Argumenta Oeconomica
Year 2026, Vol. 56, No. 1
ISSN 2720-5088
journals.ue.wroc.pl/aoe

An investigation into closing the global digital divide

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Quote as: Lee, J., & Yu, W. (2026). An investigation into closing the global digital divide. *Argumenta Oeconomica*, *1*(56), 69-87.

DOI: 10.15611/aoe.2026.1.05

JEL: O18, O47, O11, O14

Abstract

Aim: This paper aims to investigate the impact of digitalisation and city development on the economic growth of developing countries in the context of narrowing the digital divide and the significance of digital skills in various economic sectors, particularly in light of the 'servitisation' trend.

Methodology: The study employs empirical analysis using data from the OECD Creditor Reporting System (CRS) database to examine the effects of Official Development Assistance allocated for digital infrastructure and urban/rural development. The analysis includes regression models to test the relationship between ODA, digitalisation, and economic growth while controlling for factors such as the youth population ratio and urbanisation.

Results: The results indicate that increasing per-capita ODA for digital infrastructure and city development is associated with a significant increase in annual economic growth of the recipient country. Specifically, doubling the amount of ODA received for these purposes is associated with a 0.3 percentage point increase in economic growth, even after controlling for various factors such as digitalisation levels and urbanisation.

Implications and recommendations: The findings suggest that investing in digital infrastructure alongside city development projects can significantly contribute to economic growth in developing countries. Policymakers are urged to prioritise investments in digital infrastructure and city development to bridge the digital divide, promote inclusive growth, and address the challenges exacerbated by the Covid-19 pandemic.

Originality/value: This research contributes to the literature by highlighting the importance of digitalisation and city development in fostering economic growth in developing countries, particularly in the post-pandemic era. It underlines the potential of Official Development Assistance to drive positive economic changes through strategic investments in digital infrastructure and urban development.

Keywords: economic growth, digital infrastructure, city development, official development assistance (ODA)

1. Introduction

Today's world bears the imprint of a continuously evolving process known as globalisation. Although this is not a new process[1], its scope and impact appear to have expanded alongside advancement in transportation, communication and information technologies. The impact of globalisation on economic growth and development is a highly debated topic, but the consensus supports the idea that globalisation accentuates economic growth; however, global inequality has deepened as it accelerated. Global efforts such as setting Millennium Development Goals were established to address such issues. Between the start of the new millennium and 2019, economic growth positively averaged 61.7% for low income, 96.3% for lower middle income, 72.6% for upper middle income, and 36.5% for high income.[2] Consequently, the share of the world population living below the extreme poverty line of $1.90 per day fell from 35.6% in 1990 to 10.0% in 2015 (World Bank, 2018). Moreover, the recent Covid-19 pandemic has caused a major disruption in people's lives and livelihoods, pushing additional 97 million people back into poverty in 2020 (Mahler et al., 2021).[3] The pandemic highlighted the interconnectedness of the global community, where one country's problem becomes a global problem.

The pandemic has also accelerated the diffusion of digital technology and forced the world to quickly adopt and adapt to digital solutions. Furthermore, it accelerated digital transformation, and exposed the stark contrast between economies and individuals who could leverage digital technologies and those who could not. This rapid digital transformation revealed the disparity between those who were vulnerable and those who were resistant in the face of the global shock. This disparity has the potential to exacerbate global inequality, particularly because developing economies[4] lack sufficient digital technology and productive infrastructure, especially in the realm of digital infrastructure. Consequently, it is crucial to level the playing field for the vulnerable group, enabling them to seize even the smallest opportunities to integrate existing technologies and adapt to the evolving business environment during their catch-up phase. In summary, bridging the digital divide is therefore critical to ensuring equitable access to opportunities in the digital economy, eventually leading to a reduction of the global inequality gap.

However, developing digital infrastructure and improving city functions require a high amount of investment, which poses challenges for developing countries due to the high risks associated with underdeveloped economies. In the wake of the Covid-19 pandemic, there has been an increased focus on studying the impact of globalisation and digital infrastructure on economic growth. This paper contributes to the existing literature in two ways. Firstly, it examines the effectiveness of ODA as

[1] The Silk Road, an ancient network of trade routes used between Europe, North and East Africa, Central and South Asia, and the Far East, is an example of early globalisation.

[2] Calculated by the author using PWT 10.0 data. Simple averages of GDP per capita growth rates of the specified income group countries.

[3] This Covid-19-induced poverty figure is an updated estimate calculated as the difference in poverty in a world with and without the pandemic using the latest growth forecasts available from the Global Economic Prospect (GEP). The figure was updated in June 2021. The initial estimate was between 119 and 124 million people calculated in January 2021, see Mahler et al. (2021).

[4] Developing countries account for low income and upper-middle-income countries. Income level is differentiated by World Bank income level.

a channel for promoting economic development in developing countries. ODA, which has been a major external source of financing for the economic and social development of developing nations, is analysed to understand its efficacy in achieving developmental goals. Secondly, the paper emphasizes the importance of not only developing digital infrastructure but also focusing on city development. It provides evidence of the significance of allocating resources to digital infrastructure as part of broader city development strategies. It is important to note that, within the scope of this study, the term "city development" embraces all efforts directed towards regional development, encompassing both urban and rural areas. By addressing both aspects, the paper highlights the need for comprehensive approaches to maximise the potential benefits of digitalisation and urban, rural development.

Before proceeding with the empirical analysis to examine the effects of ODA related to digital and city development on the economic development of developing countries, the authors first challenged the traditional perspective on structural transformation by introducing the concept of *servitisation*, which signifies the growing integration of service offerings within the agriculture and manufacturing sectors as a result of digital advancements. Additionally, the study stressed the crucial significance of digital infrastructure and city development in the process of structural transformation. The second section of the paper outlines the empirical approach employed to identify and measure the impact of digital infrastructure and city development related ODA on economic development, and provides a detailed explanation of the methodology utilised in the analysis. The next section presents the empirical results derived from the analysis, which shed light on the relationship between ODA for digital and city development and its effects on the economic growth of developing countries. The paper concludes by summarising the key findings and implications for policy, highlighting the importance of considering digital infrastructure allocation and city development in promoting inclusive and sustainable economic growth in developing countries.

2. Theoretical framework

From a historical perspective, structural transformation has been observed as a process, which involves the redistribution of economic activity across three main sectors: agriculture, manufacturing, and services. This transformation accompanies the process of modern economic growth (Herrendorf et al., 2014). Growth theorists attach great importance to this transformation because it generates both static and dynamic gains. The intermediate stage, specifically the manufacturing industry, holds particular significance due to its unique pro-development characteristics. It provides opportunities for employing a large number of unskilled workers at a productivity premium, which can lead to spill-over effects and dynamic gains for growth and development (Hallward-Driemeier & Nayyar, 2018). However, it is worth noting that the capacity to absorb workforce varies across different stages of the transformation. As an economy moves towards higher labour productivity sectors such as tradable services and non-manufacturing industries, the ability to absorb labour diminishes. The global structural transformation gained momentum around 1990, fuelled by the emergence of information technology, which significantly reduced the cost of transferring ideas across borders. This pivotal development led to what is now known as the "Great Convergence," a term used to describe the convergence in living standards and economic development between nations (Baldwin, 2016). Multinational companies seized the opportunity to offshore labour-intensive tasks to developing nations with lower wages, while reserving high-tech and high-productivity tasks for their home countries. This transformative economic shift resulted in the denationalisation of international production and the reorganization of global value chains (GVC), which can be seen as a global-scale extension of Adam Smith's division of labour.

