Assessing the economic impact of mobile telecommunications in Egypt: a structural model approach

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Abstract

Purpose – *The purpose of this study is to use the structural model to determine the influence of mobile telecommunication on Egypt's economic growth from 2000 to 2009. By focusing on mobile unique subscribers and mobile broadband-capable device penetration as indicators of telecommunications adoption, the authors seek to understand their overarching effects on the nation's economic landscape.*

Design/methodology/approach – *The paper uses quarterly time-series data set over the period 2000–2019 and uses a structural econometric model based on an aggregate production function, a demand function, a supply function and an infrastructure function to detect causality and examine long-run relationships between variables.*

Findings – *The findings of the structural model reveal that both mobile unique subscribers and mobile broadband-capable device penetration significantly contributed to Egypt's gross domestic product (GDP) growth from 2000 to 2019. Specifically, a 1% increase in mobile unique subscriber penetration and mobile broadband-capable device adoption is estimated to result in an average annual contribution to GDP growth of 0.172% and 0.016%, respectively.*

Research limitations/implications – *The scarcity of panel data is the main research limitation for comparative study with other Middle East and North African Region (MENA) countries. Research extensions would include testing the significance of complementarities such as improving governance measures and building human capacity for both households and firms, which are necessary to boost the impact of telecommunication on economic growth in the MENA region.*

Practical implications – *Based on these findings, the study puts forth policy recommendations aimed at maximizing investment in network utilization, including mobile and internet services, as well as fixed broadband subscriptions. It highlights the crucial role of these investments in promoting social and economic development, not only in Egypt but also across the MENA region as a whole.*

Social implications – *The findings of this research emphasize the importance of strategic investments in network utilization, encompassing mobile, internet services and fixed broadband subscriptions. Such investments are pivotal for fostering social and financial inclusion. The study underscores the potential of these investments to drive social and economic progress, not just within Egypt but throughout the entire MENA region.*

Originality/value – *Overall, existing literature generally supports the notion that the telecommunications sector has a positive economic impact. However, there is a gap in the literature when it comes to understanding the specific effects of the Egyptian telecommunications sector on the country's economy, particularly in relation to the Egypt Vision 2030. The study aims to fill this gap by focusing specifically on Egypt and providing additional insights into the direct and indirect effects of the Egyptian telecommunications sector on the economy. By conducting a thorough analysis of the sector's role, the authors aim to contribute to the existing literature by providing context-specific findings and recommendations.*

Keywords *Telecommunications, ICTs, Economic growth, Egypt, Structural model*

Paper type *Research paper*

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1. Introduction

Egypt has witnessed fluctuating gross domestic product (GDP) growth rates since 1996, influenced by several factors. The 2011 Egyptian Uprising has profoundly impacted Egypt's

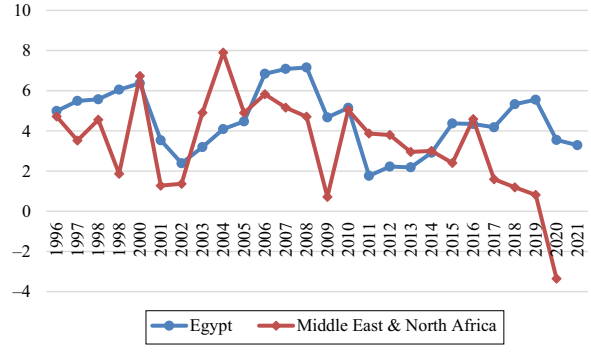
economic landscape. This significant event resulted in multiple leadership changes and was marked by a considerable decline in GDP growth, as depicted in Figure 1. The political volatility of that era probably played a role in the economic uncertainties. Building on this historical context, it is crucial to highlight that more recent events have further impacted Egypt's economy. The country has undergone a deceleration in its economic growth, with the rate dropping to 4% in the fiscal year (FY) 2022/2023. This is a stark difference from the 6.6% growth rate observed in the preceding fiscal year, FY 2021/2022 (World Bank, 2023a, 2023b). This decline can be traced back to a myriad of reasons, one of which is the Russia–Ukraine conflict's effect on global food prices, impacting Egypt due to its significant dependence on food imports. Inflation began its upward trajectory in early 2022, primarily influenced by rising food costs and a depreciating currency (IMF, 2023). In response, the government has rolled out fiscal support measures to bolster consumption. Future prospects appear promising, with a forecasted economic growth rate of 5.7% for 2024 (OECD, 2023).

Despite these challenges, the overall trend demonstrates that Egypt's economic growth has generally outperformed that of the Middle East and North African Region (MENA) region, with a few exceptions in the early 2000s and early 2010s, as depicted in Figure 1. Egypt's economy showcases its robustness and recovery capabilities from setbacks, largely driven by foundational macroeconomic reforms and bolstered by two IMF programs (EBRD, 2022).

In recent times, Egypt has witnessed significant economic challenges despite its historically robust GDP growth. The Delta variant's emergence and the persistent effects of the COVID-19 pandemic have been major contributors to these challenges. The pandemic-induced cost-push factors have set off an inflationary trend, jeopardizing Egypt's economic future. This trend was evident, with inflation rates reaching 5.28% in 2022 and then sharply rising to 13.89% in 2023 (World Bank, 2023a, 2023b). Such inflationary pressures have diminished the purchasing capabilities of households and hindered business operations. Factors such as the devaluation of currencies, inflation on imported goods and surges in fuel prices have compounded the economic strain on consumers and businesses alike.

On a global scale, the inflation rates have been on the rise, a trend that Egypt has not been immune to. A pivotal factor in this global inflationary trend was Russia's invasion of Ukraine on February 24, 2022 (Tanchum, 2022). This geopolitical upheaval, along with a marked reduction in tourism revenues for Egypt, rising global oil prices and the exit of foreign capital in anticipation of U.S. interest rate hikes, has placed even more strain on Egypt's economy (U.S. Department of State (DOS), 2023). Adding to this, the World Bank (2023a,

Figure 1 Egypt and MENA region GDP Growth (%)



Source: Authors based on WDI (2023)

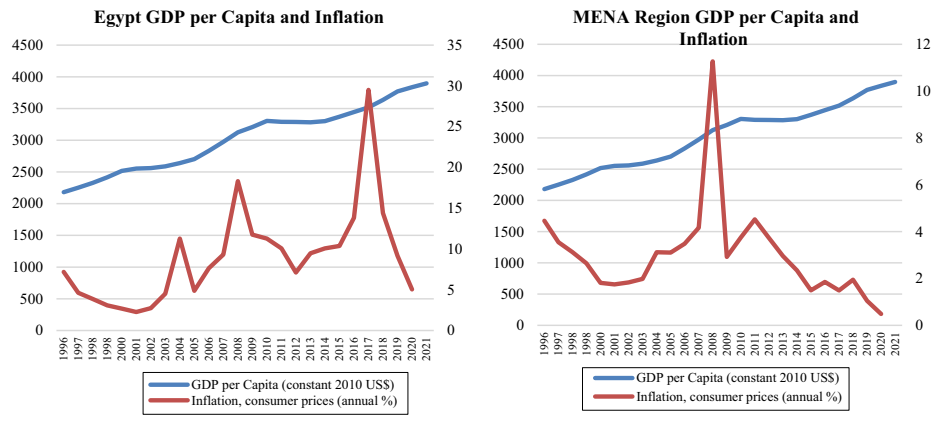
2023b) projections indicate that Egypt's inflation could climb to 15% in 2024, a rate that significantly overshadows the average inflation figures in the MENA region, as shown in Figure 2.

Regarding its fiscal balance, Egypt's recent efforts towards fiscal consolidation are expected to face temporary disruptions. The budget deficit has widened to EG£470bn, which accounts for approximately 6.2% of the GDP as of June 2023 (Trading Economics, 2023). Egypt's budget deficit has expanded due to the economic repercussions of the COVID-19 pandemic, which led to decreased business and tourism revenues and increased healthcare and stimulus costs (Gad, 2021). This situation was further exacerbated by the rising interest on loans over the past eight years, the U.S. Federal Reserve's rate hikes in 2022, diminished investor interest in emerging markets, and the devaluation of the Egyptian pound in February 2022 (Werr, 2023).

