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Enhancing human development in developing regions: Do ICT and transport infrastructure matter?

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ABSTRACT

Recent scholarly and policy discussions have focused on whether information and communication technology (ICT) and transport infrastructure enhance human development outcomes in developing countries. This study contributes to the knowledge and policy by exploring the impact of transport and ICT infrastructure on human development using comprehensive panel data for 79 countries from 1990 to 2018. Applying the two-step IV-GMM to correct endogeneity, our results reveal that for the transport infrastructure indicators, while port connectivity and port traffic enhance human development, freight and rail infrastructures do not. For the ICT infrastructure, the findings indicate that broadband, internet, and mobile phone penetration improve human development while telephone penetration and ICT goods have a neutral effect. The study also reveals that transport and ICT infrastructure have a disparate impact on human capital (education) and health (life expectancy, under-five, and maternal mortality). Further analysis reveals that the results differ among South Asia, sub-Saharan Africa, and Latin America-Caribbean. These results are robust to an alternative econometric estimator. The policy implications of these findings are discussed.

1. Introduction

This paper investigates the role of information and communication technology (ICT) and transport infrastructure in enhancing human development in developing regions. The need for critical infrastructure to support strong transitioning to sustainable development is compelling, especially in developing countries with the largest gap for most development indicators. Modernising existing infrastructure is important because it is a critical part of modern logistics that will support development in other sectors, including support for modern technologies for upcoming vaccines, electric cars, e-commerce and other modern facilities. Not modernising leaves developing countries further behind and, worse still, hinders the world's progress in meeting important targets in the match to develop sustainably for a better world together. Limitations of existing infrastructure are made more visible by the required conditions needed to facilitate the distribution of, for example, Pfizer vaccine for Covid-19, which include specific temperature storage requirements. Infrastructure that supports fast identification and deployment of critical amenities to disaster zones, facilities for modern gadgets use such as electric car/equipment charging facilities, and technologies to generate energy from available and sustainable sources, among others, could play a role in bridging the development gap.

Amartya Sen's capability approach to human development suggests that the capability to function is at the centre of human development (Sen, 1980; Sen, 1999). In recent policy discussions, basic capabilities are insufficient; enhanced capabilities are essential for people to own their lives (UNDP, 2019). Enhanced capabilities include having access to quality health and education at all levels as well as present-day technologies, and being resilient to new shocks (UNDP, 2019). Recently, the UNDP (2019) human development report indicated that the world had made a stride in improving living standards with many people escaping hunger, poverty and diseases, but lamented that many people are still left behind despite such global improvements. The report highlighted gaps that needed attention, including the fact that the difference in life

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expectancy at birth between the developed and developing countries is 19 years, while the difference in life expectancy at age 70 is approximately five (5) years. In addition, the report revealed that just about 42% of the adult population living in developing countries have primary education compared to 94% in developed economies. In the same vein, 3.2% of developing countries' adult population have tertiary education compared to the 29% in developed economies.

It is highlighted that poor human development outcomes in developing countries could be associated with lower economic growth, weak social cohesion and mistrust in government and institutions, and these further impede efforts to achieve the 2030 Agenda for Sustainable Development (UNDP, 2019). Therefore, enhancing human development in developing countries remains a priority in national and international development strategies. In recent scholarly and policy discussions, emphasis has been placed on whether investment in infrastructure (such as transport and ICT) enhances inclusive human development in developing countries (Agénor, 2010; Agénor & Neanidis, 2011; Asongu & Le Roux, 2017). The academic literature thoroughly discusses the role of transport and ICT infrastructure in sustaining economic development. For instance, in Agénor (2010) development theory, public infrastructure, including transportation and ICT, is the main engine of economic development. Agénor (2010) argues that government expenditure on public infrastructure and other commodities enhances health services and delivery. In the same vein, Arrow & Kruz (1970; 2013), including infrastructure in the production function, show that a rise in infrastructure directly affects output and indirectly affects production by raising the marginal productivity of other factors of production such as labour and capital. Calderón & Servén (2014) further highlighted that considering infrastructure just like any other input in the production function is a direct way of capturing firms' or producers' use of infrastructural services such as transport. Apart from the role of infrastructure in the production function, other strands of the literature have looked at how infrastructure affects other aspects of the economy and the well-being of people (see, for instance, Lennon, Cantore & Clara 2015; Jalan & Ravallion, 2003).

Given the role of physical infrastructure in economic development, developing countries still face transportation and ICT infrastructure challenges. For instance, the UNDP (2019) report revealed that regarding access to broadband, developing countries have less than one (1) subscription per 100 inhabitants, compared with 28 per 100 inhabitants in developed economies. From the perspective of developing regions, 26% of Sub-Saharan Africa's (SSA) population were connected to mobile internet broadband in 2019 while 49% that lived within access areas were still not connected[1] (Okeleke & Suardi, 2019). Also, 33% of South Asia's (SAR) population had access to mobile internet in 2019, while over 500 million additional people in the region gained mobile broadband coverage during the same period[2]. Whereas about 54% of the Latin America & Caribbean (LAC) population was connected to mobile internet broadband in 2019, 39% that lived within access areas were still not using it[3]. Concerning transport infrastructure, SSA's poor road, rail, and harbour infrastructure was shown to increase the cost of traded goods among SSA countries by 30-40% (Pottas, 2014). Besides, the poor state of SSA infrastructure, including transport and ICT infrastructure, was noted to have reduced the region's economic growth by 2% while reducing business productivity by approximately 40% (Pottas, 2014). Also, SAR is one of the least integrated regions globally, with poorly developed transport networks and transport facilitation measures. The infrastructure deficit in SAR has been associated with a 3-4% decline in the gross domestic product (GDP) (Kumar & Arora, 2019; UNESCAP, 2017). According to the Inter-American Development Bank, the physical infrastructure deficit in LAC is estimated to cost the region 1% of GDP and would accumulate to 15% of GDP forgone if the deficit continues over ten (10) years[4]. Generally, SAR, SSA and LAC have the worst infrastructure quality globally[5].

With the macroeconomic implications of physical infrastructure, some scholars have either examined the impact of transport infrastructure or ICT on economic growth (Marazzo, Scherre, & Fernandes, 2010; Mohmand, Wang, & Saeed, 2017; Pradhan & Bagchi, 2013; Vlahinić Lenz, Pavlić Skender, & Mirković, 2018) and trade (Francois & Manchin, 2013; Portugal-Perez & Wilson, 2012; Vijil & Wagner, 2012). However, these existing empirical studies have not actively engaged the role of transport and ICT infrastructure on inclusive human development in developing regions (for instance, see Asongu & Le Roux, 2017). Therefore, given the human development and physical infrastructure challenges in developing countries, this paper seeks to fill this research gap by investigating the impact of transport and ICT infrastructure on human development using 79 countries from SSA, SAR and LAC. This study has significant policy implications because investment in transport and ICT infrastructure can be guided by policy to achieve inclusive development outcomes in developing regions. To achieve the objective of this paper and contribute to the literature and policy discussions, we address the following three (3) key research questions:

1 *What is the unconditional effect of ICT and transport infrastructure on human development outcomes in developing regions?*
2 *Which aspect of ICT and transport infrastructure matters most in enhancing human development in developing regions?*
3 *Is there any differential effect of ICT and transport infrastructure on human development among the developing regions?*

In this study, our findings show that for the transport infrastructure indicators, port connectivity and port traffic infrastructures enhance human development but freight and rail infrastructures do not. For the ICT infrastructure, the findings indicate that broadband, internet, and mobile phone penetration improve human development while telephone penetration and ICT goods have a neutral effect. Our results also reveal that transport and ICT infrastructure have a disparate impact on the components of human development- human capital (education) and health (life expectancy, under-five, and maternal mortality). Further analysis reveals that the results differ among SAR, SSA, and LAC.

2. Theory and empirical evidence

For many years, increasing economic growth and reducing inequality have remained the primary economic agenda of governments of developing countries as they believe these would help eliminate poverty and economic hardship. The need for this growth and inequality reduction has been intense in recent times, particularly in the wake of the Sustainable Development Goals (SDGs). However, it is worrying that many developing countries are not close to achieving these goals amid the many efforts made. Attaining economic growth in recent years transcends just the possession of vast natural resources as in many African countries. Investment in ICT, energy and transport infrastructure, among others, have been critical factors driving growth, particularly in the 21st century. Investment in infrastructure and infrastructural services is upheld to reduce production costs, enhance the returns on capital and the efficiency of private inputs, open new markets, create

[1] https://www.gsma.com/r/wp-content/uploads/2020/09/Mobile-Internet-Connectivity-SSA-Fact-Sheet.pdf

[2] https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/09/Mobile-Internet-Connectivity-SouthAsia-Fact-Sheet.pdf

[3] https://www.gsma.com/r/wp-content/uploads/2020/09/Mobile-Internet-Connectivity-LatAm-Fact-Sheet.pdf

[4] https://www.iadb.org/en/news/idb-study-estimates-big-gdp-impacts-low-infrastructure-investments-latin-america

[5] https://publications.iadb.org/publications/english/document/2019_Latin_American_and_Caribbean_Macroeconomic_Report_Building_Opportunities_to_Grow_in_a_Challenging_World_en_en.pdf

jobs, and make domestic firms more competitive (Fedderke and Bogetic, 2009; Agénor, 2010).

The output effect of infrastructure has long been considered after the seminal work of Arrow & Kruz (1970; 2013), where the stock or flow (services) of infrastructure is modelled as an input of aggregate production function. The inclusion of infrastructure in the production function follows the assumption that it is a gross complement for labour and non-infrastructural capital in the production function (Calderón & Servén, 2014). In this framework, a rise in infrastructure affects output directly and indirectly by raising the marginal productivity of other factors of production, such as labour and capital. However, Barro (1990), within an endogenous growth framework, highlights that since the infrastructure is financed through taxation, expansion in infrastructure could imply a tax increase. This could offset fully or partially the complementary role of infrastructure on the other factors of production as it reduces their marginal productivities. Calderón & Servén (2014) assert that considering infrastructure just like any other input in the production function is a direct way of capturing firms' or producers' use of infrastructural services such as electricity and transport. Infrastructure may also be considered in the production function not as a direct input but as a determinant of aggregate total productivity which has a spillover effect on the productivity of other factors (Hulten & Schwab, 2000). Apart from its role in the production function, other strands of the literature have looked at how infrastructure affects other aspects of the economy and the well-being of people.

Energy infrastructure drives businesses and production, and improves the well-being of people. Access to electricity is noted as one of the seeming differences between development and underdevelopment, hence a major distinguishing factor between developed and developing countries. This is the case as electricity serves as both direct and indirect[6] factor of production, improves transportation and health as well as hygiene service delivery, makes learning and education effective, provides security and means of entertainment, provides lighting, enhances agriculture, saves time in searching for traditional means of energy (giving extra time for occupational activities), drives modern technology and enhances job creation (Adom, Opoku, & Yan, 2019; Gaye, 2008; Gujba et al., 2012; Islam et al., 2013).