However, the development of GVC has been uneven, favouring a few large or technologically advanced economies. This concentration of GVC has made it more challenging for other developing countries to fully participate in the manufacturing stage of structural transformation, which is believed to be crucial for achieving productivity gains and generating substantial employment opportunities. As a result, some

developing countries have directed their resources towards the service industry. Data indicated that service exports from countries in Sub-Saharan Africa grew six times faster than merchandise exports between 1998 and 2015 (Page, 2018). Scholars have referred to this phenomenon as 'premature deindustrialisation' and have expressed concerns about its implications. In his 2016 paper, Rodrik suggested that it can have significant economic and political consequences, including lower economic growth and challenges to democratic governance. Despite such conventional concerns towards *premature deindustrialisation*, the new technological epoch is reshaping the traditional patterns of development, largely driven by the rise of *servitisation*[5]. This shift highlights the evolving nature of development and the increasing importance of service-oriented industries in the global economy.

2.1. Servitisation through digitalisation

Servitisation entails the integration of service offerings into both the agriculture and manufacturing sectors. Even in the primary sector, e.g. in agriculture, digital services play a crucial role in enhancing precision, productivity, resource conservation, and waste reduction throughout the value chain. Within the manufacturing sector, servitisation is even more prominent as corporate strategies shift towards customer-centric approaches driven by data utilisation. Manufacturers can increase their profits by providing repair, monitoring, fleet arrangement, customisation, and other services, empowered by advancements in technology that enable real-time data transmission, cloud storage, rapid analysis, and response. Servitisation has emerged as a critical component of gaining a competitive advantage and a significant source of profit for many companies (Hofmann et al., 2019). This transformation is accompanied almost always by the widespread adoption of digital technologies, which play a central role in enabling servitisation (Belvedere et al., 2013). These technologies, as highlighted by Parida et al. (2019), are instrumental in increasing resource efficiency within organizations (Bressanelli et al., 2018). The integrated produce-service arrangement within GVCs presents an opportunity for higher levels of economic growth. By embedding digital infrastructure within city development strategies, countries can facilitate servitisation and drive sustainable economic growth.

The digital divide, defined as the disparity between those with access to digital technology and those without, has widened in between already technologically developed countries and developing countries. Therefore, the digital divide was conceptualised as the disparity in digital infrastructure and connectivity, particularly between urban and rural areas in developing countries. This paper placed a particular focus on digital infrastructure in developing economies due to its essential role as a channel for promoting development across all economic sectors. Furthermore, the pandemic has highlighted the importance of digital inclusion in addressing the disparities arising from inadequate physical infrastructure, particularly in marginalised communities. The following section delves into the relevant factors that contribute to the accumulation of adequate digital infrastructure, and explores strategies for leveraging it on a larger scale.

2.2. Scale effect by city development

This section describes population dynamics in developing countries which, as of 2020, are home to approximately 3.9 billion people. Among this population, there exists the largest share of young people globally, comprising approximately 58.9% of the world's youth population.[6] The pandemic has also had devastating effects, leading to a significant increase in poverty, the World Bank estimated that about

[5] The blurring between sectors due to integrating service to core product offerings to create additional customer value is described as 'servitisation' (Vandermerwe & Rada, 1989) or, later, 'transition from products to services' (Oliva & Kallenberg, 2003) and 'service infusion' (Brax, 2005). International Organizations are increasingly paying attention to the servitisation as discussed from UNCTAD Multi-year Expert Meeting on Trade, Services and Development (Miroudot & Cadestin 2017), and World Bank Productivity Project (Nayyar et al., 2021).

[6] Here, the youth cohort refers to those aged between 15 and 24. The share is calculated with the World Bank population data.

97 million people have been pushed into poverty. This combination of a large youth population and an increase in poverty levels has the potential to adversely impact global productivity, furthermore the rise in inequality poses another challenge. It is projected that inequality, as measured by the Gini Index, could increase by 1%, undermining the progress[7] made in the past decade. Addressing these challenges and creating opportunities for the young and marginalised populations is crucial.

In addition to the growing share of young and poor populations, rapid urbanisation is also taking place, particularly in developing countries, where among the 3.9 billion people, an estimated 41% reside in urban areas, and this number is expected to grow significantly. According to the 2018 UN World Population Prospects, it is projected that by 2050, approximately 58% of the world's urban population will be concentrated in low-income and lower-middle-income countries. These demographic and urbanisation trends necessitate increased job opportunities and improved municipal services, particularly in developing countries, suggesting the increasing importance of cities as spaces for investment and development.

Infrastructure projects hold immense potential as a powerful means for leveraging sustainable city development. The economic benefits developing countries could draw from improved infrastructure are higher than developed countries, based on the underlying diminishing returns to capital. Numerous studies have demonstrated that the provision of exogenous factors to low-income countries encourages higher returns to capital. Among various infrastructure projects, extensive research has indicated a complementary relationship between development of digital infrastructure and economic growth. For instance, Andrianaivo and Kpodar (2011) found 10% increase in telephone subscriptions led to a 16% increase in real GDP growth, and Hjort and Poulsen (2019) provided evidence on the positive relationship between fast Internet and the labour market.

The authors examined the projected increase in urban population in developing countries and the documented economic benefits associated with enhanced infrastructure. The development of digital infrastructure holds the potential to enhance digital capabilities and create opportunities for greater involvement in servitisation-related economic activities. This paper places significant emphasis on the development of both urban and rural areas, collectively referred to as city development, as they provide a suitable platform for maximising the value generated from digital advancements.

It is important to note that infrastructure development entails substantial costs and risks. Consequently, investments in low-income countries remain limited, while private sector entities are more inclined to invest in ICT infrastructure and other telecommunications services in upper middle-income countries. The paper confirms validity of allocating a higher rate of ODA to digital infrastructure and city development projects in lower-income countries, which would be not only a strategic investment in their long-term development, but also a means to bridge the digital divide and promote inclusive growth. Aid in digital infrastructure would enable younger and lower-income countries to enhance their technological capabilities, expand internet access, and promote digital literacy among their populations. This creates a conducive environment for innovation, entrepreneurship, and the development of digital services, ultimately driving economic growth and facilitating a more robust servitisation process. Additionally, directing ODA towards city development projects can lead to improvement of urban infrastructure, enhancing the quality of life and attracting investments. The paper underlines the transformative potential of ODA in facilitating positive economic changes and lays the foundation for a more efficient and prosperous future for lower-income countries.

To sum up, servitisation enables the more efficient production process of agricultural and manufacturing sectors through digitalisation. Furthermore, the impact of servitisation can be maximised in densely populated areas, taking advantage of the scale effect inherent in cities. The authors posit that developing countries can benefit the most from digitalisation and city development due to their younger demographic structure and their ample urbanisation rate. Numerous studies, including

[7] See Yonzan et al. (2020).

Vaportzis et al. (2017) argued that the younger population is more receptive and adaptable to new digital technologies compared to older adults who may experience greater barriers in interacting with these technologies. Based on this premise, one can hypothesise that investments in digital infrastructure and city development, when implemented together, yield a greater impact on economic growth than digital infrastructure investments alone. Figure 1 illustrates the theoretical framework, which supports the notion that investment in digital infrastructure and city development can lead to sustainable economic growth in developing countries.

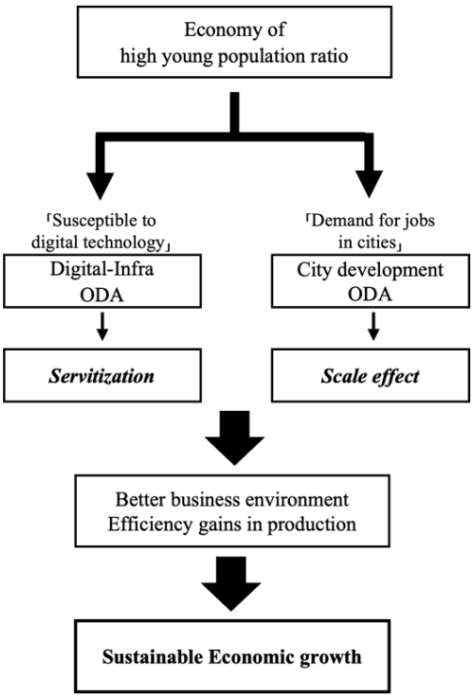

Fig. 1. Theoretical framework: channels to economic growth

Source: elaborated by the authors.