In the face of macroeconomic challenges, Egypt's information and communications technology (ICT) sector stands out for its resilience and growth potential. This sector, which encompasses a range of technologies including telecommunications, has shown remarkable strength. In the FY 2021/2022, the ICT sector experienced a growth rate of 16.7%, surpassing the country's overall GDP growth rate and exceeding the 16.1% growth rate from the previous FY (Moneim, 2023). Furthermore, investments in the ICT sector reached nearly $3bn in 2020/2021, reflecting significant investor confidence (ITA, 2022).

In the broader ICT landscape, the telecommunications segment holds particular significance and has historically played a pivotal role in Egypt's success. To leverage the economic impact of telecommunications and unlock its prospective benefits, the government has introduced Egypt Vision 2030, a comprehensive plan aimed at instilling sustainable development practices across all sectors of the country. Egypt Vision 2030 envisions transforming Egypt into a knowledge-based, competitive economy, with a strong focus on ICT as a driving force for growth and innovation (Ministry of Planning and Economic Development (MPED), 2021). As part of this vision, the Egyptian government also launched 'Digital Egypt,' a comprehensive effort to modernize ICT infrastructure, enhance digital literacy and drive innovation. Finally, to further advance this digital transformation, Egypt has introduced ICT 2030, a plan that focuses on investing in and developing ICT throughout the nation (Ministry of Communications and Information Technology (MCIT),

Figure 2 Egypt and MENA region GDP per capita and inflation



Source: Authors based on WDI (2023)

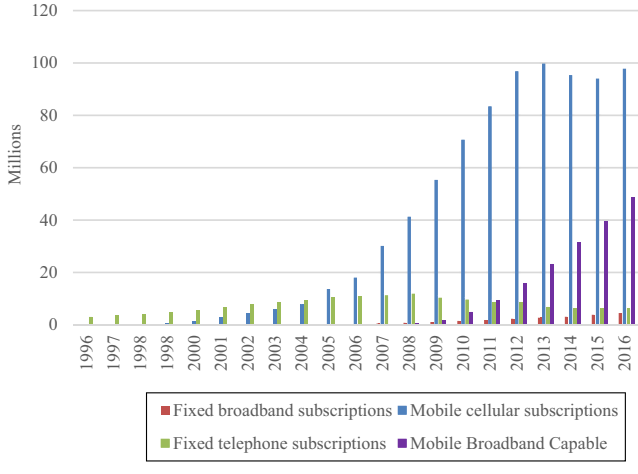
2021a, 2021b). In this context, understanding the relationship between ICT and the country's economy becomes paramount as Egypt moves forward with these initiatives.

Indeed, over the past 25 years, Egypt's telecommunication sector has witnessed significant growth and transformation, as depicted in Figure 3. Starting from 1996, where mobile cellular subscriptions were just over 3 million with no fixed broadband, the country has come a long way. By 2021, mobile cellular subscriptions surged to an impressive 103.4 million, indicating a widespread adoption of mobile technology. Fixed broadband subscriptions, which were introduced in the early 2000s, have also seen a steady rise of penetration, reaching 10.8 million in 2021. Interestingly, while fixed telephone subscriptions peaked around 2008 with over 11.8 million users, there has been a gradual decline in the subsequent years, possibly due to the shift towards mobile communication (Ministry of Communications and Information Technology (MCIT), 2021a, 2021b). Another notable trend is the rapid growth of mobile broadband-capable devices, which started being tracked in 2007 with just over 154,000 devices. This number skyrocketed to nearly 86 million by 2021, highlighting the increasing demand for high-speed internet access on the go.

By the fourth quarter of 2007, the number of mobile unique subscribers stood at approximately 22.2 million, which surged to 67.4 million by the fourth quarter of 2021, marking a threefold increase. Similarly, the adoption of mobile broadband-capable devices has seen a meteoric rise. From a modest 154,856 devices in the fourth quarter of 2007, the figure skyrocketed to nearly 86 million by the fourth quarter of 2021[Global System for Mobile Communications Association Intelligence (GSMA) (2023)]. Egypt's digital evolution, evident through the growth in mobile subscribers and broadband devices, underscores increased usage and affordability (Figure 4). These trends lead to our research questions: How does the penetration of unique mobile subscribers influence GDP growth? What is the impact of mobile broadband-capable devices on Egypt's GDP growth? What are the broader implications of these patterns for the telecommunications industry in Egypt?

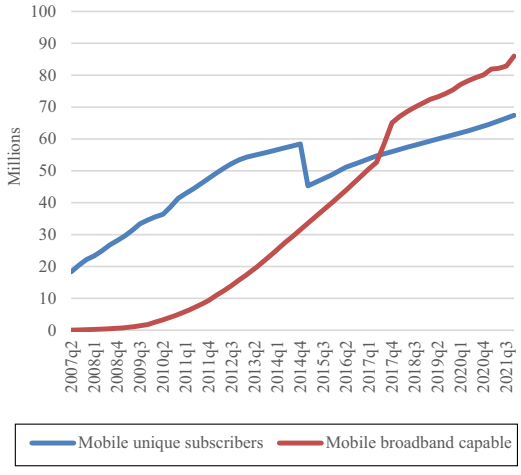
When comparing these figures to the wider MENA region, the rate of internet usage in Egypt shows a relatively moderate growth trajectory. As shown in Figure 5, the percentage of the population using the internet in Egypt reached approximately 72% in 2021. While this

Figure 3 Mobile telephony, fixed broadband, mobile broadband capable devices and fixed telephone subscribers in Egypt



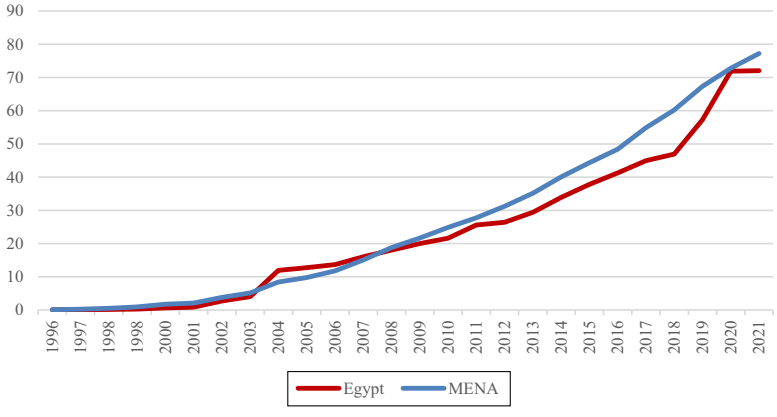
Note: All variables are per 100 people
Source: Authors based on WDI (2023) and GSMA (2023)

Figure 4 Mobile unique subscribers and mobile broadband-capable devices in Egypt



Source: Authors based on GSMA (2023)

Figure 5 Individuals using the internet in Egypt (% of population)



Source: Authors based on WDI (2023)

indicates a steady increase, the pace of growth is not as rapid as in some other countries within the region. These statistics highlight the significance of the mobile sector in Egypt's telecommunications landscape, with mobile services and mobile broadband being the primary modes of telecommunication for most of the population.

Moreover, considering the broader context of digital transformation, Egypt's commitment to embracing this wave of change is evident. The ICT sector has played a crucial role, contributing to 5% of the GDP in the FY 2021/2022 (Ministry of Communications and Information Technology (MCIT), 2023). Egypt's Ministry of Communications and Information Technology (MCIT) is actively pursuing the ambitious "Digital Egypt" strategy, which aims to establish a digital society. The telecommunications industry is a focal point in achieving this strategy's objective, with the MCIT aiming to enhance infrastructure quality, expand service provision to rural villages and invest in the fiber network.