ICT infrastructure has become an important industrialisation drive. We live in an era of technological explosion where technological trends largely dictate almost every aspect of economic activity. Besides, the taste and preference of consumers have significantly been dictated by technology in recent years. Technology can boost manufacturing in several ways, including producers getting to know the latest international demand patterns and then producing to meet these demands, getting to know the latest production methods and new equipment, and ensuring effective communication between producers and customers both home and abroad. As a result, firms that can access and utilise the latest technologies can be more productive and produce to meet demand and be competitive locally and internationally (Dahlman, 2007; Fagerberg et al., 2010; Lennon, Cantore & Clara 2015). Technology is the primary driver of manufacturing growth. Lennon, Cantore & Clara (2015) show empirically in 146 countries that technology-intensive manufacturing industries are more productive relative to low-tech manufacturing industries.

Good transportation infrastructure (including road, air, sea and railway transport infrastructure) ensures swift and effective movement of people and resources, saves time, and enhances productivity. Adequate transportation is touted to reduce trade costs (Portugal-Perez & Wilson, 2009, 2012). The reduction in trade costs affects the final prices of goods and services, which eventually positively affects consumer welfare and the competitiveness of domestic firms in international markets. In many developing countries, transportation, however, remains a challenge. For example, transportation in Africa remains one of the most expensive globally (KPMG, 2013). In addition to the high cost of transportation, many roads, air, and rail systems in the region are unconnected, rendering movement of people and goods difficult. A study conducted by KPMG (2013) revealed that only Morocco, Tunisia, Egypt, Namibia, South Africa, and Swaziland have better rail systems than the world average, and only 11 African countries have road systems that rate above the world average. Water and sanitation infrastructure saves time spent to search for water and improves health, thereby enhancing the well-being and productivity of people (Agénor, 2010).

Considering the preceding arguments, infrastructural services tend to have a strong growth-enhancing effect (Agénor, 2010). Hence, in Agénor's development theory, public infrastructure is posited as the main engine of growth. Agénor considers a closed economy populated by a single, infinitely lived household/producer that produces a single good that can be consumed or invested. Through tax on the output of the household, the government spends on public infrastructure and other commodities used in providing health services. Agénor shows that the provision of infrastructure and health services raise labour productivity and reduces the rate of time preference. The provision of infrastructure also improves health delivery. The improvement in health and labour productivity raises incentives for the household to save, thereby reducing impatience and preference for the present. With a lower time preference rate, the marginal utility of future consumption rises, hence stimulating savings, which enhance physical capital accumulation and growth. Agénor concludes that the efficacy of infrastructure will depend on the adequacy of governance. If governance is adequate to safeguard an ample degree of efficiency of public investment, a rise in the share of expenditure on infrastructure may enhance the movement from a low growth equilibrium (with its associated low productivity and savings) to a high growth steady-state (Agénor, 2010).

The growth-enhancing effects and benefits of infrastructural development have attracted a chunk of the empirical literature. Studies on the effect of infrastructure on economic growth, productivity, and welfare mainly started with Aschauer (1989). Aschauer (1989) found that the stock of public infrastructure capital highly influences aggregate total factor productivity of the United States. The researcher found the elasticity of output with respect to infrastructure to be around 0.40. A chunk of the papers that followed employed varied samples of countries and methodologies. For example, Berndt & Hansson (1992) assessed how public infrastructure capital contributes to the growth of the private sector in Sweden between the period 1960 and 1988 and generally found that infrastructure reduces production costs and increases firms' profits. In India, Datta (2012) investigates the effect of a major road improvement initiative and find that firms located on the highways targeted by the initiative had a significant cut in the cost of production. Employing panel data of 24 Chinese provinces between 1985 and 1998, Démurger (2001) identifies transport and telecommunication infrastructure as the major differentiating factors accounting for the varied provincial growth performance in explaining the growth gap. However, in a more recent study, Banerjee, Duflo & Qian (2020) find that closeness to transportation networks in China has a slight positive causal effect on per capita GDP levels across sectors but no effect on per capita GDP growth. For 75 countries between 1965 and 1995, Esfahani & Ramírez (2003) find that the contribution of infrastructure services (in the electricity and telecom sectors) to economic growth is sizeable and, at large, greater than the cost of providing those services. They, however, emphasise that attaining the effect depends on the institutional and economic characteristics of the countries. Concerning water and sanitation infrastructure, Jalan & Ravallion (2003), in their study, find that the prevalence and length of diarrhoea in children less than five years in rural India is lesser among households with pipe-borne water.

Some studies have specifically focused on energy infrastructure; for example, Yang, Zhang & Sun (2020), using data for the period 2000-2014, find that energy infrastructure investment (power grid infrastructure) in China may generate higher marginal benefits for the

[6] Energy serves as an indirect factor of production by intensifying the potency/productivity of other factors of production.

Table 1
Variable descriptions

Variables	Indicators	Definition	Mean	Std. Dev.	Min	Max	Source
Dependent variables							
Human development index	lnhdi	Human Development Index	-0.618	0.290	-1.666	-0.081	UNDP
Human capital index	lnhc	Human capital index, based on years of schooling and returns to education	0.623	0.279	0.029	1.261	Penn World Tables (9.1)
Life expectancy	lnlifexp	Life expectancy at birth, total (years)	4.116	0.170	3.265	4.383	WDI
Under-five mortality	lnunfd	Number of under-five deaths	9.213	2.579	2.303	15.044	WDI
Maternal mortality	lnmmrm	Maternal mortality ratio (modelled estimate, per 100,000 live births)	5.132	1.239	0.000	7.496	WDI
Control variables							
Income	lnY	GDP per capita (constant 2010 US$)	7.586	1.199	5.102	10.381	WDI
Trade openness	lnTRA	Trade (% of GDP)	4.118	0.491	2.406	5.741	WDI
Urbanisation	lnUR	Urban population (% of total population)	3.684	0.521	1.689	4.557	WDI
Foreign direct investment	lnFDI	Foreign direct investment, net inflows (BoP, current US$)	18.986	2.439	6.908	25.352	WDI
Financial development	lnFD	Domestic credit to private sector (% of GDP)	2.891	0.909	-0.910	5.076	WDI
Remittance	lnRE	Personal remittances, received (current US$)	18.718	2.476	8.706	25.090	WDI
Electric power losses	lnEC	Electric power transmission and distribution losses (% of output)	2.729	0.695	-3.284	4.478	WDI
Transport infrastructures variables							
Freight infrastructure	lnTF	Air transport, freight (million ton-km)	2.641	2.695	-5.615	7.902	WDI
Rail infrastructure	lnTR	Rail lines (total route-km)	7.565	1.305	5.557	11.134	WDI
Port connectivity	lnTL	Liner shipping connectivity index (maximum value in 2004 = 100)	2.539	0.767	-0.222	4.137	WDI
Port traffic	lnTP	Container port traffic (TEU: 20-foot equivalent units)	13.068	1.659	8.838	16.646	WDI
ICT infrastructures variables							
Broadband penetration	lnCB	Fixed broadband subscriptions (per 100 people)	-0.978	2.680	-9.963	3.441	WDI
Telephone penetration	lnCT	Fixed telephone subscriptions (per 100 people)	0.847	1.738	-5.118	3.959	WDI
ICT goods penetration	lnCCT	ICT goods imports (% total goods imports)	1.496	0.638	-5.177	3.460	WDI
Internet penetration	lnCI	Individuals using the Internet (% of population)	0.838	2.668	-10.953	4.443	WDI
Mobile phone penetration	lnCC	Mobile cellular subscriptions (per 100 people)	2.194	2.791	-8.371	5.284	WDI

Note: UNDP represents the United Nation Development Programme; WDI represents World Development Indicators

less developed inland areas than the developed coastal areas. Acheampong, Dzator & Shahbaz (2021), using data from 166 countries from 1990 to 2017, find that rural and urban electrification reduce global income inequality. The impact is found to be more vital for urban electrification. However, the subsampling analysis showed varied outcomes for LAC, SSA, SAR, East Asia & Pacific, Middle East & North Africa, and Europe & Central Asian countries. Using data over the period 2004–2015 on Brazilian states, Medeiros & Ribeiro (2020) show that in an instance where most of the population have access to electricity, expansion in power electricity reduces income inequality. However, the effect of increasing access to electricity on inequality is small when the quality of the power infrastructure is high. Dinkelman (2011) examines the impact of the tremendous electricity expansion in rural South Africa on employment (mainly female employment) and finds that electrification increases female employment, making them earn about 9 hours more per week in districts that experienced an average increase in electrification. Dinkelman (2011) explains that this is feasible as electricity saves females significant time in accessing energy, cooking, and lighting.

A chunk of literature has also been attributed to the effect of infrastructure on trade and trade facilitation. For instance, using bilateral trade data, Francois & Manchin (2013) show that, among other things, the export performance of countries hinges on access to quality transport and ICT infrastructure by both importers and exporters. Their results indicate that poor infrastructural development could render low-income countries trading about 74% less than high income countries. Similarly, Portugal-Perez & Wilson (2012) show evidence of 100 countries over the period 2004-2007 that general infrastructure (seaports, airports, roads, rail, ICT) improvement quality enhances export growth and performance. They, however, show that the effect of physical infrastructure and ICT on exports becomes more critical as countries get richer. Building a comprehensive infrastructure index including transport, communication, and energy indicators for 150 developed and emerging economies for the period 1992-2011, Donaubauer et al. (2018) show that improving infrastructural quality decreases trade costs and increases international trade flows. Using a sample between 2002 and 2008, Vijil & Wagner (2012) show that a 10% rise in aid for infrastructure in developing countries enhances export performance by about 2.34% on average. Thus, it is largely found that infrastructure quality and development improve trade performance, and trade is generally known to promote economic growth (see Berg & Schmidt, 1994; Greenaway, Morgan & Wright, 1999; Awokuse, 2008).

The above literature survey indicates that scholars have mainly examined the impact of transport infrastructure or ICT on economic growth (Marazzo et al., 2010; Mohmand et al., 2017; Pradhan & Bagchi, 2013; Vlahinić Lenz et al., 2018) and trade (Francois & Manchin, 2013; Portugal-Perez & Wilson, 2012; Vijil & Wagner, 2012), but these empirical studies have not actively engaged the role of transport and ICT infrastructure on inclusive human development in developing regions (for instance, see Asongu & Le Roux, 2017). This paper seeks to fill this research gap and contribute to the literature by investigating the impact of transport and ICT infrastructure on human development using 79 countries from SSA, SAR and LAC.

