
10	Kerala
11	Madhya Pradesh and Chhattisgarh
12	Maharashtra, Goa, Dadra and Nagar Haveli, and Daman and Diu
13	Odisha
14	Punjab and Chandigarh
15	Rajasthan
16	Tamil Nadu and Puducherry
17	Uttar Pradesh and Uttaranchal
18	West Bengal, Sikkim, and Adaman and Nicobar Islands
19	Northeastern Regions

Table A.2: Difference between Actual and Predicted Tax and GSM Subscribers

Year	State Tax per Capita (1)	GSM Subscribers per Capita (2)	Predicted State Tax per Capita (3)	Predicted GSM Subscribers per Capita (4)	Difference between Actual and Predicted State Tax per Capita (5) = (1) – (3)	Difference between Actual and Predicted GSM Subscribers per Capita (6) = (2) – (4)
2005	2.23818	0.071326	N/A	N/A	N/A	N/A
2006	2.449727	0.122942	N/A	N/A	N/A	N/A
2007	2.573503	0.192148	2.588131	0.189216	-0.01463	0.002932
2008	2.601531	0.272945	2.755793	0.249627	-0.15426	0.023317
2009	2.698529	0.389086	2.923454	0.310039	-0.22493	0.079048
2010	3.129462	0.536891	3.091116	0.37045	0.038346	0.166441
2011	3.451006	0.610411	3.258777	0.430861	0.192229	0.17955
2012	3.764293	0.616969	3.426439	0.491272	0.337854	0.125697
2013	3.763919	0.648749	3.5941	0.551683	0.169819	0.097066
2014	3.718641	0.615819	3.761761	0.612094	-0.04312	0.003725
2015	3.783324	0.67121	3.929423	0.672505	-0.1461	-0.0013
2016	3.993652	0.704047	4.097084	0.732916	-0.10343	-0.02887

GSM = Global System for Mobile Communications.

Note: Predicted Tax per capita is the predicted amount of tax revenues per capita that would have been collected without the SMIS program. Predicted GSM Subscribers per capita is the predicted amount of people that would have been GSM subscribers per capita without the SMIS program.

Source: Authors' calculations.

Table A.3: Correlation Matrix of Independent Variables

	GSM Subscribers per Capita	Productive Capital per Capita	No. of Persons Engaged in Industry
GSM subscribers per capita	1		
Productive capital per capita	0.561	1	
No. of persons engaged in industry	-0.0006	0.3237	1

GSM = Global System for Mobile Communications.

APPENDIX B: DIAGNOSTIC TEST RESULTS

Appendix B.1: Endogeneity Test of RDP per Capita

State Tax per Capita	
1. RDP on GSM subscribers	
GSM subscribers	76.11225 (0.000)
Tax per capita on RDP and residuals from (1)	
RDP per capita	0.0513 (0.000)
Residuals	0.0074 (0.0949)
Endogenous	

GSM = Global System for Mobile Communications, RDP = regional domestic product.

Note: p-values are in parentheses.

Appendix B.2: Endogeneity Test of GSM Subscribers per Capita

State Tax per Capita	
1. GSM subscribers per capita on population	
Population	-6.05e-06 (0.015)
State tax per capita on GSM Subscribers and residuals from (1)	
GSM Subscribers	4.063995 (0.064)
Residuals	-3.038515 (0.206)
Exogenous	

GSM = Global System for Mobile Communications, RDP = regional domestic product.

Note: p-values are in parentheses.