The country's telecommunications landscape has also evolved significantly, with Telecom Egypt being the sole provider until the 1990s. The Global System for Mobile (GSM) communications era marked the liberalization of the sector, with the entry of players like Orange Egypt and Vodafone Egypt. The market's competitiveness further intensified with the entry of Etisalat Misr in 2007 and Telecom Egypt's We in 2017. The latter's operation was initially based on Orange and Etisalat's networks, but plans were put in place to establish its own network. Recent reports indicate a mobile penetration rate of 89.69%, a decline from the previous year, and an internet penetration rate below 60%. Efforts are underway to improve internet quality, especially through fiber infrastructure, and to promote its adoption among the populace (El Hajj, 2022). In terms of market share, Vodafone Egypt leads with 43%, followed by Orange with 26%, Etisalat Misr with 22% and We telecom with 9%.

In spite of its strength, the country's current technology landscape has deficiencies, and the government's efforts are vital. The Egyptian telecommunications market currently supports 2G, 3G and 4G technologies, with no commercial 5G network available as of yet. However, preparations for the eventual launch of 5G networks are in progress, with the National Telecommunications Regulatory Authority (NTRA) allocating frequency bands to the four operators for a sum of $1.61bn. The future promises the gradual deployment of 5G networks, introducing new applications, investments and partnerships. With the low internet penetration rate, it is crucial to develop use cases ensuring broad adoption. Initiatives like smart agriculture using the internet of things (IoT) are being considered, especially since agriculture contributes 11.3% to Egypt's GDP. The NTRA has already set the regulatory framework for IoT provision, targeting areas like smart cities, transportation systems and Industry 4.0. Investments in data centers are also gaining momentum, positioning Egypt as a potential data hub between Africa and the Middle East. Moreover, the Egypt telecommunications market is projected to register a constant annual growth rate (CAGR) of 3.65% during the forecast period (2023–2028), with significant players such as Telecom Egypt, Vodafone, Orange, Etisalat Egypt and Ericsson shaping the industry's trajectory (Mordor Intelligence, 2023).

Recognizing the pivotal role of the telecommunications sector in Egypt's economic tapestry, this study seeks to unravel the complex interplay between mobile communication, data connectivity usage and adoption and their collective influence on Egypt's GDP growth. Our research is steered by the following inquiries: Firstly, how does the penetration of unique mobile subscribers influence GDP growth in Egypt, and what discernible patterns of mobile service utilization emerge from this relationship? Secondly, how has the penetration of broadband-capable devices for accessing the internet via mobile networks impacted Egypt's GDP growth, and what does this reveal about the presence and usage of these devices? Thirdly, in what ways do these patterns of mobile communication and data connectivity usage and adoption contribute to the broader realm of ICT in Egypt, and what ramifications do they present for the telecommunications sector?

By systematically addressing these inquiries, our objective is to furnish a holistic understanding of the telecommunications sector's role in sculpting Egypt's economic narrative. With a particular focus on mobile service utilization and the ubiquity of broadband-capable devices, we aim to provide not only insights but also policy recommendations that can guide future strategies in the sector. The subsequent sections of this paper are structured as follows: Section 2 offers a succinct review of relevant literature, Section 3 details the data set used, Section 4 elaborates on our methodology and model specification, Section 5 unveils our research findings and Section 6 concludes with key insights and policy recommendations.

2. Literature review

Existing literature supports the idea that ICT plays a pivotal role in facilitating economic growth, especially in developing countries. A study by Madden and Savage (2000) reveals

a significant positive relationship between telecommunications and economic growth across various countries. Similarly, Markova (2009) finds that investing in telecommunications infrastructure, such as cell towers and fiber-optic cables, stimulates economic growth more effectively than solely investing in telecommunications services or technologies, like new mobile apps or advanced call routing systems. Higher returns are observed from these foundational infrastructure investments compared to just telecommunications sector investments. Chakraborty and Nandi (2011) take this exploration further and discover that the correlation between telecommunications infrastructure investment and per capita growth depends on a country's level of development. Less-developed countries demonstrate a stronger correlation between per capita growth and fixed line tele-density, which even holds true for emerging countries. Conversely, relatively more developed countries exhibit a weaker correlation between these factors.

Studies on the impact of telecommunications on other economic indicators also show a positive effect. These include the influence of telecommunications on entrepreneurship (Alderete, 2019), the contribution of mobile broadband to a country's GDP (Eisenach and Kulick, 2020), the impact of mobile broadband on state GDP (Edquist *et al.*, 2018), the effect of broadband speed on enterprise productivity (Mack and Faggian, 2013), labor productivity (Edquist, 2022), the relationship between broadband speed and job creation (Katz *et al.*, 2010) and the impact of different measures of digitization on remittances inflow (Emara and Zhang, 2021), among others.

Another common finding among these studies is the recognition that telecommunications not only directly contribute to job creation and improved services but also generate significant externalities that drive economic change and growth (Kim *et al.*, 2021; Wang *et al.*, 2023). These positive externalities resulting from the expansion or optimization of telecommunications infrastructure play a crucial role in understanding the broader economic impact of a well-developed telecommunications sector. They include, for example, increases in employment, business productivity and overall development. Eisenach and Kulick (2020), for instance, explored the impact of the transition to 4G technology on the US economy and found that its deployment led to a substantial increase in both employment and output. Similarly, Björkegren and Karaca's (2022) study on a Rwandan mobile phone subsidy program highlights substantial network externalities. Subsidized handsets primarily stayed in rural areas and were used at a similar rate to the purchased ones, leading to considerable interconnectedness among recipients. Importantly, up to 69% of the impact on operator revenue originated from spillover effects on nonrecipients, underscoring the program's extensive positive influence and providing valuable optimization insights.

Furthermore, other studies have focused on countries with less developed telecommunications sectors, shedding light on the potential impact and making recommendations for improvement. For instance, Katz and Koutroumpis (2012a, 2012b, 2012c) examined the economic impact of telecommunications in Senegal and found that mobile phones had a measurable effect on economic growth. However, they did not observe a similar impact from fixed broadband technology, likely due to its early stages of adoption during the study. The researchers proposed recommendations such as enhancing connection speeds through advanced cellular technology or fixed broadband networks. Katz further expanded on these findings in subsequent research. In a study by Katz and Jung (2020a), the authors explored the economic impact of the telecommunications sector in Guinea. Their findings revealed significant direct and indirect improvements in economic growth attributable to the telecommunications sector.

In a study focused on Jordan, Katz and Callorda (2015a) investigated the economic impact of telecommunications, revealing a causal link between fixed broadband, wireless broadband, broadband penetration and GDP growth. However, they also observed diminishing returns, indicating that the economic impact becomes less significant as

broadband penetration increases. Other studies have also shown that the strength of the economic impact varies depending on the technology used. Fixed broadband, in particular, has been found to have the highest degree of influence, as emphasized by Ghosh (2017) and Jung and Katz (2022) in relation to enhanced broadband penetration. Similar results were later found in Morocco (Katz and Callorda, 2015b) and Tunisia (Katz and Callorda, 2015c).

Building on the focus on MENA countries, Pradhan *et al.* (2017) extended this line of inquiry by examining 22 Arab League countries, including Jordan, Morocco and Tunisia, for the period between 2001 and 2013. Their research investigated the relationship between broadband penetration, financial development and economic growth. They identified a long-run equilibrium relationship among these factors. Further, Katz and Callorda (2020b) found a fixed broadband economic impact coefficient of 0.7 in Arab States, exceeding low-income countries (0.5) yet trailing high-income ones (1.4). Mobile broadband's coefficient is 1.8, lower than that of low-income nations (2) but still significant compared to high-income counterparts, emphasizing the robust digitization effects influenced by affluent countries in the region. This suggests that while Arab States are outperforming low-income countries in terms of broadband's economic impact, they still have some way to go to match the performance of high-income nations. The data also underscores the robust digitization effects in the region, which are, in part, shaped by the standards and influence of its wealthier countries.