3. Methodology and Data

3.1. Estimation Strategy

This study evaluates the effect of transport and ICT infrastructure on human development outcomes in developing regions. In view of this, we adapt the human development empirical model used by Acheampong, Erdiaw-Kwasie, and Abunyewah (2021) and Asongu and Le Roux (2017). Following these studies, we state that human development outcomes (HD) depend on income (Y), transport infrastructure variables (T), ICT infrastructure variables (C) and other control covariates (Z)

$$HD = f(Y,\ T, C, Z) \tag{1}$$

Transforming equation (1) into its log-linear form provides an

Table 2A
The effect of ICT and transport infrastructure on composite human development (IV-GMM results)
Unconditional effect results

Variables	1	2	3	4	5	6	7	8	9
lnY	0.177***	0.077***	0.065***	0.100***	0.109***	0.103***	0.129***	0.097***	0.101***
	(0.014)	(0.026)	(0.016)	(0.015)	(0.013)	(0.018)	(0.012)	(0.013)	(0.012)
lnTRA	0.034**	0.046	0.073***	0.098***	0.074***	0.076***	0.084***	0.059***	0.035**
	(0.016)	(0.046)	(0.023)	(0.021)	(0.022)	(0.016)	(0.019)	(0.017)	(0.017)
lnUR	0.019	0.214***	0.103***	0.037	0.135***	0.134***	0.160***	0.151***	0.149***
	(0.036)	(0.060)	(0.034)	(0.034)	(0.036)	(0.032)	(0.037)	(0.032)	(0.033)
lnFDI	-0.002	0.014*	-0.031***	-0.020***	-0.020***	0.001	-0.017***	-0.008*	-0.013***
	(0.005)	(0.009)	(0.007)	(0.007)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)
lnFD	0.013	-0.014	-0.060***	-0.069***	-0.021*	-0.006	0.001	-0.015	-0.009
	(0.009)	(0.020)	(0.013)	(0.014)	(0.011)	(0.009)	(0.011)	(0.010)	(0.010)
lnRE	0.010***	0.003	-0.007	-0.003	0.006*	0.005	0.008**	-0.001	-0.002
	(0.003)	(0.007)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
lnEC	-0.061***	-0.079***	-0.191***	-0.154***	-0.104***	-0.068***	-0.078***	-0.087***	-0.075***
	(0.017)	(0.025)	(0.019)	(0.022)	(0.017)	(0.013)	(0.015)	(0.014)	(0.012)
SSA	-0.157***	-0.169***	-0.168***	-0.119***	-0.215***	-0.175***	-0.224***	-0.228***	-0.218***
	(0.019)	(0.031)	(0.026)	(0.024)	(0.024)	(0.022)	(0.023)	(0.021)	(0.021)
LAC	-0.126***	-0.191***	-0.057*	-0.051	-0.199***	-0.160***	-0.211***	-0.193***	-0.183***
	(0.030)	(0.045)	(0.032)	(0.032)	(0.032)	(0.026)	(0.031)	(0.027)	(0.027)
lnTF	-0.014***								
	(0.004)								
lnTR		-0.024*							
		(0.013)							
lnTL			0.093***						
			(0.014)						
lnTP				0.030***					
				(0.007)					
lnCB					0.008**				
					(0.004)				
lnCT						0.019			
						(0.013)			
lnCCT							0.001		
							(0.014)		
lnCI								0.020***	
								(0.003)	
lnCC									0.022***
									(0.003)
Constant	-1.989***	-1.932***	-0.355	-1.043***	-1.360***	-1.955***	-1.907***	-1.492***	-1.390***
	(0.137)	(0.255)	(0.229)	(0.188)	(0.200)	(0.155)	(0.175)	(0.168)	(0.162)
N	585	281	385	394	451	740	510	691	717
R2	0.610	0.432	0.612	0.567	0.641	0.598	0.656	0.635	0.615
Hansen-J	0.161	0.063	0.251	0.112	0.330	0.030	0.647	0.295	0.079
No. of instruments	12	12	12	12	12	12	12	12	12
No. of countries	79	79	79	79	79	79	79	79	79
F-statistics	67967.098	36515.916	58722.018	52544.678	76697.586	54892.737	74358.680	114672.494	120910.722
Stock-Yogo weak ID test critical values									
10% maximal IV size	19.93	19.93	19.93	19.93	19.93	19.93	19.93	19.93	19.93
15% maximal IV size	11.59	11.59	11.59	11.59	11.59	11.59	11.59	11.59	11.59
20% maximal IV size	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75
25% maximal IV size	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25

Heteroscedasticity robust standard errors in parentheses. *J* is Hansen J-statistics. *F-statistics* is the Cragg-Donald/Kleibergen-Paap F-statistics for weak instrument identification. The Hansen J-statistics suggests that instruments are not over-identified. The Cragg-Donald/Kleibergen-Paap F-statistics also suggests the instrument are not weak since its values are greater than the Stock-Yogo weak ID test critical values.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

empirical equation for estimating the effect of transport and ICT infrastructure on human development outcomes. The log-linear empirical model for human development is stated in equation (2) as below:

$$lnHD_{it} = \alpha_0 + \beta_1 lnY_{it} + \beta_2 \ln T_{it} + \beta_3 lnC_{it} + \beta_j lnZ_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

Where:

i	1—79
t	1990—2018
$lnHD$	natural logarithm of human development outcomes
lnY	natural logarithm of income
lnT	natural logarithm of transport infrastructure variables
lnC	natural logarithm of ICT infrastructure variables
lnZ	natural logarithm of control variables
α_0	constant parameter to be estimated
$\beta_1 - - - \beta_j$	coefficients to be estimated
ε_{it}	error term

We estimate equation (1) using the Baum et al. (2002) instrumental variable generalised method of moment (IV-GMM) technique. The IV-GMM technique is best suited for this study because it can address endogeneity sources such as measurement errors, reverse causality and omitted variable bias. It is indicated that using a conventional estimator such as the ordinary least square (OLS) to estimate an empirical model with endogeneity issues can create attenuation bias, whereby OLS estimates are downwards-biased (Acheampong, Amponsah, & Boateng, 2020). In addition to addressing the endogeneity issue, the IV-GMM estimator allows consistent estimations in the presence of AR (1) autocorrelation within panels and heteroscedasticity (Baum et al., 2002). Unlike the dynamic system-GMM estimator, which estimates short-run coefficients, the IV-GMM estimator, which is a static estimator, provides long run coefficients. Also, the IV-GMM estimator is consistent with Driscoll and Kraay (1998) standard errors that are robust to 'spatial' and temporal cross-sectional dependence even when the time dimension becomes relatively large (Baum et al., 2002; Boateng, Agbola,

Table 2B
The effect of ICT and transport infrastructure on human capital (IV-GMM results)

Variables	1	2	3	4	5	6	7	8	9
lnY	0.175***	0.202***	0.187***	0.197***	0.170***	0.146***	0.185***	0.157***	0.164***
	(0.012)	(0.016)	(0.013)	(0.013)	(0.015)	(0.013)	(0.013)	(0.011)	(0.010)
lnTRA	0.140***	0.116***	0.070***	0.081***	0.119***	0.129***	0.100***	0.099***	0.094***
	(0.015)	(0.024)	(0.014)	(0.015)	(0.017)	(0.011)	(0.015)	(0.013)	(0.013)
lnUR	-0.083***	-0.118***	-0.089**	-0.089**	0.019	-0.012	0.008	-0.010	-0.028
	(0.028)	(0.040)	(0.035)	(0.037)	(0.033)	(0.026)	(0.032)	(0.028)	(0.028)
lnFDI	0.003	-0.002	-0.004	-0.003	-0.006	0.008***	-0.005	0.000	-0.001
	(0.003)	(0.006)	(0.005)	(0.006)	(0.006)	(0.003)	(0.005)	(0.004)	(0.004)
lnFD	-0.006	-0.016	-0.018**	-0.018*	-0.003	-0.013	0.011	-0.008	-0.006
	(0.009)	(0.012)	(0.008)	(0.009)	(0.010)	(0.009)	(0.009)	(0.007)	(0.007)
lnRE	0.008**	-0.007*	-0.004	-0.002	0.007*	0.003	0.004	-0.001	-0.001
	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
lnEC	-0.035**	-0.053***	-0.028**	-0.031**	-0.035***	-0.030***	-0.019	-0.040***	-0.036***
	(0.014)	(0.017)	(0.011)	(0.014)	(0.011)	(0.009)	(0.012)	(0.009)	(0.009)
SSA	-0.132***	-0.217***	-0.167***	-0.186***	-0.184***	-0.171***	-0.196***	-0.196***	-0.197***
	(0.023)	(0.023)	(0.027)	(0.029)	(0.029)	(0.023)	(0.027)	(0.023)	(0.022)
LAC	-0.014	-0.115***	-0.069**	-0.089**	-0.139***	-0.117***	-0.136***	-0.128***	-0.116***
	(0.027)	(0.041)	(0.029)	(0.035)	(0.029)	(0.024)	(0.029)	(0.023)	(0.023)
lnTF	0.006*								
	(0.003)								
lnTR		0.020**							
		(0.008)							
lnTL			0.028***						
			(0.010)						
lnTP				0.008					
				(0.006)					
lnCB					0.007*				
					(0.004)				
lnCT						0.025***			
						(0.008)			
lnCCT							-0.006		
							(0.012)		
lnCI								0.018***	
								(0.003)	
lnCC									0.015***
									(0.003)
Constant	-0.985***	-0.562***	-0.351**	-0.557***	-0.916***	-0.919***	-0.961***	-0.604***	-0.589***
	(0.119)	(0.133)	(0.152)	(0.158)	(0.152)	(0.100)	(0.125)	(0.117)	(0.117)
N	630	294	385	394	451	785	513	710	743
R2	0.695	0.713	0.741	0.722	0.689	0.695	0.705	0.709	0.693
Hansen-J	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No. of instruments	11	11	11	11	11	11	11	11	11
No. of countries	79	79	79	79	79	79	79	79	79
F-statistics	132664.515	68711.829	107963.267	94136.601	143802.182	111891.678	138176.657	211847.662	218631.849
Stock-Yogo weak ID test critical values									
10% maximal IV size	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38
15% maximal IV size	8.96	8.96	8.96	8.96	8.96	8.96	8.96	8.96	8.96
20% maximal IV size	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66
25% maximal IV size	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53

Heteroscedasticity robust standard errors in parentheses. *J* is Hansen J-statistics. *F-statistics* is the Cragg-Donald/Kleibergen-Paap F-statistics for weak instrument identification. The Hansen J-statistics suggests that instruments are exactly identified. The instruments are exactly identified in the models because a single instrument was used to prevent instrument over-identification. The Cragg-Donald/Kleibergen-Paap F-statistics also suggests the instrument are not weak since the values are greater than the Stock-Yogo weak ID test critical values. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

& Mahmood, 2021). In estimating equation (2) using the IV-GMM, we applied the robust option to control for heteroskedasticity. We also used the Hansen J-statistics and the Cragg-Donald/Kleibergen-Paap F-statistics to test the validity of the instruments. The Hansen J-statistics tests for instruments over-identification while the Cragg-Donald/Kleibergen-Paap F-statistics test for weak instrument identification. The IV-GMM estimator has been utilised in current applied research (Acheampong, Adams, & Boateng, 2019; Acheampong et al., 2020; Acheampong, Dzator, & Shahbaz, 2021; Boateng, Agbola, & Mahmood, 2021).