Finally, despite the clear link between digitalisation and growth, empirical research on the interaction between ODA for digital infrastructure and city development remains limited. To address this gap, the following research questions were posed:

1. How does ODA for digital infrastructure impact economic growth of developing countries?
2. What role does city development play in maximising the effectiveness of digital infrastructure investments?
3. Does the combination of digital infrastructure and city development yield greater economic benefits than digital infrastructure alone?

3. Data

3.1. Construction of digital infrastructure ODA data

The study used ODA data from the OECD's Creditor Reporting System (CRS) database to examine the impact of digital infrastructure and city development on economic growth, the sum of grant, loan, and equity investment which are the three components of ODA. The ODA amount was divided into CRS purpose codes, and according to their descriptions, the authors created two types of ODA panel data variables. The first variable was digital infrastructure ODA (DI_ODA), which included ODA on digital communications technology and infrastructure (CRS purpose codes: 22010, 22020, 22030, and 22040). The second group also included city development components of ODA (DICD_ODA), involving ODA on

urban and rural development and management, housing, and disaster risk reduction infrastructure (CRS purpose codes: 16030, 16040, 43030, 43040, and 43060). Table 1 shows descriptions of each CRS purpose codes for digital infrastructure and city development ODA types. The data analysis was confined to 86 sample countries[8], including those that were recipients of DI_ODA or DICD_ODA between 1990 and 2019 at least once.

Table 1. Top 10 Digital Infrastructure ODA Recipients (Million USD, 1990-2019)

Type	CRS Purpose Code	Short Description
ODA on Digital Infrastructure (D.I.)	22010	Communications policy and administrative management
	22020	Telecommunications
	22030	Radio/television/print media
	22040	Information and communication technology (ICT)
ODA on City Development (C.D.)	16030	Housing policy and administrative management
	16040	Low-cost housing (including slum clearance)
	43030	Urban development and management
	43040	Rural development
	43060	Disaster risk reduction (including risk assessments, structural (e.g. flood prevention infrastructure) and normative (e.g. building codes, land-use planning) prevention measures

Source: OECD CRS Database.

Figure 2 shows the time-series trend of DI_ODA and DICD_ODA amounts from 1990 to 2019. While the DI_ODA maintained a similar level of allocation throughout the sample period (380 in 1990 to 619 million USD in 2019), DICD_ODA amount soared from 459 in 1990 to 3,804 million USD. ODA donor countries and institutions clearly focused their budget on city development issues and left digital infrastructure development to other private sector agents.

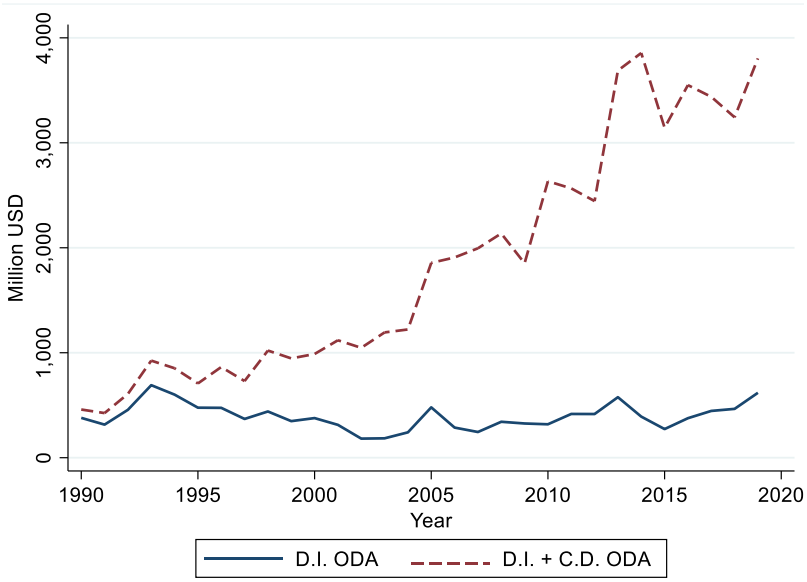

Fig. 2. Time-series Trend of DI_ODA and DICD_ODA (Total of 86 Sample Countries)

Source: authors' calculations with ODA data from the OECD CRS Database.

[8] Sample countries in ISO codes: AGO, ALB, ARG, ARM, BFA, BGD, BHR, BOL, BRA, BWA, CHL, CHN, CIV, CMR, COD, COG, COL, CRI, CYP, DOM, DZA, ECU, EGY, ETH, GAB, GHA, GMB, GTM, GUY, HND, HRV, HTI, IDN, IND, IRN, IRQ, JAM, JOR, KAZ, KEN, KOR, LBR, LKA, MAR, MDA, MDG, MEX, MLI, MLT, MMR, MNG, MOZ, MWI, MYS, NAM, NER, NGA, NIC, PAK, PAN, PER, PHL, PRY, SAU, SDN, SEN, SLE, SLV, SRB, SVN, SYR, TGO, THA, TTO, TUN, TUR, TZA, UGA, UKR, URY, VEN, VNM, YEM, ZAF, ZMB, ZWE.

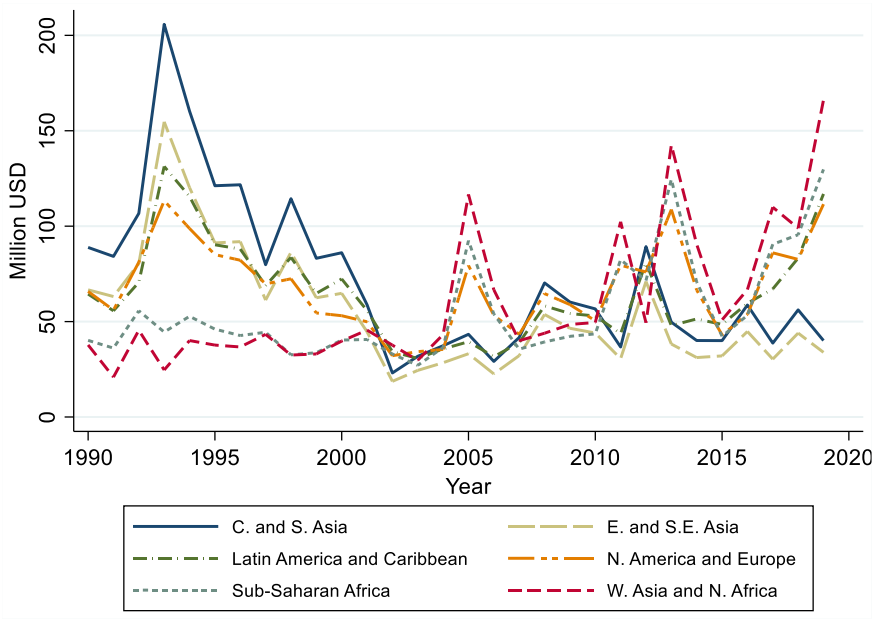

Fig. 3. Time-series Trend of DI_ODA by Region

Note: 5-year moving averages, C (Central), S (South), E (East), SE (South East), W (West), N (North)

Source: authors' calculations with ODA data from the OECD CRS Database.