Research on network economies suggests that products with network effects experience a period of slow growth followed by explosive growth (Shapiro *et al.*, 1998). The transition to explosive growth occurs at a point called the "critical mass" level. For instance, a study examining the diffusion of mobile telephone technology attempts to estimate the critical mass point, which is defined as the point at which further diffusion occurs without a change in price. The study also argues that this pattern of technology penetration is applicable to newer technologies exhibiting network effects (Grajek, 2010; Vu, 2019).

In the context of broadband penetration, Czernich *et al.* (2011) conducted a study on a panel of OECD countries over the period 1996–2007. Their research tested for the critical mass point by introducing dummy variables for reaching 10% and 20% broadband penetration rates. They found that a significant positive effect on economic growth becomes evident only after surpassing the 10% threshold. In contrast, Gruber *et al.* (2011) identified the critical mass point at a 30% level of penetration, using annual data from 1990 to 2007 for 192 countries. These findings indicate that reaching a certain threshold of broadband penetration is crucial for unlocking its positive impact on economic growth (Mayer *et al.*, 2020). While the specific threshold may vary across studies, its existence underscores the importance of achieving a significant level of penetration to maximize the economic benefits associated with broadband technology. Furthermore, the study of Czernich *et al.* (2011) indicates that beyond the 20% penetration level, the effect of further broadband penetration on economic growth does not significantly surpass that of the 10% level. This finding aligns with other studies that highlight the presence of a "saturation effect" or "diminishing returns to scale" in technologies exhibiting network effects.

Empirical research assessing the diffusion trajectory of ICT technologies in developing countries supports this notion. A study analyzing data from 46 developing countries between 2000 and 2011 visualizes the diffusion of ICT technologies through an S-shaped curve, which represents four distinct phases. The initial phase involves slow growth, followed by explosive growth in the second phase. After surpassing the inflection point, the third phase exhibits slower growth, and the final phase represents stabilization when growth eventually plateaus. The study finds that mobile communication technology aligns neatly with this S-shaped curve in most lower and middle-income countries. However, in the case of internet users at the time of the study, most countries are still in the initial phase of the S-shaped pattern (Lechman, 2014).

Similarly, Qiang's (2009) study examines the economic impact of broadband penetration in both developing and developed countries. The study reveals that the coefficient for broadband penetration is statistically significant at the 10% level in lower-middle-income countries, suggesting that these countries have not yet reached the critical mass point for broadband penetration. In addition, in line with the saturation phase of the S-shaped curve, the study finds that a 10-percentage point increase in broadband penetration is associated with a 1.38 percentage point increase in economic growth for low-middle-income countries, compared to a 1.21 percentage point increase for high-income countries. This provides implicit support for the saturation effect hypothesis.

All the evidence suggesting the positive effects of ICT and telecommunications is not a reason to ignore its potential adverse effects on economic development, particularly in developing countries. Scholars like Freeman and Soete (1997) and Aghion and Howitt (1998) explore in their research how the growth of ICT can trigger technical changes that lead to labor-saving practices, potentially resulting in the elimination or reduction of certain unskilled jobs, thus negatively impacting employment rates. In addition, Nour (2002) highlights that developed countries can achieve increased comparative advantages through ICT, thereby bolstering their global competitiveness, often to the detriment of developing nations. In contrast, Talla Fokam *et al.* (2023) discovered that ICT adoption in developing countries fosters employment growth. While job displacement does occur, the overall increase in jobs generated outweighs those lost in these contexts.

Nevertheless, it is worth noting that studies that consider the various components of ICT individually show that the benefits of mobile networks and broadband technology can offset the drawbacks. The expansion of mobile networks, for example, contributes to job creation. Studies in South Africa (Klonner and Nolen, 2010) and Malawi (Batziillis *et al.*, 2010) have demonstrated a significant increase in employment with the introduction of enhanced wireless networks in these regions. Furthermore, a more efficient mobile network makes the job search and application process easier and more convenient, facilitating a higher number of individuals finding suitable employment opportunities in the labor market. Similarly, broadband technology plays a role in improving business productivity through the adoption of more efficient processes such as inventory optimization and marketing (Katz and Jung, 2020b). Therefore, the improvement of broadband penetration has the potential to enable enterprises in developing countries to compete with those in more developed countries, leveling the playing field to some extent.

In recent years, the intersection of telecommunications and economic development has witnessed a dynamic evolution, giving rise to new trends and themes that have garnered significant scholarly attention. This dynamic area of study delves into the multifaceted interplay between telecommunications accessibility and poverty alleviation, particularly focusing on how improved access to digital technologies can empower individuals and communities in low-income and developing regions (Emara and Mohieldin, 2020; Phan, 2023; Emara, 2023). In addition, scholars like Benitez *et al.* (2023) investigate how IT-enabled remote work initiatives were embraced by 100 firms in Spain during the pandemic and their relationship to economic development. Their findings reveal that such proactive adoption of IT-enabled remote work practices not only positions firms for growth and resilience but also supports their developmental objectives, particularly during disruptive periods, contributing significantly to their overall development. Furthermore, Gaglio *et al.* (2022) analyzed 711 manufacturing firms from 2019 and found that digital communication technologies, such as social media and business mobile phones, enhance innovation. This innovation, in turn, boosts labor productivity, contributing to development.

Building on the theme of digital technology's role in economic development, another area that has seen significant growth and impact is the domain of mobile money. Mobile money has been a transformative force in the MENA region, as underscored by recent research.

The study by Mouna and Jarboui (2022) underscores a connection between the uptake of mobile money and economic progress. In the MENA region, the research suggests that individuals with advanced education are more likely to embrace mobile money and related digital financial tools. In addition, those actively used show a preference for digital transactions. This suggests a correlation between increasing educational attainment and the growing use of mobile money, which in turn drives economic growth. In Egypt, mobile money has been a cornerstone for economic growth. Hassouba (2023) conducted interviews with key figures in Egypt's financial inclusion journey, revealing that the country's economic surge is closely tied to the widespread use of mobile money. In addition, Cusolito *et al.* (2021) studied the potential of mobile money in various MENA countries, including Egypt. They found that mobile money is a powerful catalyst for the transition to digital payments, especially in areas where traditional banking and credit card services are scarce. Despite the MENA region boasting an ICT infrastructure comparable to other parts of the world, especially in mobile broadband, it lags in creating a favorable regulatory environment for the digital economy and the adoption of crucial digital services like mobile money.

Furthermore, Gévaudan and Lederman (2020) showed that countries can transition directly from cash to digital payments, bypassing traditional banking. The rise of mobile money facilitates this leapfrogging. Liberalizing the MENA region's telecommunications markets could boost mobile money adoption. Combined with traditional banking initiatives, this could lead to a dynamic telecommunications sector, promoting mobile broadband innovations and widespread mobile money use. These studies underscore the growing significance of mobile money as a catalyst for economic growth and advancement in Egypt and the wider MENA area.

Bridging the emphasis on mobile money's role in economic growth in the MENA region, particularly in Egypt, it is crucial to delve deeper into Egypt's unique position in this landscape. In essence, Egypt emerges as an exceptionally distinctive case among MENA nations in the realm of telecommunications and its economic implications. Several factors contribute to this uniqueness. With its status as the most populous country in the Arab world, Egypt's large and diverse population presents distinct challenges and opportunities within the telecommunications sector. Furthermore, its strategic geographical location at the crossroads of Africa and the Middle East, coupled with its historical significance as a cultural and economic hub, adds layers of complexity to its telecommunications landscape. These distinct characteristics set Egypt apart, and despite a multitude of global studies highlighting the positive economic impact of telecommunications, a noticeable gap exists when it comes to comprehensive investigations centered specifically on Egypt. While prior research has indeed furnished valuable insights into the broader telecommunications field and its economic effects across various countries, much of it undertaken in MENA countries, the dearth of in-depth analyses tailored to Egypt's singular context underscores the pressing need for more focused examinations of its distinctive dynamics and challenges.