Following Acheampong et al. (2021), we further applied the Driscoll-Kraay estimator to test the robustness of the IV-GMM results. The Driscoll and Kraay (1998) estimator, based on nonparametric time-series covariance matrix estimator, assumes that the error structure is heteroskedastic, autocorrelated up to some lag, and perhaps correlated between the panels. Applying the Driscoll–Kraay nonparametric estimator for a robustness check is crucial since the estimator produces robust results in both cross-sectional and temporal dependence (Hoechle, 2007). Also, the Driscoll–Kraay estimator can handle missing data series and works with both balanced and unbalanced panels (Hoechle, 2007).

3.2. *The Data*

In this study, we use comprehensive panel data for a total of 79 countries[7] from South Asia (SAR), sub-Saharan Africa (SSA), and Latin America-Caribbean (LAC) to investigate the impact of transport and ICT infrastructure variables on human development outcomes from 1990 to 2018. The number of years and countries have been chosen strictly based on data availability for all the variables employed in the study.

[7] The countries for this study are presented in Appendix Table 1

Table 2C
The effect of ICT and transport infrastructure on life expectancy (IV-GMM results)

Variables	1	2	3	4	5	6	7	8	9
lnY	0.055***	0.038***	0.051***	0.059***	0.038***	0.030***	0.049***	0.046***	0.050***
	(0.006)	(0.007)	(0.006)	(0.007)	(0.005)	(0.006)	(0.005)	(0.004)	(0.004)
lnTRA	0.043***	0.010	0.034***	0.024***	0.014**	0.039***	0.032***	0.024***	0.017***
	(0.007)	(0.012)	(0.009)	(0.007)	(0.007)	(0.005)	(0.007)	(0.006)	(0.006)
lnUR	-0.052***	0.012	-0.070***	-0.104***	-0.082***	-0.042***	-0.068***	-0.054***	-0.056***
	(0.012)	(0.017)	(0.016)	(0.016)	(0.010)	(0.010)	(0.011)	(0.009)	(0.009)
lnFDI	0.001	-0.001	0.002	0.005*	0.002	0.006***	0.004**	0.003	-0.000
	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
lnFD	0.010**	-0.013**	0.008	0.002	-0.003	-0.003	0.019***	0.004	0.006
	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
lnRE	0.001	0.000	-0.010***	-0.008***	-0.010***	-0.002	-0.007***	-0.006***	-0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
lnEC	-0.011*	-0.019***	-0.016**	-0.005	0.001	-0.012***	0.000	-0.016***	-0.016***
	(0.006)	(0.007)	(0.006)	(0.007)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
SSA	-0.174***	-0.239***	-0.191***	-0.175***	-0.170***	-0.169***	-0.201***	-0.193***	-0.194***
	(0.011)	(0.013)	(0.015)	(0.014)	(0.011)	(0.010)	(0.012)	(0.010)	(0.009)
LAC	0.042***	-0.009	0.029**	0.054***	0.046***	0.010	0.048***	0.014*	0.013
	(0.012)	(0.013)	(0.013)	(0.012)	(0.009)	(0.010)	(0.011)	(0.009)	(0.008)
lnTF	0.002								
	(0.002)								
lnTR		-0.002							
		(0.004)							
lnTL			0.009*						
			(0.005)						
lnTP				-0.007					
				(0.005)					
lnCB					0.012***				
					(0.002)				
lnCT						0.026***			
						(0.004)			
lnCCT							-0.012**		
							(0.006)		
lnCI								0.011***	
								(0.001)	
lnCC									0.011***
									(0.001)
Constant	3.767***	3.978***	4.146***	4.239***	4.394***	3.928***	3.994***	4.079***	4.109***
	(0.054)	(0.065)	(0.085)	(0.073)	(0.080)	(0.057)	(0.059)	(0.059)	(0.059)
N	630	294	385	394	451	785	513	710	743
R2	0.805	0.808	0.831	0.816	0.849	0.812	0.839	0.824	0.820
Hansen-J	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No of instruments	11	11	11	11	11	11	11	11	11
No. of countries	79	79	79	79	79	79	79	79	79
F-statistics	132664.515	68711.829	107963.267	94136.601	143802.182	111891.678	138176.657	211847.662	218631.849
Stock-Yogo weak ID test critical values									
10% maximal IV size	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38
15% maximal IV size	8.96	8.96	8.96	8.96	8.96	8.96	8.96	8.96	8.96
20% maximal IV size	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66
25% maximal IV size	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53

Heteroscedasticity robust standard errors in parentheses. J is Hansen J-statistics. F-statistics is the Cragg-Donald/Kleibergen-Paap F-statistics for weak instrument identification. The Hansen J-statistics suggests that instruments are exactly identified. The instruments are exactly identified in the models because a single instrument was used to prevent instrument over-identification. The Cragg-Donald/Kleibergen-Paap F-statistics also suggests the instrument are not weak since the values are greater than the Stock-Yogo weak ID test critical values. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

- The dependent variables: Following Acheampong et al. (2021), five human development outcome variables are used in this study. First, the human development index (HDI) is used as the composite indicator for human development. We further disaggregate the HDI into education and health components. We used the human capital index to represent education, while life expectancy, maternal mortality and under-five mortality were used to capture health.
- The independent variables of interest: Following the existing studies on transport and ICT, we use four (4) transport infrastructure variables, namely freight, rail, port connectivity, and port traffic. Also, five (5) ICT variables, namely, fixed-broadband subscriptions, fixed telephone subscriptions, ICT goods, internet usage and mobile cellular subscriptions, are used in this study.
- The control covariates: Following (Asongu & Le Roux, 2017; Burns, Jones, Goryakin, & Suhrcke, 2017; Zhuang, 2017; Zhunio, Vishwasrao, & Chiang, 2012), the control variables included in the human development model to prevent variable omission bias are income (economic growth), trade openness, urbanisation, foreign direct investment, financial development, remittance and electric power transmission and distribution losses. The definition, sources and descriptive statistics of the variables are provided in Table 1. It must be noted that the empirical equation was estimated using the natural logarithm of the variables.

4. Results and Discussions

4.1. Unconditional effect results

Table 2A displays the results for using the composite human development index as a dependent variable. Regarding transport infrastructure variables, the estimates from these models show that freight and rail coefficients are negative and statistically significant at the 1% and 10% levels, respectively. Thus, freight and rail have not been effective in enhancing human development in developing countries. The role of

Table 2D
The effect of ICT and transport infrastructure on under-five mortality (IV-GMM results)

Variables	1	2	3	4	5	6	7	8	9
lnY	-1.161***	-1.038***	-1.143***	-1.302***	-0.920***	-0.532***	-1.198***	-0.996***	-1.064***
	(0.080)	(0.117)	(0.087)	(0.096)	(0.070)	(0.076)	(0.076)	(0.064)	(0.060)
lnTRA	-1.769***	-0.958***	-1.581***	-1.658***	-1.510***	-1.910***	-1.648***	-1.573***	-1.453***
	(0.100)	(0.156)	(0.118)	(0.104)	(0.106)	(0.072)	(0.106)	(0.082)	(0.081)
lnUR	1.110***	0.638**	1.019***	1.567***	1.223***	0.772***	1.237***	1.076***	1.111***
	(0.186)	(0.314)	(0.234)	(0.223)	(0.151)	(0.146)	(0.166)	(0.139)	(0.128)
lnFDI	0.224***	0.203***	0.393***	0.325***	0.376***	0.205***	0.289***	0.313***	0.342***
	(0.024)	(0.047)	(0.039)	(0.045)	(0.030)	(0.020)	(0.032)	(0.026)	(0.026)
lnFD	-0.181***	-0.028	-0.121*	-0.048	0.085	0.208***	-0.230***	0.006	-0.020
	(0.069)	(0.079)	(0.070)	(0.076)	(0.065)	(0.057)	(0.062)	(0.056)	(0.055)
lnRE	0.157***	0.206***	0.293***	0.251***	0.281***	0.190***	0.250***	0.248***	0.239***
	(0.025)	(0.030)	(0.025)	(0.029)	(0.020)	(0.021)	(0.023)	(0.022)	(0.022)
lnEC	0.073	0.096	0.162**	0.177**	-0.013	-0.053	0.094	0.037	0.002
	(0.095)	(0.087)	(0.082)	(0.090)	(0.071)	(0.043)	(0.076)	(0.051)	(0.048)
SSA	0.343**	0.575***	0.722***	0.471***	0.306*	0.068	0.555***	0.494***	0.547***
	(0.153)	(0.166)	(0.178)	(0.171)	(0.157)	(0.143)	(0.164)	(0.137)	(0.129)
LAC	-1.476***	-0.830***	-1.425***	-1.611***	-1.516***	-1.195***	-1.802***	-1.368***	-1.316***
	(0.162)	(0.241)	(0.173)	(0.177)	(0.153)	(0.149)	(0.160)	(0.126)	(0.119)
lnTF	0.111***								
	(0.021)								
lnTR		0.252***							
		(0.071)							
lnTL			-0.084						
			(0.081)						
lnTP				0.137*					
				(0.070)					
lnCB					-0.219***				
					(0.023)				
lnCT						-0.582***			
						(0.050)			
lnCCT							0.519***		
							(0.083)		
lnCI								-0.200***	
								(0.018)	
lnCC									-0.199***
									(0.015)
Constant	14.838***	9.793***	7.717***	7.327***	5.054***	11.781***	10.425***	9.177***	9.107***
	(0.801)	(1.015)	(1.140)	(1.142)	(1.041)	(0.725)	(0.850)	(0.815)	(0.782)
N	630	294	385	394	451	785	513	710	743
R2	0.800	0.802	0.862	0.857	0.876	0.821	0.844	0.836	0.835
Hansen-J	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No of instruments	11	11	11	11	11	11	11	11	11
No. of countries	79	79	79	79	79	79	79	79	79
F-statistics	132664.515	68711.829	107963.267	94136.601	143802.182	111891.678	138176.657	211847.662	218631.849
Stock-Yogo weak ID test critical values									
10% maximal IV size	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38	16.38
15% maximal IV size	8.96	8.96	8.96	8.96	8.96	8.96	8.96	8.96	8.96
20% maximal IV size	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66
25% maximal IV size	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53	5.53