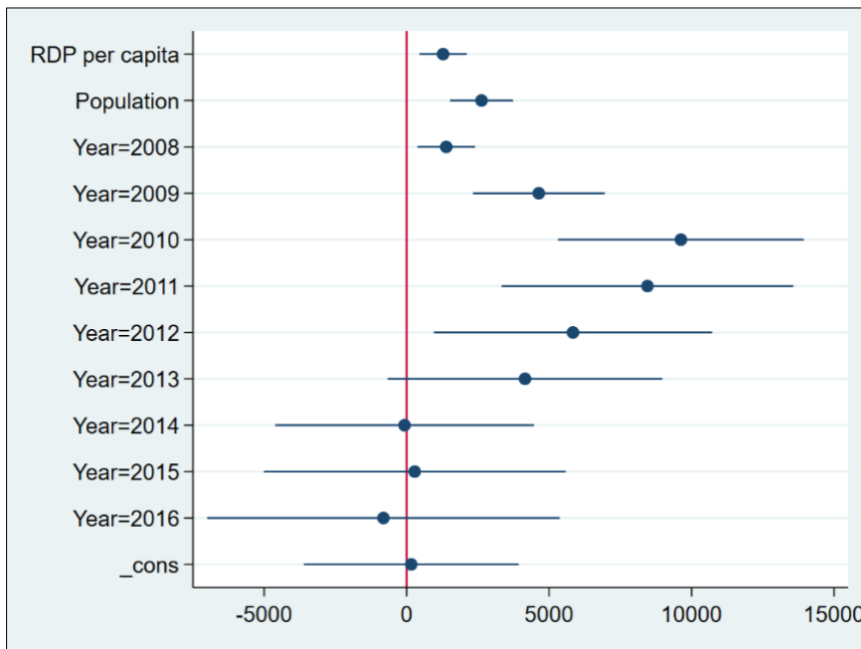
Appendix B.3: Fixed Effect vs Random Effect (Equation 1)

State Tax	
Chi-squared	68.82
p-value	0.0000
Preferred model	Fixed Effect

Appendix B.4: Fixed Effect vs Random Effect (2SLS)

State Tax	
Chi-squared	13.58
p-value	0.0088
Preferred model	Fixed Effects

Appendix B.5: Coefficient Plot on the Regression of the Number of GSM Subscribers on RDP per Capita and Population

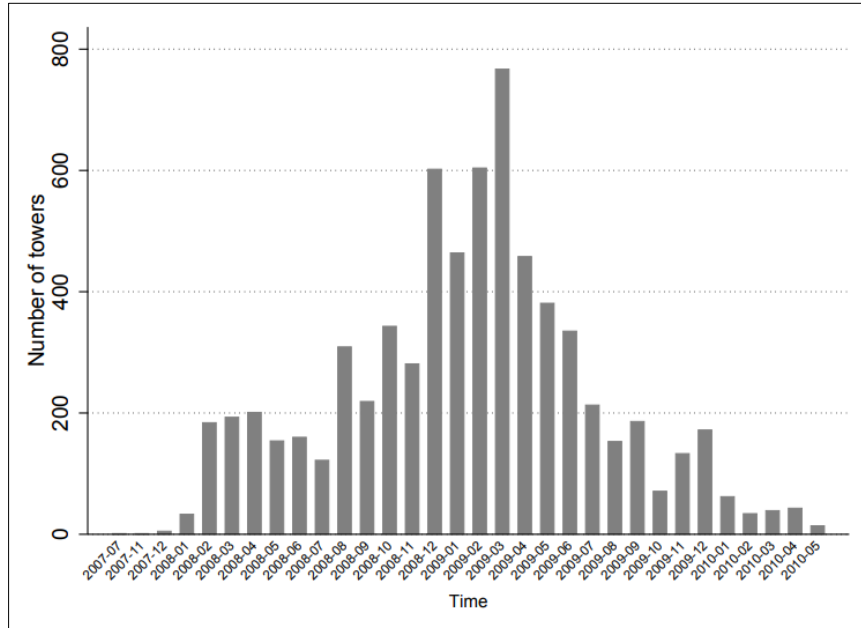


Note: This figure plots the coefficients shown in Table 3 along with their time dummies. The lines represent a 90% confidence interval.

Source: Authors' calculation.