Given Egypt's exceptional distinctiveness among MENA nations in the field of telecommunications and its far-reaching economic impact, this study seeks to rectify this deficiency by undertaking a concentrated examination of the Egyptian telecommunications sector. We focus on two critical aspects: the influence of unique mobile subscriber penetration and the impact of mobile broadband-capable devices for accessing the internet via mobile networks on GDP growth. Through rigorous empirical analysis and the subsequent revelation of our findings, our objective is to contribute a wealth of context-specific knowledge to the existing literature, thereby facilitating a deeper and more nuanced understanding of the pivotal role telecommunications have played in Egypt's dynamic and evolving economy.

3. Data

To analyze the impact of the telecommunication sector on the Egyptian economy, our study relies on a comprehensive panel of 14 relevant variables, as outlined in Table 1. These variables have been chosen to capture a wide spectrum of economic and telecommunication-related factors. By incorporating indicators such as GDP, gross fixed capital formation, labor and rural population, we can gauge the macroeconomic context. Simultaneously, we assess the accessibility and adoption of telecommunications services in Egypt by examining metrics such as the penetration of mobile unique subscribers and mobile broadband-capable device penetration [1]. It is important to note that while we are not directly addressing mobile money, these metrics are closely tied to mobile telecommunications as they reflect the prevalence of mobile devices and connectivity, which are fundamental for the adoption and use of mobile financial transactions in the Egyptian context. Highlighting the correlation between these metrics and mobile money in Egypt is relevant because it showcases how a higher number of mobile subscribers and widespread access to mobile broadband-capable devices can facilitate greater participation in money transactions and promote financial inclusion within the country. This connection underscores their significance as vital components of the broader economic system in Egypt.

Moreover, the variable average revenue per user (ARPU) provides insights into the accessibility, adoption and pricing of telecommunications services, which are pivotal for

Table 1 Variables, abbreviations and sources, Egypt 2000–2019

Item	*Variable*	*Comments*	*Abbreviation*	*Source*
1	GDP	Data converted to quarterly frequency by assuming CAGR within each year	*GDP*	WDI
2	Gross fixed capital formation	Data converted to quarterly frequency by assuming CAGR within each year	*K*	WDI
3	Labor	Human capital index (HDI), based on years of schooling and returns to education; see Human capital in PWT9. Data converted to quarterly frequency by assuming CAGR within each year	*Labor*	PWT
4	Mobile unique subscribers	Total mobile unique subscribers, that is individuals, regardless of the number of SIM cards and thus mobile connections they have	*Mob_uni*	GSMA
5	Mobile broadband capable device penetration	Penetration of devices capable of attaining broadband access	*Mob_bb*	GSMA
6	Rural population	Data converted to quarterly frequency by assuming CAGR within each year	*Rural*	WDI
7	GDP per capita	GDP per capita (constant 2010 US$). Data converted to quarterly frequency by assuming CAGR within each year	*GDPpc*	WDI
8	ARPU	Average revenue per user in dollars. Used as a proxy for mobile price	*Mob_uni_price*	GSMA
9	Mobile broadband price	Data-only mobile broadband 1.5 GB Price basket in dollars	*Mob_bb_price*	ITU
10	HHI mobile	Industrial concentration index for overall mobile services	*HHI_mob_uni*	GSMA
11	HHI broadband	Calculated as the sum of the squares of the 3G technology market shares. It is used as a proxy for the mobile broadband model	*HHI_mob_bb*	GSMA
12	Mobile revenue	Total revenue of Orange, Vodafone and Etisalat	*Mob_uni_rev*	GSMA
13	Mobile broadband capable revenue	Calculated by multiplying total mobile broadband capable times data-only mobile broadband 1.5 GB Price basket in dollars	*Mob_bb_rev*	Authors' Calculation
14	Oil price	Global Price of Brent Crude	*Shock*	FRED

digital inclusion and economic engagement. The inclusion of indices measuring market concentration (e.g. HHI), coupled with revenue figures, grants us an understanding of industry competitiveness and its economic contributions. Lastly, the inclusion of the oil price factor acknowledges the external influence that can significantly impact the Egyptian economy. This comprehensive array of variables ensures that our analysis captures the full spectrum of factors shaping the dynamic relationship between the telecommunications sector and the Egyptian economy, facilitating a more thorough and insightful examination. The data for these variables is primarily sourced from the World Bank's World Development Indicators (WDI), Penn World Tables (PWT), Global System for Mobile Communications Association (GSMA) Intelligence, the International Telecommunication Union (ITU) and the Federal Reserve Economic Data (FRED).

To ensure a robust analysis, the study focuses on data specific to Egypt, covering a period spanning 2000–2019. The data is collected on a quarterly basis, offering a detailed view of trends and patterns over time. This granularity allows us to capture short-term fluctuations, seasonal variations and potential cyclical trends that might not be evident in annual data. It enhances the precision of our analysis and provides insights into the dynamic relationship between the telecommunication sector and the Egyptian economy, facilitating more informed decision-making and policy formulation. In cases where quarterly data is unavailable, we use interpolation techniques to estimate quarterly values based on the available annual data. This approach enables us to construct a comprehensive quarterly time series study and provides a more granular analysis of the relationship between the telecommunication industry and the Egyptian economy.

We selected the 2000–2019 time period for this study for three reasons. Firstly, by excluding the COVID-19 era, we aim to ensure the robustness of our estimation, avoiding the disruptions and uncertainties introduced by the pandemic. Secondly, this timeframe encompasses periods of both economic stability and significant transitions, offering insights into how the sector responded to various challenges and contributed to the economy during different phases. Thirdly, starting in 2000 aligns with significant technological milestones and policy changes in the telecommunications sector, optimizing data availability and reliability for a more comprehensive analysis.

4. Estimation methodology

In line with the existing literature on this topic (Roeller and Waverman, 2001; Koutroumpis, 2009; Katz and Callorda, 2020a, 2020b), our study adopts structural model [2] to analyze causality, estimate the impact of mobile technology and examine long-run relationships among variables. This approach allows us to account for correlated error terms and explicitly assess their effects while controlling for endogeneity.

The structural model used in our study comprises four equations: the aggregate production function, demand function, supply function and infrastructure function. Each equation serves a specific purpose in capturing the complex interactions and interdependencies among the variables of interest. The first equation focuses on estimating the country's overall economic performance, while the subsequent three equations control for potential reverse causality issues. All variables are expressed in logarithms to account for the logarithmic relationship between them.

Within our structural model, we present two distinct models. In the initial model, we use mobile unique subscribers as the independent variable, whereas in the subsequent model, we use mobile broadband-capable devices for the same term. The objective of both models is to evaluate the influence of mobile communication and data connectivity usage and adoption on GDP growth in a developing country such as Egypt. These variables serve as indicators of the extent and frequency of mobile service utilization and the presence of devices capable of accessing broadband internet via mobile networks. Such usage and

adoption patterns are integral components of the telecommunications sector and contribute to the broader realm of ICT as well.

The first equation, the aggregate production function, estimates the country's overall economic performance. It establishes a relationship between the gross domestic product (GDP_t) to gross fixed capital formation (k_t), labor ($labor_t$), mobile penetration (mob_pen_t), oil price shock ($shock_t$) and the error term (ε_{1t}) as presented in model (1) as follows:

$$Aggregate\ production\ function: GDP_t = a_1 k_t + a_2 labor_t + a_3 mob\_pen_t + a_4 shock_t + \varepsilon_{1t} \quad (1)$$

This aggregate production function is estimated twice for our two distinct models, where the first one, "mob_pen_t," will be replaced with "mob_uni_t" to represent the mobile unique subscribers' penetration and the second model with "mob_bb_t" to represent "mobile broadband capable device penetration."