Heteroscedasticity robust standard errors in parentheses. J is Hansen J-statistics. F-statistics is the Cragg-Donald/Kleibergen-Paap F-statistics for weak instrument identification. The Hansen J-statistics suggests that instruments are exactly identified. The instruments are exactly identified in the models because a single instrument was used to prevent instrument over-identification. The Cragg-Donald/Kleibergen-Paap F-statistics also suggests the instrument are not weak since the values are greater than the Stock-Yogo weak ID test critical values. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

freight and rail inhibiting human development highlights freight and rail infrastructure challenges in developing countries. In many developing countries, particularly SSA, these means of transportation are underdeveloped and are not popular in transporting goods and people. On the other hand, the estimate shows that the port connectivity and port traffic coefficients are positive and statistically significant at the 1% level. Thus, all else being equal, a 10% increase in port connectivity and port traffic contributes to human development in developing countries by 0.93% and 0.30%, respectively. The implication is that higher integration of nations to global shipping networks and increasing flow of containers at the port are vital for enhancing human development. Regarding the ICT infrastructure variables, while the estimate shows that telephone and ICT goods penetration have a neutral effect on human development, the coefficients of broadband, internet, and mobile phone penetration are positive and statistically significant at the 5% and 1% levels, respectively. Thus, all else being equal, 10% increase in broadband, internet and mobile phone penetration contributes to human development by 0.08%, 0.20% and 0.22%, respectively. This suggests that increasing broadband, internet and mobile phone penetration would enhance human development in developing countries. This result aligns with the Asongu and Le Roux (2017) and Asongu, Nwachukwu, and Pyke (2019) findings that telephone, internet and mobile phone penetration spurs human development in SSA.

Table 2B displays the results for using human capital as the dependent variable. The estimates show that while port traffic has a neutral effect on human capital, freight, rail, and port connectivity coefficients are positive and statistically significant at the 10% and 5% levels, respectively. Thus, all else being equal, a 10% increase in freight, rail, and port connectivity contributes to increases around 0.06%, 0.20% and 0.28%, respectively, in human capital. This finding suggests that increasing freight, rail and integration of global shipping networks are instrumental for enhancing human capital development. Regarding the ICT infrastructure variables, while ICT goods penetration has a neutral effect on human capital, the estimate shows that the coefficients of

Table 2E
The effect of ICT and transport infrastructure on maternal mortality (IV-GMM results)

Variables	1	2	3	4	5	6	7	8	9
lnY	-0.637***	-0.422***	-0.503***	-0.632***	-0.538***	-0.296**	-0.619***	-0.528***	-0.578***
	(0.112)	(0.143)	(0.110)	(0.107)	(0.089)	(0.122)	(0.099)	(0.095)	(0.088)
lnTRA	-0.382**	-0.228	-0.342**	-0.305**	-0.114	-0.348***	-0.216	-0.233*	-0.263*
	(0.181)	(0.217)	(0.162)	(0.150)	(0.139)	(0.124)	(0.136)	(0.131)	(0.144)
lnUR	0.587**	0.594	0.516**	0.758***	0.781***	0.495**	0.704***	0.576**	0.691***
	(0.289)	(0.417)	(0.263)	(0.258)	(0.221)	(0.223)	(0.220)	(0.224)	(0.217)
lnFDI	-0.021	-0.031	-0.001	-0.039	-0.027	-0.105***	-0.044	-0.050*	-0.067**
	(0.026)	(0.060)	(0.036)	(0.035)	(0.035)	(0.026)	(0.028)	(0.028)	(0.030)
lnFD	-0.076	-0.091	-0.098	-0.159**	-0.180**	-0.036	-0.229***	-0.139**	-0.154**
	(0.089)	(0.090)	(0.066)	(0.078)	(0.071)	(0.073)	(0.080)	(0.067)	(0.067)
lnRE	0.095***	0.133***	0.143***	0.157***	0.151***	0.146***	0.139***	0.145***	0.148***
	(0.028)	(0.041)	(0.024)	(0.027)	(0.025)	(0.027)	(0.025)	(0.026)	(0.025)
lnEC	0.002	-0.081	0.057	-0.136	-0.200**	-0.021	-0.161*	-0.093	-0.107
	(0.106)	(0.139)	(0.143)	(0.126)	(0.085)	(0.091)	(0.093)	(0.088)	(0.088)
SSA	0.964***	0.774***	1.340***	1.242***	1.148***	0.964***	1.296***	1.164***	1.150***
	(0.168)	(0.235)	(0.163)	(0.156)	(0.174)	(0.178)	(0.154)	(0.162)	(0.165)
LAC	-0.380	-1.007***	-0.384	-0.360	-0.371*	-0.121	-0.407*	-0.253	-0.317
	(0.261)	(0.357)	(0.258)	(0.268)	(0.205)	(0.217)	(0.220)	(0.213)	(0.221)
lnTF	-0.022								
	(0.023)								
lnTR		-0.126**							
		(0.057)							
lnTL			-0.200**						
			(0.083)						
lnTP				-0.007					
				(0.053)					
lnCB					-0.070**				
					(0.028)				
lnCT						-0.278***			
						(0.089)			
lnCCT							0.085		
							(0.095)		
lnCI								-0.077**	
								(0.036)	
lnCC									-0.033
									(0.033)
Constant	7.882***	6.556***	5.781***	6.471***	4.854***	6.262***	6.818***	6.451***	6.895***
	(1.445)	(1.318)	(1.465)	(1.351)	(1.387)	(1.275)	(1.089)	(1.364)	(1.298)
N	142	54	120	127	148	175	150	173	172
R2	0.795	0.812	0.818	0.800	0.799	0.787	0.806	0.787	0.774
Hansen-J	0.221	2.355	1.003	0.559	1.280	0.355	0.108	0.186	0.353
No of instruments	12	12	12	12	12	12	12	12	12
No. of countries	79	79	79	79	79	79	79	79	79
F-statistics	15998.344	6913.659	10261.479	11747.671	15664.181	8861.402	15977.705	21329.841	24552.490
Stock-Yogo weak ID test critical values									
10% maximal IV size	19.93	19.93	19.93	19.93	19.93	19.93	19.93	19.93	19.93
15% maximal IV size	11.59	11.59	11.59	11.59	11.59	11.59	11.59	11.59	11.59
20% maximal IV size	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75	8.75
25% maximal IV size	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25	7.25

Heteroscedasticity robust standard errors in parentheses. J is Hansen J-statistics. F-statistics is the Cragg-Donald/Kleibergen-Paap F-statistics for weak instrument identification. The Hansen J-statistics suggests that instruments are not over-identified. The Cragg-Donald/Kleibergen-Paap F-statistics also suggests the instrument are not weak since the values are greater than the Stock-Yogo weak ID test critical values. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

broadband, telephone, internet, and mobile phone are positive and statistically significant. Thus, all else being equal, 10% increase in broadband, telephone, internet, and mobile phone penetration contributes to increases of 0.07%, 0.25%, 0.18% and 0.15%, respectively, in human capital. Thus, like the transport variables, broadband, telephone, internet, and mobile phone penetration in developing countries contributes to human capital improvement. A similar result is reported by Bankole, Shirazi, and Brown (2011).

Table 2C displays the results for using life expectancy as the dependent variable. The estimates suggest that while freight, rail, and port traffic have a neutral effect on life expectancy, the coefficient of port connectivity is positive and statistically significant at the 10% level. All else being equal, a 10% increase in port connectivity contributes around 0.09% to life expectancy. Thus, among the transport infrastructure variables, port connectivity contributes to improving life expectancy in developing countries. Regarding the ICT infrastructure variables, the estimate shows that the broadband, telephone, internet, and mobile phone penetration coefficients are positive and statistically significant. Thus, all else being equal, 10% increase in broadband, telephone, internet, and mobile phone penetration contributes to increases of 0.12%, 0.26%, 0.11% and 0.11%, respectively, in life expectancy. The implication is that broadband, telephone, internet, and mobile phone penetration enhance life expectancy. This result agrees with the findings of Bankole et al. (2011). In contrast, the ICT goods penetration coefficient is negative and statistically significant at a 5% level.

Table 2D presents the results for using under-five mortality as the dependent variable. The estimates suggest that while port connectivity has a neutral effect on under-five mortality, the freight, rail, and port traffic coefficients are positive and statistically significant. Thus, freight, rail, and port traffic have not effectively enhanced human development (under-five mortality) in developing countries. Regarding the ICT infrastructure variables, the estimates show that the broadband, telephone, internet, and mobile phone penetration coefficients are negative

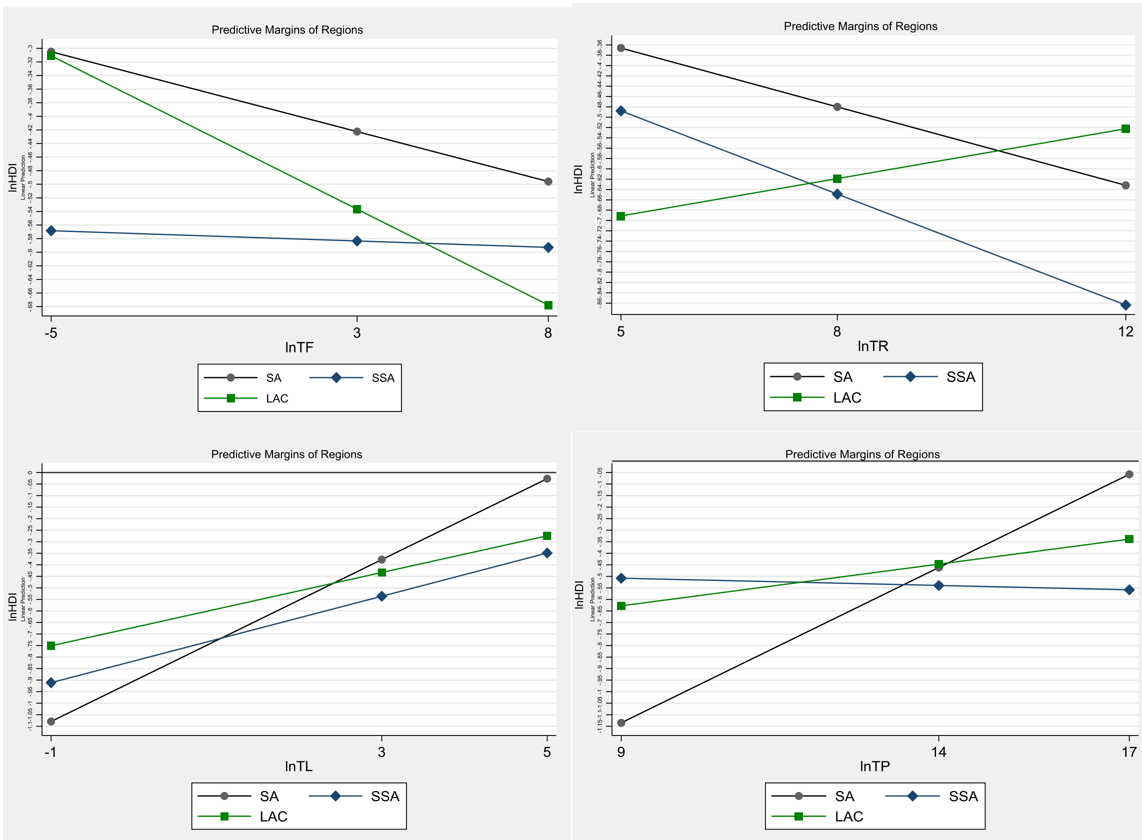

Fig 1a. Marginal effect of transport infrastructures on human development index: Regional groupings

and statistically significant. Thus, all else being equal, a 10% increase in broadband, telephone, internet, and mobile phone penetration reduces under-five mortality by 2.19%, 5.82%, 2.00% and 1.99%, respectively. The implication of this finding is that policies that enhance broadband, telephone, internet, and mobile phone penetration would reduce under-five mortality in developing countries. Contrarily, the ICT goods penetration coefficient is positive and statistically significant at the 1% level. This result suggests that ICT goods penetration does not reduce under-five mortality.,