Looking at the DI_ODA amount received by regions, it is interesting that West Asia and North Africa had the lowest values during the 1990s but rocketed to the first of the group since the mid-2000s, whereas countries in Central and South Asia received by far the most of DI_ODA in the 1990s. However, this figure decreased sharply from the mid- 1990s and has remained low since the early 2000s. Latin America and Caribbean and North America and Europe followed similar trends. This can be interpreted as evidence that DI_ODA was much more concentrated in the regions of Central and South Asia in the 1990s but shifted elsewhere from the mid-2000s.

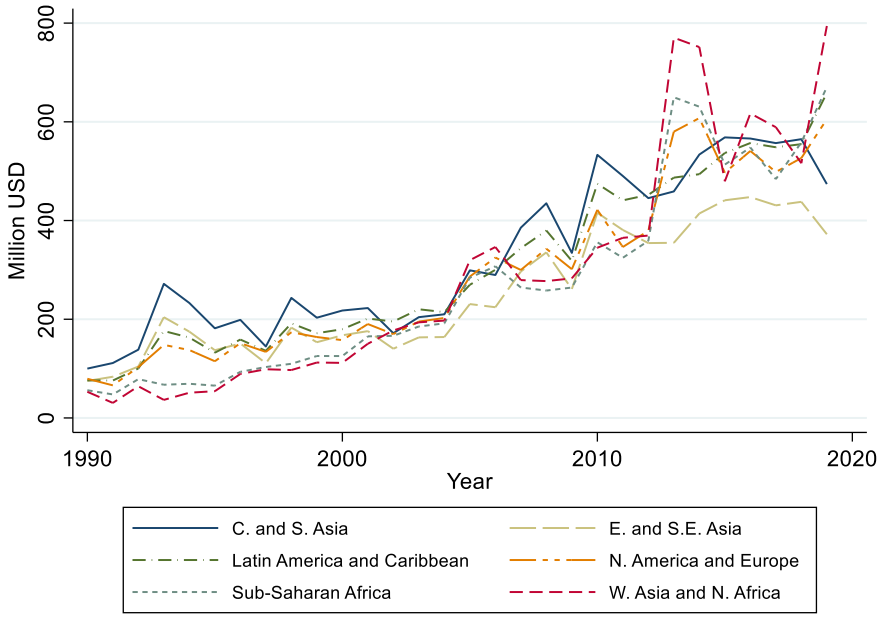

Fig. 4. Time-series Trend of DICD_ODA by Region

Note: 5-year moving averages

Source: authors' calculations with ODA data from the OECD CRS Database.

The time-series trends of the regional DI and CD ODA (DICD_ODA) recipients paint a slightly different picture. Figure 4 illustrates that all regional trends moved almost monotonically upward, yet West Asia and North Africa still show the similar trends, shifting from the recipients of the lowest amount in the beginning to the group receiving most in the later period of the analysis. Central and South Asia countries were also the highest DICD receiving region in the beginning, which then declined after the mid-2010s.

Table 2 lists the rankings of the top 10 DICD_ODA recipients from 1990 to 2019. Whilst China was the number one recipient of DI_ODA, Bangladesh was the top recipient of DICD_ODA, followed by India DICD_ODA, yet not listed among the top 10 DI_ODA recipients. This was probably because India has already established a relatively sound digital infrastructure, or utilised different sources such as national or private money to establish a digital infrastructure.

Table 2. Top DI_ODA and DICD_ODA Recipients (Million USD, 1990-2019)

Ranking	Country	DI_ODA	Ranking	Country	DICD_ODA
1	China	1,231.1	1	Bangladesh	4062.8
2	Indonesia	1,170.7	2	India	4045.4
3	Turkey	688.8	3	Indonesia	3501.5
4	Bangladesh	528.4	4	Viet Nam	2834.3
5	Pakistan	504.8	5	Egypt	2406.4
6	Iraq	483.9	6	China	2224.9
7	Viet Nam	430.8	7	Ethiopia	2000.9
8	Sri Lanka	418.6	8	Pakistan	1938.4
9	Egypt	337.7	9	Turkey	1755.4
10	Kenya	320.6	10	Morocco	1752.0

Source: authors' calculations using ODA data from the OECD CRS Database.

Table 3 shows the rankings of the top 10 average DI and DI plus CD_ODA receipts *per person* between 1990 and 2019. Mongolia and Tunisia were in the top 3 of both tables. The top 10 countries were mostly African countries, but those from other regions – Middle Eastern (Iraq), European (Albania), Asian (Mongolia, Sri Lanka), and Caribbean (Haiti) – also appeared in the top 10 list tables.

Table 3. Top 10 DI_ODA and DICD_ODA per person (USD, Averages during 1990-2019)

Ranking	Country	DI_ODA/Pop	Ranking	Country	DICD_ODA/Pop
1	Mongolia	46.6	1	Guyana	197.5
2	Tunisia	26.5	2	Tunisia	126.7
3	Gambia	25.5	3	Mongolia	104.2
4	Sri Lanka	21.7	4	Namibia	102.4
5	Namibia	19.7	5	Nicaragua	84.6
6	Nicaragua	19.3	6	Sri Lanka	68.4
7	Senegal	16.8	7	Albania	65.4
8	Iraq	16.7	8	Senegal	59.0
9	Ecuador	14.9	9	Haiti	54.3
10	Mozambique	12.9	10	Morocco	52.4

Source: authors' calculations using ODA data from the OECD CRS Database.

3.2. Digitalisation, urbanisation, and youth population

The authors considered two variables expected to strongly influence the ODA donor's aid allocation decision. The first was the level of digitalisation which may affect aid decisions regarding digital infrastructure ODA, and the second was the level of urbanisation which may affect aid decisions on city development ODA. Therefore, two proxy variables were selected that could indicate the level of digitalisation and urbanisation. As the World Bank report (2021) adopted mobile subscriptions per person as the proxy variable for the advancement of digitalisation of developing countries, similarly this variable from the World Development Indicators (WDI) database was used to proxy for the level of digitalisation. Moreover, the authors adopted urbanisation ratio data, also taken from the WDI database, to proxy for the level of urbanisation.

Sample-country averages of these two variables showed almost monotonically increasing patterns (Figure 3), however their shapes differed. Mobile subscriptions per 100 persons rose from almost zero in 1990 to more than 100 in 2019, which implies that the mobile infrastructure has fully developed during the 1990 to 2019 period as a single person owned more than one cellular phone on average by 2013. The s-shaped curve indicates that the mobile infrastructure has rapidly grown during the 2000s, and the urbanisation ratio increased almost linearly from 1990 to 2019, rising from 46% to 58%.

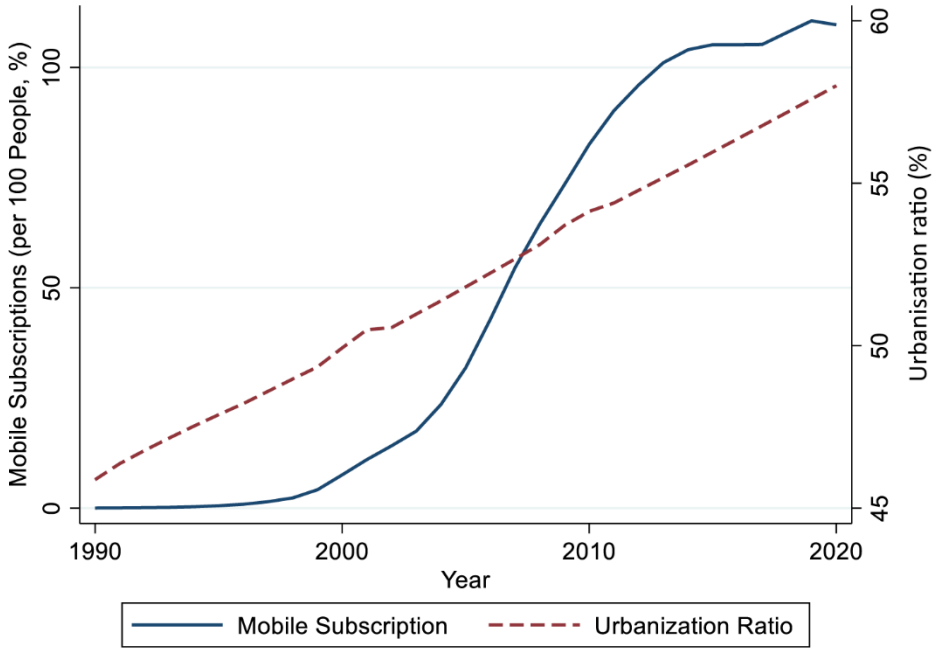

Fig. 5. Time-series Trend of Mobile Subscriptions and Urbanisation Ratio

Source: authors' calculations using data from the WDI database.