Next, the demand function, a pivotal component of our analysis, delves into the determinants of mobile penetration and their impact on demand within the telecommunications sector. It plays a central role in fulfilling our research objectives. Specifically, this function examines how various factors influence mobile penetration (mob_pen_t), shedding light on the dynamics that drive its growth:

$$Demand\ function: mob\_pen_t = b_1 rural_t + b_2 GDPpc_t + b_3 mob\_price_t + b_4 HHI_t + \varepsilon_{2t} \quad (2)$$

In model (2), the demand function is presented, enabling us to delve into the intricate relationship between mobile penetration and a set of key variables. These variables include rural population ($rural_t$), reflecting the urban–rural divide in mobile adoption; per capita GDP ($GDPpc_t$), which measures the economic capacity of individuals to subscribe to mobile services; mobile service price (mob_price_t), an indicator of the cost of mobile access; and the industrial concentration index (HHI_t), which characterizes the market structure of the mobile services industry; and, crucially, the error term (ε_{2t}), which accounts for unexplained variations and disturbances in the demand function.

To estimate our two distinct models, mob_price_t will be replaced with $mob\_uni\_price_t$ to reflect ARPU, which is used as a proxy for the price of mobile unique subscribers, and $mob\_bb\_price_t$ will represent the price of mobile broadband, specifically the data-only mobile broadband 1.5 GB price basket in dollars. This approach allows us to gain valuable insights into the demand-side factors that shape mobile penetration and, by extension, its influence on Egypt's economic landscape. Similarly, in our two distinct models, the variable "HHI_t" will be replaced with "$HHI\_mob\_uni_t$" to reflect the market concentration index for mobile unique subscribers in one model and with "$HHI\_mob\_bb_t$" to represent the market concentration index for mobile broadband capable device penetration in the other model. This adjustment allows us to explore the specific impacts of market concentration on these distinct aspects of the mobile services industry in Egypt.

The supply function sheds light on the factors influencing the revenue generation in the mobile telecommunications sector. It focuses on estimating the impact of mobile service price (mob_price_t), per capita GDP ($GDPpc_t$), industrial concentration index (HHI_t) and the error term (ε_{3t}) on total revenue of mobile providers ($revenue_t$) as follows in model (3):

$$Supply\ function: revenue_t = c_1 mob\_price_t + c_2 GDPpc_t + c_3 HHI_t + \varepsilon_{3t} \quad (3)$$

Again, in our two distinct models, the variable "$revenue_t$" will be replaced by $mob\_uni\_rev_t$ to reflect mobile unique subscribers' revenue in one model and by $mob\_bb\_rev_t$ to represent mobile broadband capable device revenue in the other model.

Finally, the infrastructure function provides insights into the role of infrastructure investment and its effect on the expansion of mobile penetration, or mobile adoption growth. It captures the change (Δ) in mobile penetration (mob_pen_t) based on the total revenue of mobile providers ($revenue_t$) and the error term (ε_{4t}). This relationship is presented in model (4) as follows:

$$Infrastructure\ function: \Delta mob\_pen_t = d_1 revenue_{t+\varepsilon_{4t}} \quad (4)$$

The structural model methodological approach enables us to evaluate the economic impact comprehensively while effectively managing potential endogeneity effects. As clarified by Roeller and Waverman (2001), this approach uses all exogenous variables within the system of equations, such as labor quantity and total capital, as instruments for the endogenous variables, encompassing output, penetration level and prices [3].

5. Estimation results

In this section, we discuss the estimation results of our structural model, which encompasses two distinct models that encompass four essential functions: the aggregate production function, demand function, supply function and infrastructure function, as mentioned above. The estimation results appear in Table 2.

Regarding the aggregate production function in both models, it is noteworthy that the coefficients associated with mobile unique subscribers (mob_uni_t) and mobile broadband-capable devices (mob_bb_t) are determined to be statistically significant. This reveals a robust correlation between these independent variables and the GDP growth rate. The positive relationship between GDP and telecommunications penetration suggests that an increase in penetration is associated with higher economic growth in Egypt. Specifically, a 1% increase in mob_uni_t penetration is associated with a 0.172% increase in the GDP growth rate, while the same increase in mob_bb_t is associated with a 0.016% increase, holding all other variables constant. The higher coefficient for mobile telephony can be attributed to the fact that it serves as the primary mode of access for a significant portion of the Egyptian population. On the other hand, the lower coefficient for mobile broadband may reflect fixed broadband having already captured a portion of the economic effects. These findings provide valuable insights into the relationship between telecommunications penetration and economic growth in Egypt, highlighting the significant contribution of mobile telephony and its potential impact on the country's economy (Abdelrashied and Bhattacharya, 2021; Elsaadani, 2014).

In addition to the telecommunications penetration variables, our econometric regression analysis reveals that gross fixed capital formation (k_t), including infrastructure and equipment, has a more substantial impact on GDP growth when broadband penetration (0.232%) is considered, compared to mobile subscriptions (0.019%). This suggests the vital role of infrastructure investment in driving economic growth, particularly in the era of broadband technology (Koutroumpis, 2009). These findings emphasize the importance of prioritizing and strategically allocating resources for building and enhancing broadband infrastructure in Egypt to stimulate significant economic growth and competitiveness (Gruber *et al.*, 2011; Czernich *et al.*, 2011).

In both models, the variable representing human capital index (HDI), or $labor_t$, has the most substantial impact. When considering mob_uni_t penetration, a 1% increase in $labor_t$ corresponds to a 0.612% rise in the GDP growth rate. However, when we factor in mob_bb_t, the increase in GDP growth rate jumps to 2.32% per unit increase in $labor_t$. This suggests that a larger labor force significantly boosts economic growth in Egypt. The difference in coefficients arises from the varying influence of mobile technology penetration. In the first model, where the variable mob_uni_t is considered, it appears that basic mobile communication services somewhat temper the positive effects of human development on

Table 2 Econometric impact of mobile telecommunications

	[I]	[II]
Aggregate production function	*Log (GDP_t)*	*Log (GDP_t)*
Log (*mob_uni_t*)	0.172*** (0.021)	
Log (*mob_bb_t*)		0.016*** (0.005)
Log (*k_t*)	0.019*** (0.006)	0.232*** (0.016)
Log (*$labor_t$*)	0.612** (0.224)	2.316*** (0.138)
Log (*$shock_t$*)	0.002* (0.002)	0.016*** (0.003)
Demand function	*Log (mob_uni_t)*	*Log (mob_bb_t)*
Log (*$rural_t$*)	3.48*** (0.452)	−1.239*** (0.059)
Log (*$GDPpc_t$*)	5.048*** (0.417)	7.448*** (0.370)
Log (*$mob\_uni\_price_t$*)	−0.030** (0.014)	
Log (*$mob\_bb\_price_t$*)		−0.815*** (0.137)
$HHI\_mob\_uni_t$	−0.091* (0.050)	
$HHI\_mob\_bb_t$		−3.342*** (0.350)
Supply function	*Log ($mob\_uni\_rev_t$)*	*Log ($mob\_bb\_rev_t$)*
Log (*$GDPpc_t$*)	2.844** (1.291)	6.605*** (0.338)
Log (*$mob\_uni\_price_t$*)	−0.602** (0.252)	
Log (*$mob\_bb\_price_t$*)		0.282** (0.133)
$HHI\_mob\_uni_t$	−1.70** (0.715)	
$HHI\_mob\_bb_t$		−3.438*** (0.341)
Infrastructure function	*Δmob_uni_t*	*Δmob_bb_t*
Log (*$mob\_uni\_rev_t$*)	−0.037*** (0.004)	
Log (*$mob\_bb\_rev_t$*)		−0.142*** (0.001)
Observations	77	50
Quarter fixed effects	Yes	Yes
Years	2000q4–2019q4	2007q2–2019q4
R-squared first equation	0.9493	0.9981

Notes: ***; ** and * significant at 1, 5 and 10% critical value, respectively. Numbers in parenthesis are standard errors of the coefficients
Source: Egypt 2000–2019

economic growth. However, in the second model, when we control for *mob_bb_t*, it becomes evident that access to advanced mobile technology amplifies the positive influence of human development. This underscores the understanding that the availability of more advanced and versatile mobile technology can greatly facilitate and accelerate the positive effects of human development on economic growth in Egypt's specific context (Donner, 2008; Aker and Mbiti (2010).