Table 2E shows the results for using maternal mortality as the dependent variable. From these models, the results suggest that while freight and port traffic have a neutral effect on maternal mortality, the rail and port connectivity coefficients are negative and statistically significant. Thus, all else being equal, a 10% increase in rail and port connectivity reduces maternal mortality by 1.26% and 2.00% respectively. This result indicates that expanding rail infrastructure and integration of nations to global shipping networks improves maternal mortality. Regarding the ICT infrastructure variables, while mobile phone and ICT goods penetration have a neutral effect on maternal mortality, the estimates show that the broadband, telephone, and internet penetration coefficients are negative and statistically significant. Thus, all else being equal, a 10% increase in broadband, telephone and internet penetration reduces maternal mortality by 0.70%, 2.78%, and 0.77%, respectively. This result indicates that broadband, telephone, and internet penetration contribute to maternal mortality reduction in developing countries. This result complements micro studies that argue that information and communication technologies are vital for enhancing maternal health in developing countries (Nurmatov et al., 2014; Nyamawe & Seif, 2014; West, 2015).

With regards to the control variables, the estimates show that income contributes significantly by improving human development, human capital, life expectancy, under-five mortality and maternal mortality. This result indicates that expanding the economy is associated with increasing the financial resources needed by governments to build infrastructure facilities and spending pro-poor projects, and this finding aligns with the results of Acheampong, Erdiaw-Kwasie, et al. (2021) and Salahuddin, Vink, Ralph, and Gow (2020). Consistent with Nourzad and Powell (2003) and Panda (2020), our estimates also show that trade openness significantly enhances human development, human capital, life expectance, under-five mortality and maternal mortality in developing countries. It is also observed that as urbanisation improves the composite human development significantly, it does not seem to improve human capital, life expectancy, under-five mortality and maternal mortality. Contrary to the findings of Asongu and Le Roux (2017), Burns et al. (2017) and Salahuddin et al. (2020), our estimates show that foreign direct investment does not improve human development, human capital, life expectance, under-five mortality and maternal mortality.

Inconsistent with the findings of Acheampong, Erdiaw-Kwasie, et al. (2021) and Ozcan (2018), our estimates suggest that financial development does not improve human development, human capital and life expectancy, but it improves under-five mortality and maternal mortality. In addition, it is observed that whereas remittance improves human development and human capital, it does not enhance life expectancy, under-five mortality and maternal mortality, which is consistent with the argument of Ssozi and Asongu (2016) that remittances are not likely to improve all human development components equally. The results also suggest that electric power losses worsen human development, human capital, life expectance, under-five mortality and maternal mortality. Thus, increasing electric power losses is inimical to human development because electric power transmission and distribution losses are associated with increasing energy poverty. It is indicated that limited access to electricity or energy poverty impedes human development in developing countries (see Acheampong, Erdiaw-Kwasie, et al., 2021; Pan,

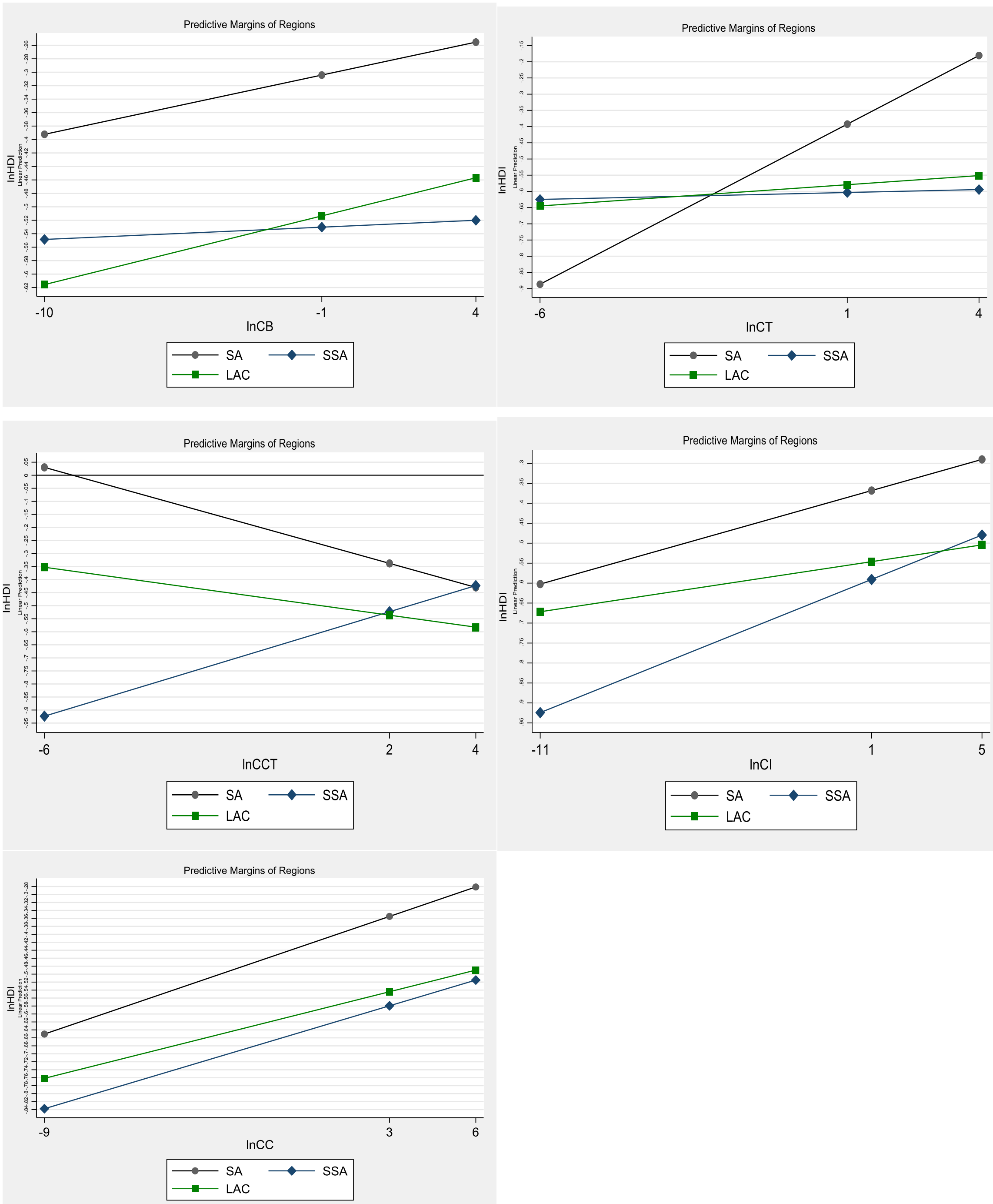

Fig 1b. Marginal effect of ICT infrastructures on human development index: Regional groupings

Biru, & Lettu, 2021). The regional dummies indicate that relative to SAR countries, SSA countries are more likely to have lower human development index, human capital and life expectancy while having more under-five and maternal mortality. Also, relative to SAR countries, LAC countries are more likely to have a lower human development index, human capital, under-five, and maternal mortality while having higher life expectancy.

4.2. Does the effect of ICT and transport infrastructure on human development differ among the developing regions?

As indicated in the analysis above, there are significant differences in the human development outcomes among the regions. We probe further by examining how transport and ICT infrastructure explain these differences. In doing so, we rely on the marginal analysis approach, which is obtained from the estimation results presented in the supplementary material.

4.2.1. Regional effects of ICT and transport infrastructure on human development index

Fig. 1A displays the marginal effect of transport infrastructures on the human development index. The freight slope is shown to be negative for all the regions. This indicates that, from the regional perspective, freight does not improve human development in all the regions.

Regional effects of ICT and transport infrastructure on human capital: marginal analysis