Interestingly, these two variables were both negatively related to the youth (aged 15 to 29) population ratio. In Figures 5 and 6, the downward relationship between mobile subscriptions and the youth ratio, and between the urbanisation ratio and the youth ratio are clearly shown, which emphasises the need for digital infrastructure and city development in countries with a higher youth population ratio. Note that young people are more susceptible and flexible to new digital technology compared to older generations (Vapotzis, 2017), which implies that countries with a higher youth ratio have the possibility of a faster growth if promoted appropriately – the younger the country, the greater the possibility of investment return for digital infrastructure. A similar mechanism applies to city development.

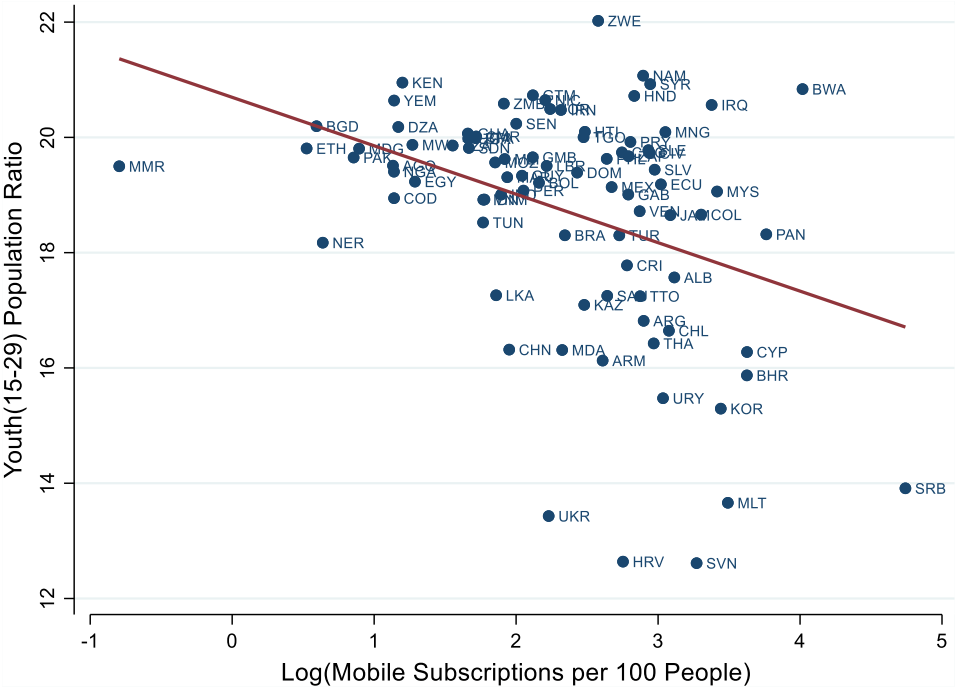

Fig. 6. Scatter Plot Graph of Youth Ratio and Mobile Subscriptions ('90~'19 Averages)

Source: authors' calculations using data from the WDI database.

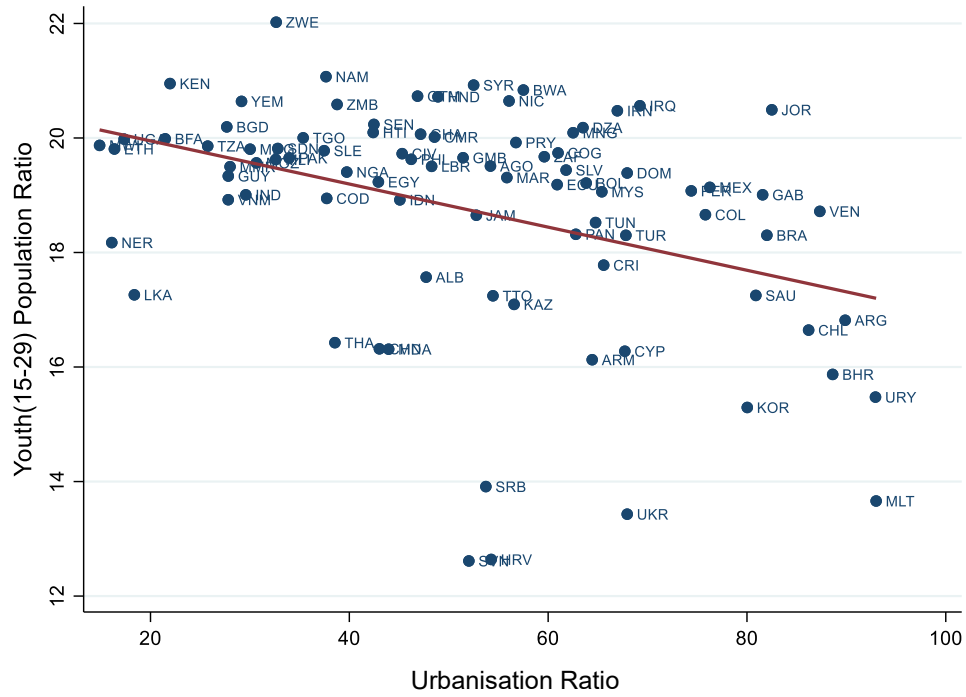

Fig. 7. Scatter Plot Graph of Youth Ratio and Urbanisation Rate ('90~'19 Averages)

Source: authors' calculations using data from the WDI database.

Table 4 shows the fixed effect panel regression models for the relationships between mobile subscription, the urbanisation ratio, and the youth population ratio. Regardless of the inclusion of country fixed effects, both variables were strongly and negatively related to the youth population ratio with statistical significance. Therefore, developing countries have a greater potential to exploit the effects of digitalisation and urbanization, considering their high youth population ratio.

Table 4. Regression Table: Youth Ratio, Mobile Subscription, and Urbanisation Ratio

	Dependent Variable: Youth Population Ratio			
Log(Mobile Subscription)	-0.211	-0.140		
	(0.000)***	(0.000)***		
Urbanisation Ratio			-0.038	-0.083
			(0.000)***	(0.000)***
Country FE		Yes		Yes
Observations	2278	2278	2576	2576
R-Squared	0.067	0.710	0.113	0.712

Note: P-values in parenthesis (*: p<0.1, **: p<0.05, ***p<0.01)

Source: produced by the authors using data from the WDI database.