In addition, Table 2 shows that when examining *mob_uni_t* penetration, a 1% increase in oil prices, or *$shock_t$*, corresponds to a modest 0.002% uptick in the GDP growth rate. This suggests that while mobile phone penetration is undoubtedly an important factor in economic development, its sensitivity to fluctuations in oil prices is limited. Oil prices are a crucial factor when interpreting a study on telecommunications and economic development. They reflect economic health, affect telecommunications company costs and influence consumer spending. In oil-producing regions, government revenue depends on oil prices, impacting telecommunications infrastructure investments. Furthermore, oil prices offer a broader economic context and are influenced by global factors. Our findings suggest factors other than mobile phone penetration might have a more substantial influence on GDP growth in Egypt (Bastianin and Manera, 2018; Liu and Huang, 2021).

On the other hand, when we consider *mob_bb_t* penetration, the influence of oil prices becomes more pronounced, resulting in a more substantial increase of 0.016% in the GDP growth rate per unit rise in oil prices. This suggests that mobile broadband penetration, which represents a more advanced and versatile form of connectivity, is more closely tied to economic growth and is more sensitive to changes in oil prices.

According to Bastianin and Manera (2018), fluctuations in oil prices directly impact industries and sectors heavily reliant on mobile broadband technology, leading to a stronger correlation between the two variables. Similarly, Liu and Huang (2021) have emphasized the significance of forecasting crude oil prices using event extraction, indicating the intricate relationship between technological advancements and oil price dynamics.

Next, our research delves into the demand functions, shedding light on the intricate factors influencing mob_uni_t penetration and mob_bb_t penetration in Egypt. We discern intriguing patterns in the coefficients of specific variables, offering valuable insights into the dynamics of the telecommunications sector within the country. Firstly, we observe that the variable representing ARPU, or $mob\_uni\_price_t$, which serves as a proxy for mobile pricing, demonstrates a negative relationship with mob_uni_t penetration. As the penetration rate of mobile phones rises rapidly and markets like Egypt's mobile telecommunications sector approach saturation, the growth of new subscribers slows down and ARPU declines (Chen *et al.*, 2008). Such outcomes imply that with a rise in ARPU (signifying increased costs for mobile services), the growth of mobile unique subscribers declines. This finding warrants closer examination. As highlighted by Luan and Shu (2019), elevated mobile service costs could pose a barrier to entry for potential subscribers, particularly in regions where affordability remains a significant concern.

Conversely, our analysis reveals that the mobile broadband price, or $mob\_bb\_price_t$, defined as the cost of the data-only mobile broadband 1.5 GB price basket in dollars, exerts a substantial negative effect on $mob\_bb\_price_t$ penetration, with a coefficient of −0.815%. This implies that when mobile broadband prices in Egypt rise, the adoption of broadband-capable devices diminishes, emphasizing the pivotal role of affordable pricing in promoting broadband accessibility. This result aligns with the research conclusions of Ghosh (2017) and Jung and Katz (2022), emphasizing the economic advantages of enhanced broadband penetration, largely attributed to the decrease in broadband costs that likely drives this result.

The discrepancy between the impact of the coefficient for $mob\_uni\_price_t$ (−0.03%) and $mob\_bb\_price_t$ (−0.815%) in their respective models suggests the complex interplay of various factors within the Egyptian telecommunications landscape. While ARPU primarily reflects pricing dynamics, the mobile broadband price encapsulates the cost of accessing a specific data amount, reflecting a more tangible aspect of affordability. The relatively smaller coefficient for $mob\_uni\_price_t$ may indicate that while pricing is a factor, broader considerations, such as market competition and infrastructure availability, also significantly influence subscriber penetration (Mothobi and Grzybowski, 2017). Findings underscore the pivotal role of pricing and affordability in shaping technology adoption trends while also emphasizing the multifaceted nature of telecommunications dynamics in Egypt.

Building on the insights of previous studies (Gruber *et al.*, 2011; Ng and Ng, 2016; Doshi and Narwold, 2018), our research reveals compelling findings regarding the relationship between GDP per-capita growth rate and the demand for telecommunications services. Notably, we find that a 1% increase in GDP growth rate exerts a significant influence on the demand for both mobile subscriptions and broadband penetration in Egypt. Specifically, the results indicate that in Egypt, a 1% increase in GDP per-capita, or $GDPpc_t$, leads to about 5.05% increase in demand for mob_uni_t. This suggests that as the Egyptian economy grows, the desire for mobile services rises substantially, reflecting the positive correlation between economic prosperity and telecommunications consumption.

Our analysis unveils an even more pronounced effect in the case of mob_bb_t penetration. A 1% increase in $GDPpc_t$ corresponds to a remarkable 7.45% increase in demand for broadband services in Egypt. This substantial impact highlights the crucial role of economic growth in driving the adoption of broadband technology, especially in a nation striving to expand its digital infrastructure and connectivity.

Furthermore, the higher coefficient for broadband penetration (7.45%) compared to mobile subscriptions (5.05%) suggests that the influence of GDP growth on broadband demand is more pronounced in Egypt. This could be attributed to the evolving digital landscape in the country, where broadband internet becomes increasingly essential for various sectors, including education, business and healthcare (Kamel, 2021). These findings contribute to our understanding of the dynamics in Egypt's telecommunications sector and the pivotal role of economic growth in shaping technology consumption trends.

In addition, our results from Table 2 sheds the light on the correlation between rural population growth, or $rural_t$, and mobile subscriptions. Specifically, we found that a 1% rise in $rural_t$ corresponds to a 3.48% increase in mobile subscriptions. This trend aligns with Björkegren (2022) observations of the significance of mobile network coverage in rural areas. However, the negative coefficient of −1.24% for mobile capability suggests that while mobile services are increasingly adopted, advanced features might be underused. This discrepancy could be attributed to the higher costs of advanced devices and potential infrastructure limitations, as noted by Uwamariya *et al.* (2021) and Delaporte and Bahia (2022).

Next, our findings indicate that the variable representing HHI for mobile unique subscribers, or $HHI\_mob\_uni_t$, has a negative relationship with mob_uni_t penetration, with a coefficient of −0.09%. This suggests that as the market becomes more concentrated, mobile subscriber penetration may decline slightly. Such a relationship can be attributed to reduced competition, potentially leading to higher prices or less innovation, thereby affecting the rate of new subscriptions. This observation aligns with the research findings of Naldi and Flamini (2018) and Bardey *et al.* (2022), both of which emphasized the impact of reduced competition on the mobile telecommunications market. Such reduced competition can lead to higher prices and reduced innovation, consequently influencing the rate of new subscriptions in the industry.

Furthermore, the HHI for broadband-capable devices, or $HHI\_mob\_bb_t$, has a more pronounced negative coefficient of −3.34% on mob_bb_t penetration. This larger negative coefficient suggests a stronger inverse relationship for broadband services compared to general mobile services. The reasons for this pronounced effect could be multifaceted. Broadband services, especially those based on advanced 3G technologies, might be more sensitive to market concentration due to the higher costs associated with broadband infrastructure and services (Benseny *et al.*, 2019). In addition, in concentrated markets, providers may have less incentive to expand or upgrade broadband infrastructure, especially in regions that are more challenging to serve.