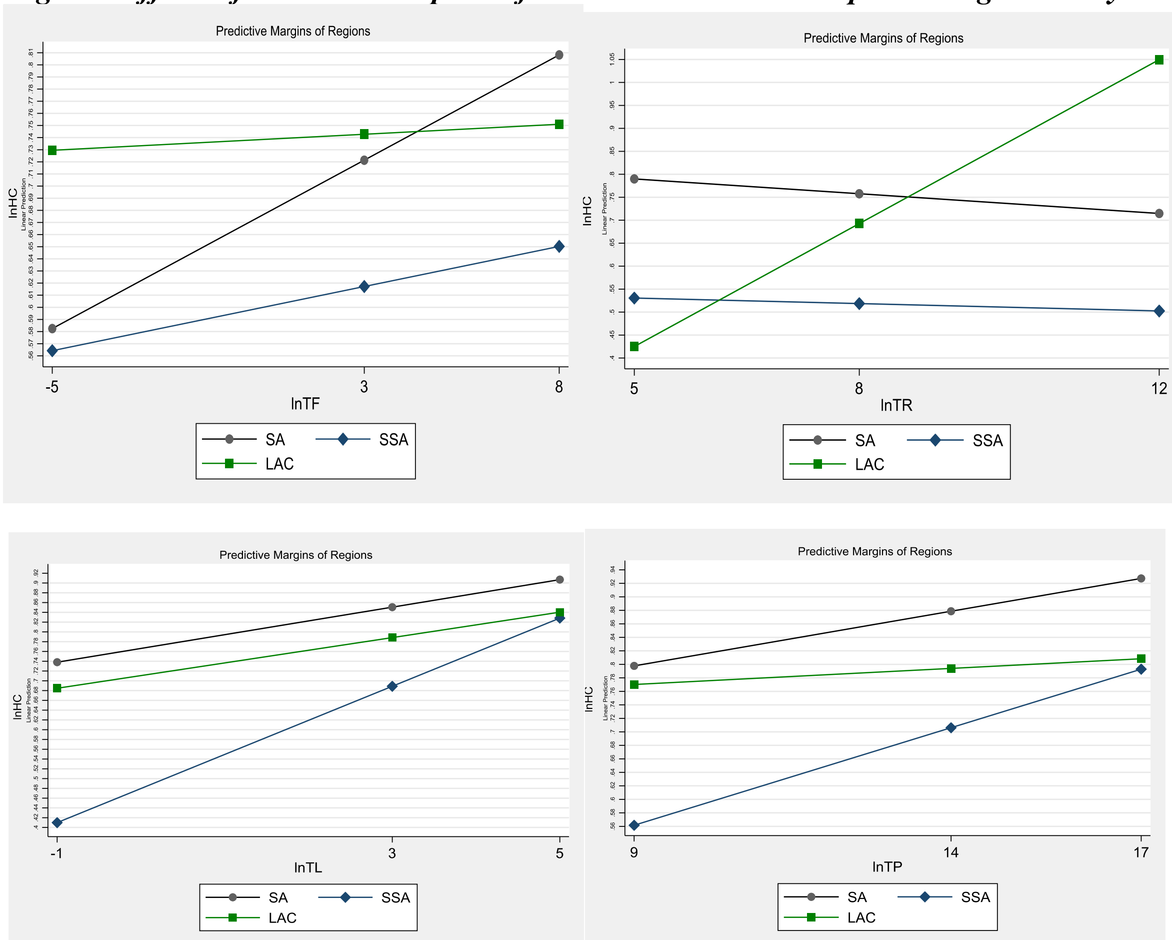

Fig 1c. Marginal effect of transport infrastructures on human capital: Regional groupings

However, the conditional level of human development is highest in SAR, followed by LAC and then SSA. Also, from Fig. 1A, the rail slope is negative for SAR and SSA countries, but positive for LAC countries. This suggests that rail improves human development in LAC, but not in SAR and SSA; however, the conditional level of human development is highest for SAR countries. Furthermore, the slope for port connectivity is positive for all the regions. However, at the minimum value of port connectivity, the conditional level of human development is highest for LAC, followed by SSA and SAR. But at the mean and maximum values of port connectivity, the conditional level of human development is highest for SAR, followed by LAC and SSA. This result indicates that although port connectivity enhances human development for all the regions, the relative levels of human development in the various regions depend on the level of port infrastructure. It is also observed from the graphs that the port traffic slope is positive for all the regions. However, at the minimum value of port traffic, the conditional level of human development is highest for SSA, followed by LAC and SAR. But at the mean and maximum value of port traffic, the conditional level of human development is highest for SAR, followed by LAC and SSA. This result also suggests that although port traffic enhances human development in all the regions, the relative levels of human development in the regions depend on the level of port traffic.

Fig. 1B displays the marginal effect of ICT variables on the human development index. The broadband penetration slope is positive for all the regions; however, at the minimum value of broadband, the conditional level of human development is highest for SAR, followed by the SSA and LAC. But at the mean and maximum values of broadband, the conditional level of human development is highest for SAR, followed by the LAC and SSA. Generally, this result suggests that although broadband penetration contributes positively to human development in all the regions, SAR experiences the highest conditional level of human development. Also, the slope for telephone penetration is positive for all the regions; however, at the minimum value of telephone penetration, the conditional level of human development is highest for SSA, followed by the LAC and SAR. But at the mean and maximum values of telephone penetration, the conditional level of human development is highest for SAR, followed by the LAC and SSA. This implies that increasing telephone penetration benefits human development in all regions, but the highest conditional level of human development is experienced in SAR. It is also observed from Fig. 1B that the ICT goods penetration slope is negative for SAR and LAC, but positive for SSA. Comparatively, the conditional level of human development is higher for SAR and lower for LAC. This observation implies that, generally, increasing ICT penetration improves human development in SSA but worsens human development in SAR and LAC. Also, Fig. 1B suggests that the internet penetration slope is positive for all the regions; however, the conditional level of human development is highest for SAR at the minimum, mean and maximum values of internet penetration. Furthermore, at the minimum and mean values of internet penetration, the conditional level of human development is higher for LAC than SSA, but at the maximum value of internet penetration, the conditional level of human development is higher for SSA than LAC. This result suggests that increasing internet penetration spurs human development in all regions, but the relative levels of human development in LAC and SSA depend on the level of internet penetration. Even more, the slope for mobile phone penetration is positive for all the regions; however, the conditional level

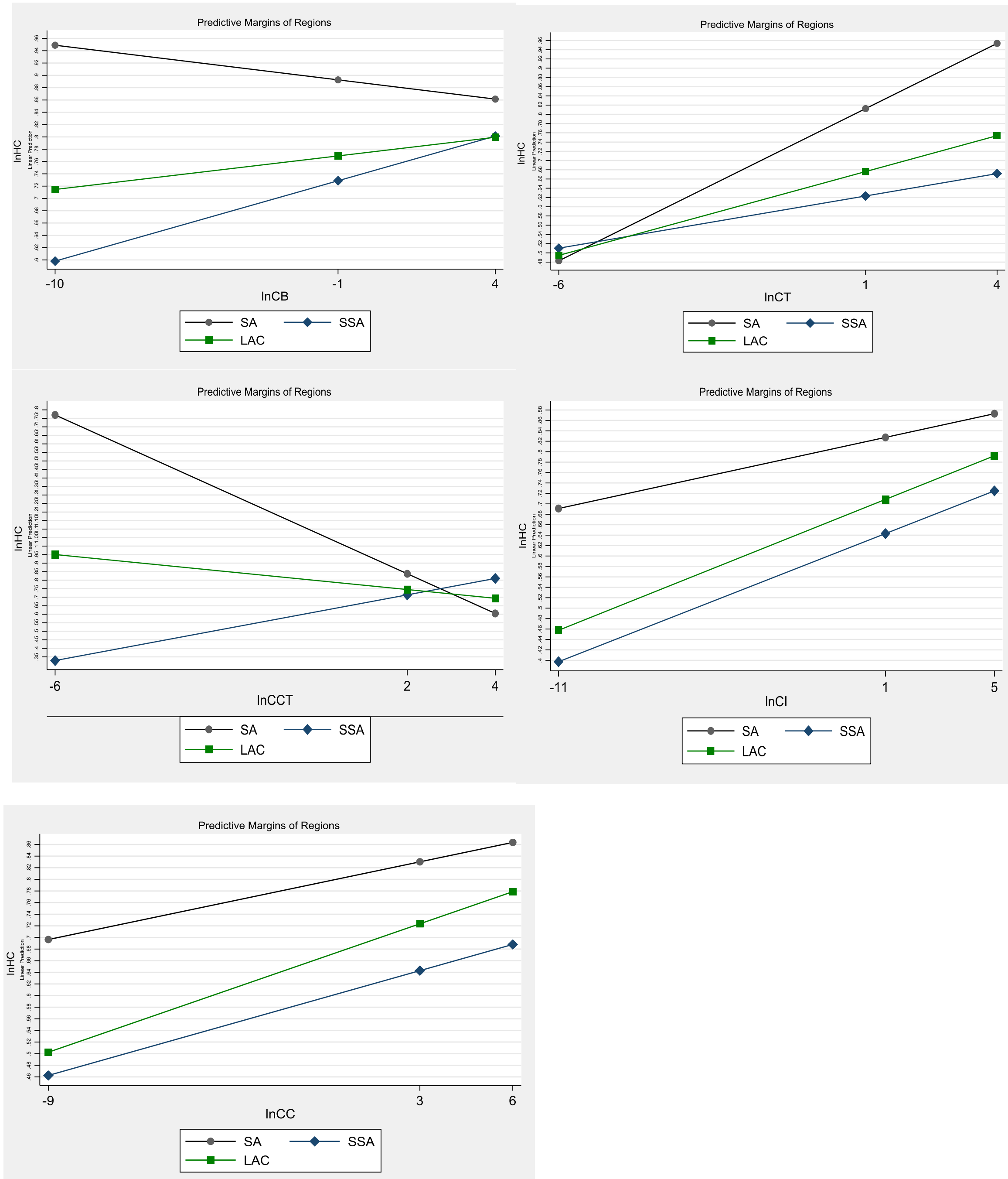

Fig 1d. Marginal effect of ICT infrastructures on human capital: Regional groupings

of human development is highest for SAR, followed by LAC and SSA.

4.2.2. Regional effects of ICT and transport infrastructure on human capital

Fig. 1C displays the marginal effect of transport infrastructure on human capital. The freight slope is positive for all the regions. At the minimum and mean values of freight, the conditional level of human capital is highest for LAC, followed by SAR and SSA. But at the maximum value of freight, the conditional level of human capital is highest for SAR, followed by LAC and SSA. Similarly, the slopes for port connectivity and port traffic are positive for all the regions. However, their conditional levels of human capital are highest for SAR, followed by LAC and SSA. These results suggest that freight, port connectivity, and port traffic do not only improve human capital in all the regions, but also their levels influence the relative levels of human capital in the various regions. Also, it is observed that the rail slope is negative for SAR and SSA countries, but positive for LAC countries. Thus, while rail limits human capital in SAR and SSA, it improves human capital in LAC.