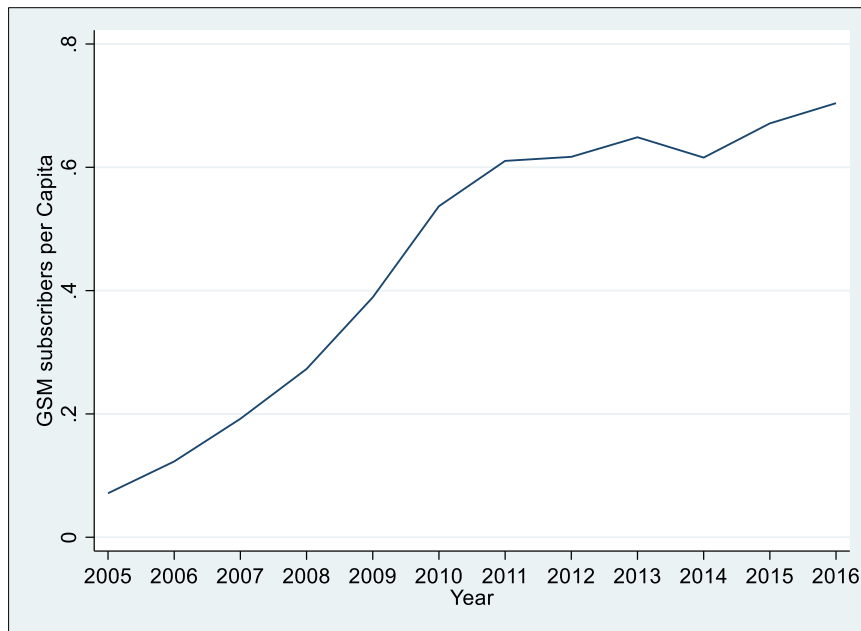
APPENDIX C: GSM SUBSCRIBERS

Figure C1: Shared Mobile Infrastructure Scheme (SMIS) in India

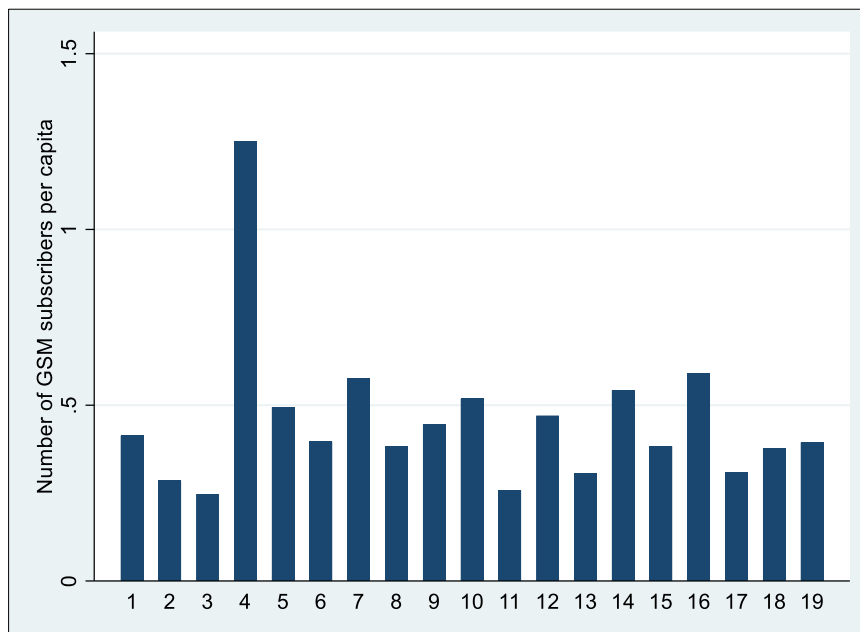


Source: Gupta et al. (2021).

Figure C2: Number of GSM Subscribers by Year (average of all states)



Source: Authors' own based on data from COAI.

Figure C3: GSM Subscribers by State (average 2005–2016)

Note: 1: Andhra Pradesh and Telangana; 2: Assam; 3: Bihar and Jharkhand; 4: National Capital Territory of Delhi; 5: Gujarat; 6: Haryana; 7: Himachal Pradesh; 8: Northern India; 9: Karnataka; 10: Kerala; 11: Madhya Pradesh and Chhattisgarh; 12: Maharashtra, Goa, Dadra and Nagar Haveli, and Daman and Diu; 13: Odisha;^a 14: Punjab; 15: Rajasthan; 16: Tamil Nadu and Puducherry; 17: Uttar Pradesh and Uttaranchal; 18: West Bengal and Sikkim; 19: North East. Note that the capital territory of Delhi has no central tax revenue.

Source: Authors' calculations using data from COAI.

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