The supply function provides insights into the factors influencing the supply of mobile subscriptions and broadband services, as indicated by mobile unique subscribers' revenue ($mob\_uni\_rev_t$) and mobile broadband capable devices revenue ($mob\_bb\_rev_t$), respectively. The results highlight the significant influence of $GDPpc_t$ on telecommunications revenue. Specifically, a 1% rise in $GDPpc_t$ is associated with about 2.84% increase in $mob\_uni\_rev_t$. Even more striking is the impact on $mob\_bb\_rev_t$, where a 1% increase in $GDPpc_t$ leads to about 6.61% revenue surge. This larger coefficient suggests a growing emphasis on high-speed internet and advanced mobile services in flourishing economies (Edquist, 2022). Such trends resonate with findings from Gruber *et al.* (2011) and Waverman *et al.* (2005), emphasizing the significant relationship between economic growth and telecommunications revenue.

Furthermore, the analysis uncovers distinct dynamics between $mob\_uni\_price_t$ and $mob\_uni\_rev_t$. Specifically, a negative coefficient of −0.602 for $mob\_uni\_price_t$ suggests that as ARPU increases by 1%, $mob\_uni\_rev_t$ drops by 0.60%. This finding corresponds with the conclusions made by Samanta *et al.* (2008) that those with a high access price have a low penetration, resulting in diminished revenue for the operator. Similarly, in less-

penetrated markets like developing countries, consumers' heightened price elasticity not only impacts demand when prices increase but also influences operator revenue, as demonstrated by Sawadogo (2021). Conversely, the positive 0.28 coefficient for $mob\_bb\_price_t$ underscores the value Egyptian consumers associate with high-speed internet, indicating their willingness to pay a premium for enhanced services, resonating with findings by Greenstein and McDevitt (2011).

In addition, our results show that the $HHI\_mob\_uni_t$ has a coefficient of −1.70. This suggests that as the mobile market becomes more concentrated, mobile revenue decreases, potentially due to reduced competition leading to higher prices or diminished innovation, a phenomenon highlighted by Stucke (2013). Conversely, $HHI\_bb\_uni_t$ exhibits a more pronounced negative coefficient of −3.44, indicating a stronger sensitivity in the broadband market to concentration levels. The larger magnitude for 3G services might be attributed to the capital-intensive nature of broadband, where higher concentration can deter new entrants and reduce competitive pricing, as observed by Galperin and Ruzzier (2013).

Our results highlight the nuanced dynamics of Egypt's telecommunications infrastructure. Specifically, for every percentage increase in mobile unique subscribers' revenue, or $mob\_uni\_rev_t$, the growth rate of mob_uni_t adoption decreases by approximately 3.7%. This could be due to market saturation, where existing subscribers, rather than new ones, derive higher revenues. A phenomenon Gruber and Verboven (2001) discussed.

More pronounced is the relationship with mobile broadband-capable devices revenue, or $mob\_bb\_rev_t$. For every percentage increase in this revenue, the growth rate of mob_bb_t adoption decreases by around 14.2%. This difference can be attributed to their capital-intensive nature of broadband services and the need for advanced infrastructure. Given that broadband services often come at a premium, higher prices that higher revenues require might deter new subscribers, especially in regions like Egypt where disposable income is limited. Clearly, El-Moghazi *et al.* (2014) emphasis on the importance of affordability in Egypt's journey towards digital transformation has continued to hold.

6. Conclusions

Using a structural model on a quarterly data spanning from 2000 to 2019, this study provides a comprehensive analysis of the economic impact of mobile telecommunications in Egypt. The findings from this study, consistent with prior research, provide compelling evidence of the positive impact of mobile unique subscribers (voice and data) and mobile broadband-capable devices on the GDP growth of Egypt, thereby underscoring their significance for social and economic development in both Egypt and the wider MENA region.

Our analysis reveals that both mobile unique subscribers' penetration and mobile broadband capable devices have a statistically significant correlation with GDP growth rate. A one-unit increase in mobile subscriber penetration is associated with a 0.172% increase in the GDP growth rate, while the same increase in broadband penetration is associated with a 0.016% increase, holding other variables constant. These results highlight the importance of telecommunications penetration, particularly mobile telephony, in driving economic growth in Egypt.

Moreover, the demand function analysis illuminates the role of economic growth in driving the adoption of mobile subscriptions and broadband penetration. As the Egyptian economy grows, there is a significant surge in the demand for these telecommunications services. This indicates a mutually reinforcing relationship between economic prosperity and the telecommunications sector. A thriving economy can better afford and sustain the expansion of telecommunications infrastructure and services.

Furthermore, the impact of rural population size on mobile subscriptions further underscores the importance of extending telecommunications services to underserved regions. The positive correlation suggests that a larger rural population contributes to increased mobile subscriptions, potentially bridging the urban–rural digital divide. Enabling rural areas with access to telecommunications services can empower local communities, foster economic activities and promote digital inclusion. Conversely, the negative correlations involving broadband price, 3G concentration and rural population highlight the challenges of acquiring broadband services in rural areas. These findings pinpoint the need for targeted policies aimed at reducing broadband costs, improving infrastructure in rural regions and enhancing the affordability of high-speed internet services to ensure equitable access across the country.

In addition, the supply function analysis reveals that ARPU and the HHI have negative correlations with mobile subscription supply, while GDP per capita has a positive effect. For broadband supply, mobile broadband price exhibits a positive correlation, while GDP per capita and HHI 3G show negative correlations. These findings highlight the factors influencing the supply of mobile subscriptions and broadband services in Egypt. Moreover, our analysis of the infrastructure function indicates a negative relationship between revenue and the growth of both mobile subscriptions and broadband services. As mobile and broadband revenues increase, the growth rates of subscriptions and services tend to decrease. These results suggest that higher revenue levels in the telecommunications sector may impede the expansion of mobile and broadband services in Egypt.

In a broader context, these findings underscore the pivotal socioeconomic and sociopolitical implications of telecommunication penetration, especially mobile telephony, in driving economic growth. This correlation highlights the potential for digital inclusion and income equality, particularly in underserved rural areas, empowering individuals with opportunities for education, entrepreneurship and government services. Furthermore, the telecommunications sector's job creation potential and economic diversification can significantly contribute to reducing youth unemployment, enhancing economic resilience and fostering political participation and governance. Enhanced access to telecommunications can revolutionize education and skill development and improve healthcare access and affordability, ultimately strengthening Egypt's position in the global digital economy and contributing to its long-term sustainable development.

In conclusion, based on our study's findings, we recommend several policy actions with relevance not only for Egypt but also the broader MENA region. Priorities include efforts to boost telecommunication penetration, especially in underserved areas, by reducing service costs and promoting affordable device availability. Encouraging private sector investment and competition in telecommunication infrastructure is vital. Digital literacy programs should be promoted for users to fully benefit from expanded services. In addition, policies fostering innovation and entrepreneurship within the telecommunications sector can aid economic diversification. Finally, regulatory frameworks should balance competition and infrastructure investment. These steps can unlock telecommunications' potential for economic growth, digital inclusion and sociopolitical development.

Notes

1. The measure, mobile broadband capable device penetration has greater precision, inclusivity, and relevance in today's multi-device usage landscape than mobile broadband unique subscriber penetration. It provides a comprehensive view of the technological infrastructure, encompasses various devices (e.g., smartphones, tablets, IoT, smart home devices, etc.), reflects market dynamics, gauges infrastructure readiness, and enables comparative analysis. This makes it a more suitable metric for our study's objective since it offers a comprehensive view of both direct and indirect economic activities linked to mobile telecommunications, capturing the depth of technology adoption and its integration into Egypt's economic fabric.

2. This approach, introduced by Roller and Waverman in 2001was later built upon and employed by Koutroumpis in 2009, and subsequently expanded upon by Katz and Koutroumpis in 2012 (2012a; 2012b), as well as by Katz and Callorda in 2014, 2016, and 2017.
3. The procedure for instrumentalizing endogenous variables essentially involves extracting the segment of a specific endogenous variable that can be attributed to the exogenous variables within the system (referred to as "instruments"), and then using this isolated component as a regressor.

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