4. Empirical strategy

4.1. Model specification

The empirical analysis tests the effects of DI_ODA and DICD_ODA on income growth adopting growth regression models represented by reduced-form equations

DI_ODA Models:

$$g_{yi,t} = \beta_0 + \beta_1 log(CD\_ODA_{i,t}) + \beta_2 C_{i,t} + \beta_3 \log(y_{i,t}) + \gamma X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i,t} \quad (1)$$

DICD_ODA Models:

$$g_{yi,t} = \beta_0 + \beta_1 log(DICD\_ODA_{i,t}) + \beta_2 C_{i,t} + \beta_3 \log(y_{i,t}) + \gamma X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i,t}, \quad (2)$$

where dependent variable g_y is the average annual growth rate of country i's per-capita GDP during the five-year-term period t. DI_ODA is the per-capita amount of ODA on digital infrastructure received, $DICD\_ODA$ is the per-capita amount of ODA on digital infrastructure and city development received. C refers to one of the three control variables that are related to the status of city development and may affect the dependent variable, i.e. one of the following three variables: i) the number of mobile subscribers per hundred people, which is a proxy variable that controls for the initial level of digital infrastructure, ii) youth population ratio, and iii) urbanisation ratio. Moreover, y is the lagged income variable, and X is the set of external environmental and policy variables that may influence the dependent variables (namely, trade openness, investment ratio, log of fertility rate, years of schooling, one over life expectancy, government consumption ratio, rule of law, inflation rate, democracy, and terms of trade change). DI_ODA, $DICD\_ODA$, C, and X are in the form of period-average, and lagged income variable, y, is the values at the first year, α, of each period t, taking weighted moving averages with weights 1, 2, 3, 2, and 1 for $\alpha - 1$, $\alpha - 2$, α, $\alpha + 1$, and $\alpha + 2$. Lastly, ν and υ were included to control for the country-specific and yearly period-specific fixed effects, respectively.

4.2. Regression variables

4.2.1. Dependent variable

Per-capita GDP growth is used as the dependent variable to assess how ODA for digital infrastructure, ODA for city development, and ODA for combined digital infrastructure and city development affect economic growth. The Penn World Table (PWT) version 10.0 provided data for real GDP ('*rgdpna*') and population ('*pop*'). GDP per capita was calculated by dividing real GDP by population; the five-year average annual growth rate was calculated and taken as the main dependent variable.

4.2.2. Key explanatory variables

The two versions of ODA variables: i) digital infrastructure ODA (DI_ODA), ii) digital infrastructure and city development ODA (DICD_ODA), were calculated as described in Section 2, and were population weighted.

4.2.3. Independent variables

The study collected 13 macroeconomic, environmental, and policy variables (including two squared variables) as used in Lee (2017), and the log of mobile subscriptions per 100 person data, which were used as control variables to test the effect of DI_ODA and $DICD\_ODA$ on the dependent variables.

The following independent variables were used in these models; GDP per capita and growth data were based on the 2017 constant national prices and PWT 10.0, while the investment ratio was `*csh i*', openness ratio was `*csh x*' minus `*csh m*', and government consumption ratio was `*csh g*' of PWT 10.0. Yearly inflation rate was calculated with the price level variable `pl con' of PWT 10.0. The variables of life expectancy at birth and log of fertility rate were adopted from the World Development Index (WDI). Years of schooling data were taken from the PWT Labour Detail dataset, and yearly terms-of-trade change was calculated with the commodity export and import price index data from the International Financial Statistics of the IMF. The rule of law data, based on a 0-6 scale (with 6 being the most favourable), were retrieved from the rule-of-law index of the Political Risk Services' International Country Risk Guide. The democracy index is the political-rights indicator from Freedom House, and is set to a 1-7 scale, with 7 being the most favourable (highest rights).

Table 5. Summary Statistics

	Obs.	Mean	S.D.	Min	Max	Unit	Source
Key explanatory variables							
Digital Infra (D.I.) ODA	2,336	23.645	49.651	0.000	673.816	Million USD	OECD DAC
D.I. ODA / Pop	2,336	1.036	1.800	0.000	19.942	USD	OECD DAC, PWT10.0
D.I. & City Dev (City) ODA	2,284	9.100	22.247	0.000	345.216	Million USD	OECD DAC
D.I. & City ODA / Pop	2,284	0.463	1.282	0.000	19.181	USD	OECD DAC, PWT10.0
Data used to generate dependent variables (GDP per capita)							
Real GDP	2,577	419,200	1,412,647	591	20,600,000	Million USD	PWT10.0
Population	2,577	58.727	186.706	0.362	1433.784	Million	PWT10.0
Real GDP per Capita	2,577	9,125	9,215	234	50,989	USD	PWT10.0
Control variables							
Real GDP per Capita	2,577	9,125	9,215	234	50,989	USD	PWT10.0
Mobile Subscription	2,543	45.263	50.300	0.000	210.049	Per 100 People	World Bank WDI
Youth (15-29) Ratio	2,577	18.805	2.335	9.090	25.470	One	World Bank WDI
Urbanisation Ratio	2,577	51.708	20.486	11.076	95.426	One	World Bank WDI
Investment / GDP	2,577	0.203	0.089	-0.030	0.840	One	PWT10.0
Fertility Rate	2,484	3.614	1.669	0.977	8.606	%	World Bank WDI
Years of Schooling	2,577	6.199	2.875	0.218	13.673	One	PWT10.0 Labour Detail
Life Expectancy	2,577	65.853	9.475	37.083	83.033	One	World Bank WDI
Gov. Spend. / GDP	2,577	0.168	0.074	0.005	0.609	One	PWT10.0
Law and Order	2,529	3.172	1.161	0.000	6.000	Unit-free Index	Political Risk Services
Inflation	2,491	0.023	0.144	-0.686	3.609	One	PWT10.0
Democracy Index	2,573	4.079	1.910	1.000	7.000	Unit-free Index	Freedom House
Trade Openness	2,577	0.404	0.301	0.000	1.906	One	PWT10.0
Terms of Trade	2,462	0.005	0.133	-0.378	0.837	One	IMF

Note: 86 sample countries during 1990-2019

Source: produced by the authors using data from various sources, including the WDI, OECD, Political Risk Services, Freedom House, IMF, and PWT databases.

The authors included three additional control variables other than the benchmarked variables from Lee (2017), i.e. log of mobile subscriptions per 100 people, the youth (ages 15 to 29) population ratio, and the urbanization ratio, which came from the WDI database. The study included mobile subscription to control for the current level of digitalisation of the country, as the amount of digital infrastructure could vary in accordance with the current level of digitalisation. When this level is high, the amount of ODA on digital infrastructure that the country receives may be less than other developing countries with a lower level of digitalisation, hence it can be a proxy for the level of digitalisation. The youth population ratio was included to control for the possible bias that arrived from the greater ability of the young cohort of adopting the digital advancement. Lastly, the urbanisation ratio was also included as developing countries with a higher urbanization ratio may tend to boost the effect of digital infrastructure development on economic growth. Table 5 shows the summary statistics for the regression variables.

4.3. Issues relating to endogeneity

In the literature on development aid and growth, addressing the issue of endogeneity is crucial. Several key aspects merit consideration when discussing endogeneity in the context of international development aid. Firstly, the direction of causality may not be clear as it is not always evident whether increased aid leads to economic growth or improved economic performance incentivises more aid allocation. Secondly, there is the presence of simultaneity bias – higher growth rates may encourage donor countries to provide additional assistance, intending to establish more infrastructural foundations in the recipient country, especially if the donor country identifies the recipient as a potential export market.

To tackle these challenges, the authors employed the two-step GMM estimation method proposed by Blundell and Bond (1998) and to mitigate the endogeneity concerns. This approach was complemented by presenting both the OLS fixed effects and GMM estimations in the analysis. Thus the equation for the two-step GMM estimation strategy includes two lagged dependent variables on the right-hand side:

DI_ODA GMM Models:

$$g_{yi,t} = \beta_0 + \beta_1 g_{yi,t-1} + \beta_2 g_{yi,t-2} + \beta_3 \log(CD\_ODA_{i,t}) + \beta_4 C_{i,t} + \beta_5 \log(y_{i,t}) + \gamma X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i,t} \quad (3)$$

DICD_ODA GMM Models:

$$g_{yi,t} = \beta_0 + \beta_1 g_{yi,t-1} + \beta_2 g_{yi,t-2} + \beta_3 \log(DICD\_ODA_{i,t}) + \beta_4 C_{i,t} + \beta_5 \log(y_{i,t}) + \gamma X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i,t} \quad (4)$$

5. Results

Table 6 presents a comprehensive overview of the growth regression results, with the numbers in the cells representing regression coefficients. The estimation outcomes revealed that both ‘DI ODA’ and ‘DICD ODA’ significantly contributed to economic growth, even when accounting for factors such as the youth population ratio, the urbanisation ratio, and the initial level of digitalisation, proxied with mobile subscription rates. Notably, the regression coefficients of the ‘DICD ODA’ on economic growth consistently surpassed those of ‘DI ODA’ within the same model specification. This implies that the growth effect is more pronounced when digital infrastructure ODA is implemented in conjunction with city development ODA, thereby supporting the study’s premise that the effectiveness of digitalisation is maximised when paired with city development.

In fact, the empirical analysis revealed that i) doubling per-capita ODA received for digital infrastructure was associated with a statistically significant 0.16 to 0.22 percentage point increase in annual economic growth, and ii) doubling per-capita ODA received for digital infrastructure and city development was associated with a statistically significant 0.21 to 0.28 percentage point increase in annual economic growth. The results were confirmed when tested by GMM estimation reported in Table 7. The findings remain consistent and robust, further reinforcing the validity and reliability of the authors' conclusions.

Table 6. Estimation Results: Digital Infrastructure (DI) ODA

Dependent Variable: GDP per Capita Growth								
	FE (1)	GMM (1)	FE (2)	GMM (2)	FE (3)	GMM (3)	FE (4)	GMM (4)
1-Period-Lagged GDP per Capita Growth		0.900		0.714		0.781		0.846
		(0.000)***		(0.000)***		(0.000)***		(0.000)***
2-Period-Lagged GDP per Capita Growth		-0.248		-0.302		-0.283		-0.307
		(0.000)***		(0.000)***		(0.000)***		(0.000)***
Ln(DI ODA/Pop)	0.156	0.200	0.164	0.156	0.163	0.222	0.167	0.181
	(0.001)***	(0.020)**	(0.000)***	(0.008)***	(0.000)***	(0.024)**	(0.000)***	(0.034)**
Ln(Mobile/Pop)			0.133	0.072				
			(0.076)*	(0.549)				
Ln(Youth Ratio)					-0.202	-0.289		
					(0.004)***	(0.122)		
Ln(Urbanisation)							0.060	0.111
							(0.011)**	(0.254)
Ln(Lagged Income)	-0.086	-0.066	-0.077	-0.079	-0.088	-0.082	-0.086	-0.062
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Investment/GDP	0.029	-0.001	0.014	0.043	0.030	0.022	0.030	0.024
	(0.014)**	(0.982)	(0.198)	(0.003)***	(0.011)**	(0.499)	(0.010)***	(0.314)
Log(Fertility Rate)	0.022	0.006	0.022	-0.006	0.011	-0.020	0.024	-0.022
	(0.006)***	(0.794)	(0.003)***	(0.460)	(0.186)	(0.479)	(0.002)***	(0.237)
Years of Schooling	-0.004	-0.004	-0.002	-0.001	-0.005	-0.016	-0.004	-0.006
	(0.014)**	(0.228)	(0.132)	(0.418)	(0.002)***	(0.002)***	(0.013)**	(0.131)
1/(Life Expectancy)	-2.513	3.540	-0.173	-0.710	-2.889	2.778	-2.375	1.514
	(0.002)***	(0.086)*	(0.841)	(0.656)	(0.000)***	(0.401)	(0.003)***	(0.630)
Govt. Spending/GDP	-0.103	-0.012	-0.097	0.006	-0.108	-0.060	-0.103	-0.051
	(0.000)***	(0.620)	(0.000)***	(0.670)	(0.000)***	(0.025)**	(0.000)***	(0.037)**
Rule of Law	0.003	-0.004	0.002	-0.003	0.003	-0.006	0.003	-0.003
	(0.037)**	(0.079)*	(0.091)*	(0.150)	(0.024)**	(0.043)**	(0.020)**	(0.068)*
Inflation	-0.057	-0.013	-0.060	0.006	-0.054	-0.004	-0.057	-0.037
	(0.000)***	(0.341)	(0.000)***	(0.283)	(0.000)***	(0.819)	(0.000)***	(0.007)***
Democracy	0.003	-0.002	0.004	0.000	0.003	0.000	0.003	0.002
	(0.000)***	(0.284)	(0.000)***	(0.811)	(0.000)***	(0.865)	(0.000)***	(0.312)
Trade Openness	0.056	0.044	0.060	0.079	0.055	0.036	0.057	0.035
	(0.000)***	(0.004)***	(0.000)***	(0.000)***	(0.000)***	(0.069)*	(0.000)***	(0.037)**
Terms of Trade Chg.	0.088	0.009	0.093	0.023	0.090	0.025	0.089	0.035
	(0.000)***	(0.513)	(0.000)***	(0.000)***	(0.000)***	(0.077)*	(0.000)***	(0.006)***
Observations	1,916	1,915	1,861	1,860	1,916	1,915	1,916	1,915
R-Squared	0.583		0.597		0.585		0.585	
Adj. R-Squared	0.555		0.569		0.557		0.557	
AR (1)		0.006		0.002		0.010		0.006
AR (2)		0.610		0.191		0.417		0.503

Note: P-values in parenthesis (*: p<0.1, **: p<0.05, ***p<0.01); The regression coefficients for 'DI ODA', mobile, youth ratio, and urbanisation are reported with the multiplications of 100; country and period fixed effects are included; Arellano-Bond tests AR(1) and AR(2) report the p-values for a test of first and second order serial correlation in the residual. The results of Arellano-Bond tests in the first-differenced errors do not reject the validity of the model specifications.

Source: produced by the authors using data from various sources, including the WDI, OECD, Political Risk Services, Freedom House, IMF, and PWT databases.

Table 7. Estimation Results: Digital Infrastructure and City Development (DICD) ODA

Dependent Variable: GDP per Capita Growth								
	FE (1)	GMM (1)	FE (2)	GMM (2)	FE (3)	GMM (3)	FE (4)	GMM (4)
1-Period-Lagged GDP per Capita Growth		0.940		0.714		0.781		0.846
		(0.000)***		(0.000)***		(0.000)***		(0.000)***
2-Period-Lagged GDP per Capita Growth		-0.298		-0.302		-0.283		-0.307
		(0.000)***		(0.000)***		(0.000)***		(0.000)***
Ln(DI ODA/Pop)	0.257	0.211	0.251	0.252	0.277	0.232	0.269	0.208
	(0.000)***	(0.015)**	(0.000)***	(0.002)***	(0.000)***	(0.014)**	(0.000)***	(0.000)***
Ln(Mobile/Pop)			0.092	0.145				
			(0.214)	(0.421)				
Ln(Youth Ratio)					-0.223	-0.248		
					(0.001)***	(0.043)**		
Ln(Urbanisation)							0.034	-0.088
							(0.138)	(0.101)
Ln(Lagged Income)	-0.088	-0.055	-0.076	-0.062	-0.090	-0.056	-0.088	-0.042
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Investment/GDP	0.028	-0.001	0.010	-0.007	0.029	0.005	0.028	-0.000
	(0.017)**	(0.961)	(0.352)	(0.864)	(0.013)**	(0.837)	(0.015)**	(0.999)
Log(Fertility Rate)	0.022	-0.009	0.021	-0.024	0.011	-0.031	0.024	-0.006
	(0.005)***	(0.731)	(0.005)***	(0.095)*	(0.213)	(0.262)	(0.003)***	(0.496)
Years of Schooling	-0.004	-0.003	-0.003	-0.002	-0.006	-0.010	-0.005	-0.003
	(0.007)***	(0.254)	(0.062)*	(0.226)	(0.001)***	(0.001)***	(0.006)***	(0.022)**
1/(Life Expectancy)	-3.143	0.979	-0.563	-1.214	-3.539	-0.276	-3.074	-1.333
	(0.000)***	(0.611)	(0.508)	(0.553)	(0.000)***	(0.892)	(0.000)***	(0.198)
Govt. Spending/GDP	-0.090	-0.022	-0.090	-0.009	-0.096	-0.048	-0.090	0.028
	(0.000)***	(0.372)	(0.000)***	(0.651)	(0.000)***	(0.067)*	(0.000)***	(0.116)
Rule of Law	0.001	-0.006	0.001	-0.004	0.002	-0.005	0.002	-0.003
	(0.299)	(0.009)***	(0.311)	(0.071)*	(0.242)	(0.019)**	(0.259)	(0.092)*
Inflation	-0.058	-0.013	-0.060	0.002	-0.056	-0.014	-0.058	-0.007
	(0.000)***	(0.329)	(0.000)***	(0.903)	(0.000)***	(0.304)	(0.000)***	(0.154)
Democracy	0.003	-0.001	0.003	0.001	0.003	0.001	0.003	0.000
	(0.000)***	(0.610)	(0.000)***	(0.657)	(0.000)***	(0.722)	(0.000)***	(0.941)
Trade Openness	0.058	0.026	0.060	0.087	0.057	0.021	0.058	0.062
	(0.000)***	(0.123)	(0.000)***	(0.000)***	(0.000)***	(0.203)	(0.000)***	(0.000)***
Terms of Trade Chg.	0.089	0.023	0.094	0.023	0.092	0.021	0.089	0.017
	(0.000)***	(0.037)**	(0.000)***	(0.015)**	(0.000)***	(0.060)*	(0.000)***	(0.001)***
Observations	1,916	1,915	1,861	1,860	1,916	1,915	1,916	1,915
R-Squared	0.583		0.597		0.585		0.585	
Adj. R-Squared	0.555		0.569		0.557		0.557	
AR (1)		0.002		0.002		0.010		0.006
AR (2)		0.544		0.191		0.417		0.503

Note: P-values in parenthesis (*: p<0.1, **: p<0.05, ***p<0.01); The regression coefficients for 'DI ODA', mobile, youth ratio, and urbanisation are reported with the multiplications of 100; country and period fixed effects were included; the Arellano-Bond tests AR(1) and AR(2) report the p-values for a test of first and second order serial correlation in the residual. The results of Arellano-Bond tests in the first-differenced errors do not reject the validity of the model specifications.

Source: produced by the authors using data from various sources, including the WDI, OECD, Political Risk Services, Freedom House, IMF, and PWT databases.

6. Discussion

The empirical results revealed a strong and positive relationship between ODA allocated to digital infrastructure and economic growth of the developing countries, and their impact was further amplified when digital infrastructure investment was combined with city development initiatives. The findings indicate that doubling per-capita ODA for digital infrastructure alone leads to a statistically significant increase in annual economic growth ranging from 0.16 to 0.22 percentage points. However, when digital infrastructure investments are paired with city development, the growth effect increases to a range of 0.21 to 0.28 percentage points.

These results highlight the complimentary nature of digital infrastructure and city development. While digitalisation fosters economic growth through improved connectivity and enhanced productivity, the broader physical and institutional environment significantly influences its effectiveness. Investment in city development, such as urban planning, transportation networks, and disaster resilience, strengthen the ability of digital infrastructure to facilitate economic activity. The findings suggest that integrated approaches combining urban and digital infrastructure strategies generate greater economic benefits than standalone investments in digital connectivity.

Furthermore, this suggests that the impact of digital infrastructure is stronger in countries with higher youth population ratios and increasing urbanisation levels. These demographic trends indicate that younger and more urbanised populations are more capable of adopting and utilising digital technologies, which in turn accelerates economic transformation. This underlines the importance of aligning digitalisation policies with broader socio-economic factors such as education and labour market readiness.

Comparing these results with prior studies, one can observe that while earlier research established the role of ICT in development (Hjort & Poulsen, 2019), this study extends this knowledge by quantifying the combined effects of digital infrastructure and city development. These findings offer a new perspective for policymakers and development practitioners, emphasising the need for holistic strategies that integrate digital connectivity with broader economic planning. Additionally, by empirically evaluating the effect of ODA, this study provides specific guidance on how development aid can be strategically allocated to support sustainable growth in developing nations, ultimately contributing to global efforts to close the digital divide.

7. Conclusions

The era of globalisation has witnessed simultaneous economic growth and development alongside a widening global inequality. While substantial global efforts have been made to alleviate extreme poverty, the recent pandemic has exacerbated global disparities, with the digital divide emerging as a critical determinant of success and failure during crises. Acknowledging the urgency of addressing the digital divide in the post-pandemic landscape, where digital skills are indispensable across economic sectors, this paper explored the impact of Official Development Assistance (ODA) allocated to digital infrastructure on economic growth. Additionally, the authors examined the synergies between digital infrastructure development and city development, aiming to contribute valuable insights to the existing literature on the efficacy of ODA in fostering growth through these channels.

In utilising the OECD CRS data to scrutinise the relationship between ODA and economic growth, our findings stressed the significant positive effects of ODA allocated to digital infrastructure (‘DI ODA’) and the combination of digital infrastructure and city development (‘DICD ODA’) on economic growth. Even after controlling for the youth population ratio, the urbanization ratio, and the initial level of digitalisation, both ‘DI ODA’ and ‘DICD ODA’ exhibited substantial contributions to economic growth. Particularly noteworthy is the consistent superiority of ‘DICD ODA’ over ‘DI ODA’ within the same model specification, emphasising the strategic importance of placing productive digital infrastructure.

The empirical analysis demonstrated that: i) doubling per-capita ODA received for digital infrastructure is associated with a statistically significant 0.16 to 0.22 percentage point increase in annual economic growth, and ii) doubling per-capita ODA received for digital infrastructure and city development is associated with a statistically significant 0.21 to 0.28 percentage point increase in annual economic growth. Note that the results remained the same even when tested with GMM estimations to control for endogeneity laid in development aid and economic growth relationship.

The paper provides compelling evidence highlighting the vital role of digitalisation and city development in the context of developing countries. The challenges posed by the Covid-19 pandemic stress the significance of promoting digitalisation as a crucial strategy for bridging the gap between developing and developed nations. Moreover, digitalisation has emerged as a key pillar for economic development, enabling smarter production processes that promote productive servitisation over 'premature deindustrialization.' Governments are strongly urged not to underestimate the significance of digital infrastructure and city development. Encouraging the accumulation of productive digital infrastructure and its judicious allocation should be a priority in policy formulation. These efforts, in addition to enhancing the effectiveness of ODA, hold the potential to catalyse overall economic growth and development in developing countries. The strategic integration of digitalisation and city development is not merely a response to current challenges, but also a forward-looking approach in line with the evolving needs of a rapidly changing global landscape.

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Received: March 2024, revised: April 2025

Acknowledgement: *Woosik Yu is the corresponding author. Jean Lee and Woosik Yu contributed equally as co-first authors. The authors appreciate the valuable comments from the anonymous reviewers, which greatly improved the paper.*