Fig. 1D displays the marginal effect of ICT variables on human capital. The broadband penetration slope is positive for LAC and SSA regions while negative for SAR. This result suggests that while broadband penetration does not improve human capital in SAR, it improves human capital in LAC and SSA. Also, the slope for telephone penetration is positive for all the regions; however, at the mean and maximum value of telephone penetration, the conditional level of human capital is highest for SAR, followed by the LAC and SSA. This result suggests that telephone penetration improves human capital in all the regions, but the relative levels of human capital in the various regions depend on the

Regional effects of ICT and transport infrastructure on life expectancy: marginal analysis

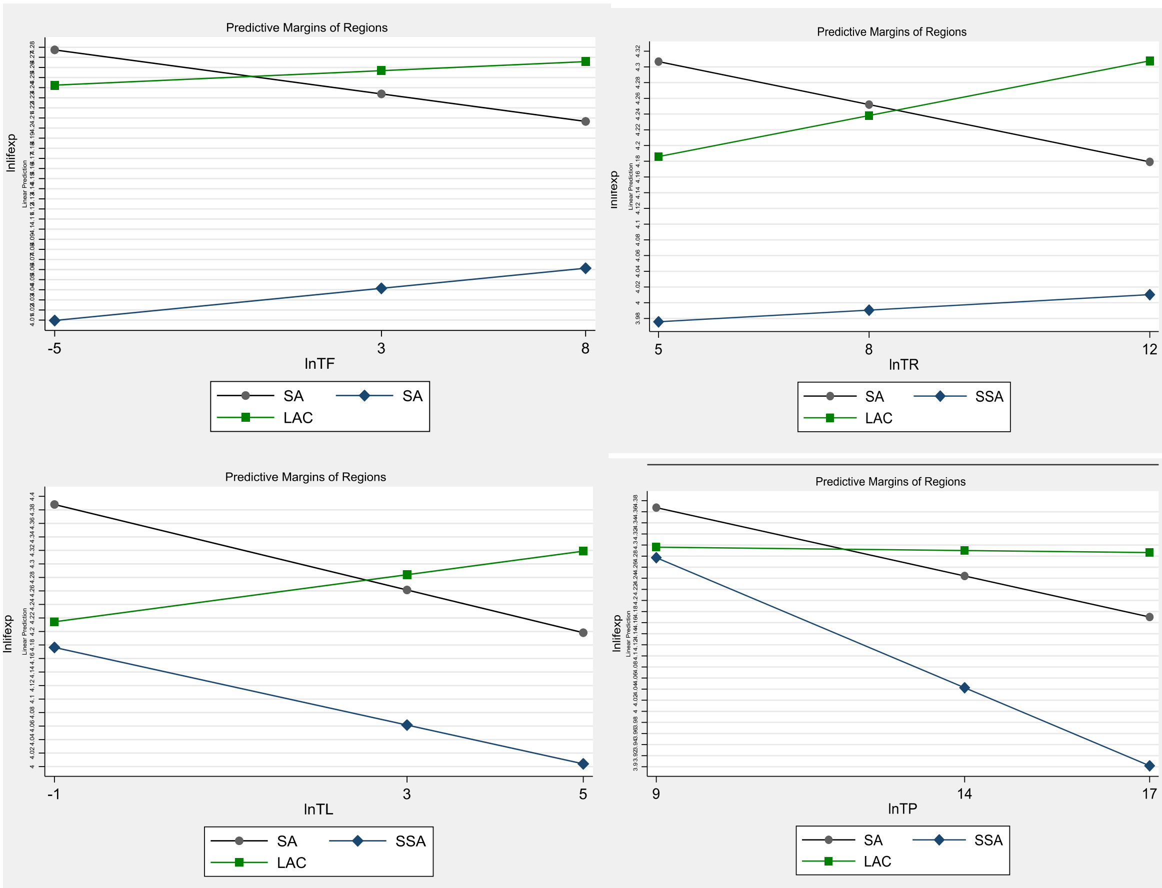

Fig 1e. Marginal effect of transport infrastructures on life expectancy: Regional groupings

level of telephone penetration. It is also observed that the ICT goods penetration slope is negative for SAR and LAC, but positive for SSA. This result indicates that ICT goods penetration enhances human capital in SSA while limiting human capital in LAC and SAR. Also, the slopes for internet and mobile phone penetration are positive for all the regions; however, the conditional level of human capital is highest for SAR, followed by LAC and SSA.

4.2.3. Regional effects of ICT and transport infrastructure on life expectancy

Fig. 1E displays the marginal effect of transport infrastructures on life expectancy. It is observed that the freight and rail slopes are positive for LAC and SSA, but negative for SAR. This result indicates that while freight and rail enhance life expectancy in LAC and SSA, they worsen it in SAR. Also, the slopes for port connectivity and port traffic are positive for LAC, but negative for SAR and SSA. This result suggests that port connectivity and port traffic enhance human capital in LAC while worsening it in SAR and SSA.

Fig. 1F displays the marginal effect of ICT on life expectancy. The slopes for broadband, internet, and mobile phone penetration are positive for all the regions, but the conditional level of life expectancy is highest for LAC, followed by SAR and SSA. Similarly, the slope for telephone penetration is positive for all the regions; however, at the maximum value of telephone penetration, the conditional level of life expectancy is highest for SAR, followed by LAC and SSA. These findings suggest that broadband, internet, mobile phone, and telephone penetration improve life expectancy in all the regions. Also, it is observed that the ICT goods penetration slope is negative for SAR and SSA, but positive for LAC. Thus, ICT goods penetration enhance life expectancy in LAC while impeding it in SAR and SSA.

4.2.4. Regional effects of ICT and transport infrastructure on under-five mortality

Fig. 1G displays the marginal effect of transport infrastructures on under-five mortality. It is observed that freight and port traffic slopes are positive for all the regions; however, the conditional level of under-five mortality is highest in SSA. This suggests that freight and port traffic do not improve under-five mortality in all the regions, but the level of under-five mortality is highest in SSA. It is also observed that the slope for rail transport is positive for SAR, but negative for LAC. This finding indicates that while investment in rail reduces under-five mortality in LAC, it has been ineffective in reducing under-five mortality in SAR and SSA. Also, the slope for port connectivity is positive for SAR while negative for SSA and LAC. This result suggests that while port connectivity worsens under-five mortality in SAR, it has effectively contributed to under-five mortality reduction in LAC and SSA.

Fig. 1H displays the marginal effect of ICT on under-five mortality. The slopes for broadband, telephone, internet and mobile phone penetration are negative for all the regions, but the conditional level of under-five mortality is highest for SSA. This result indicates that broadband, telephone, internet, and mobile phone penetration have significantly improved under-five mortality in the regions, but the conditional level of under-five mortality remains highest in SSA. Contrarily, the slope for ICT goods is positive for all the regions. This result suggests that ICT goods penetration worsens under-five mortality in all the regions. However, at the maximum value of ICT goods

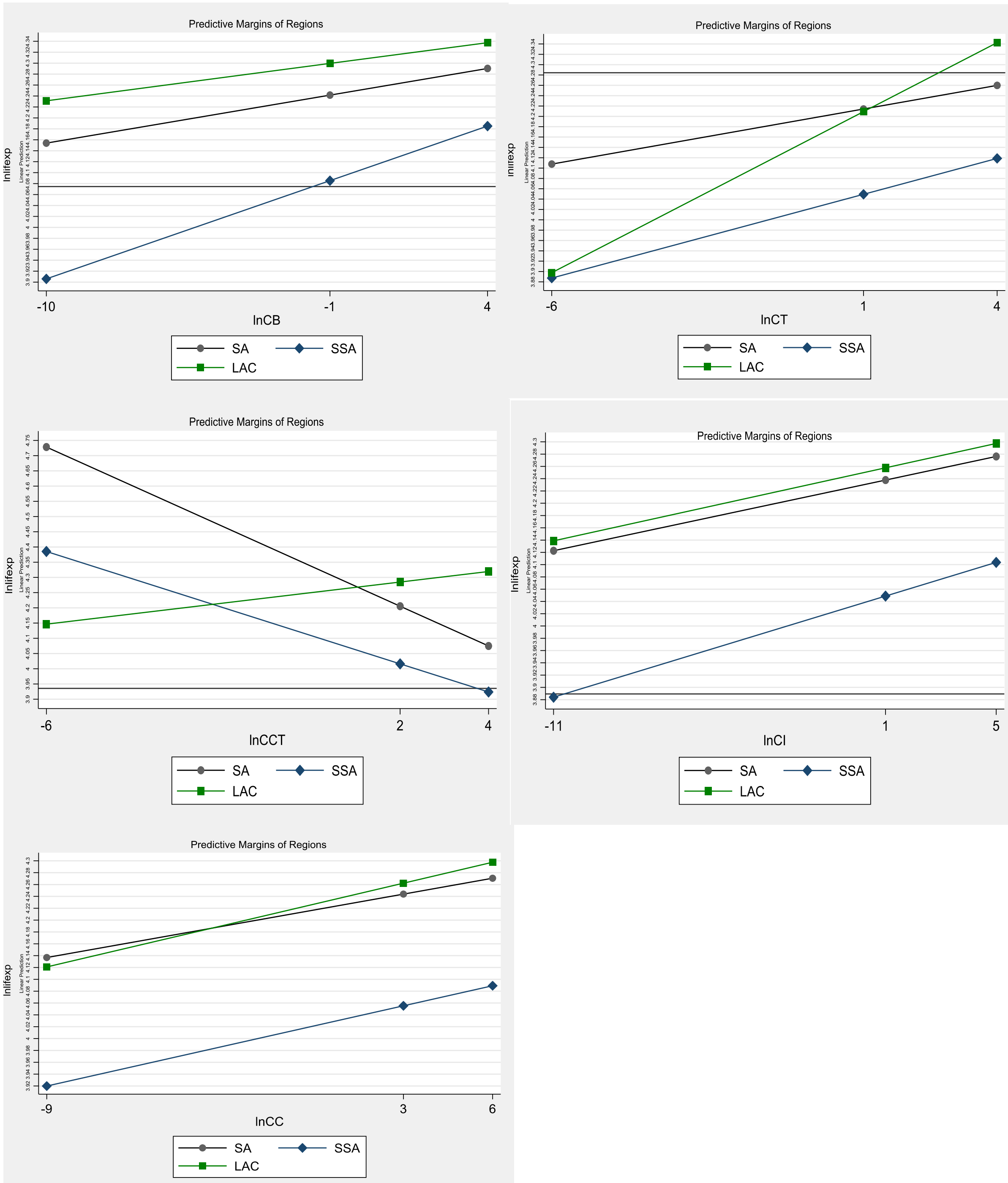

Fig 1f. Marginal effect of ICT infrastructures on life expectancy: Regional groupings

penetration, SAR has the highest conditional level of under-five mortality.

4.2.5. Regional effects of ICT and transport infrastructure on maternal mortality

Fig. 1I displays the marginal effect of transport infrastructure on maternal mortality. The slopes for freight, port connectivity, and port traffic are positive for SSA while negative for SAR and LAC. These findings indicate that freight, port connectivity, and port traffic worsen maternal mortality in SSA while improving maternal mortality in SAR and LAC. It is also observed from Fig. 1I that the rail slope is negative for SSA and LAC while positive for SAR. This result suggests that rail worsens maternal mortality in SAR, but improves it in SSA and LAC.

Fig. 1J displays the marginal effect of ICT on maternal mortality. It is observed that the slopes for broadband, internet and mobile phone penetration are negative for SAR and LAC while positive for SSA. These results indicate that broadband, internet, and mobile phone penetration enhance maternal mortality in SAR and LAC while worsening it in SSA. It is also observed that the slope for telephone penetration is negative for all the regions. This result implies that telephone penetration enhances maternal mortality in all regions. Contrarily, the slope for ICT goods penetration is positive for all the regions, indicating that ICT goods penetration worsens maternal mortality in the developing regions.

Regional effects of ICT and transport infrastructure on under-five mortality: marginal analysis

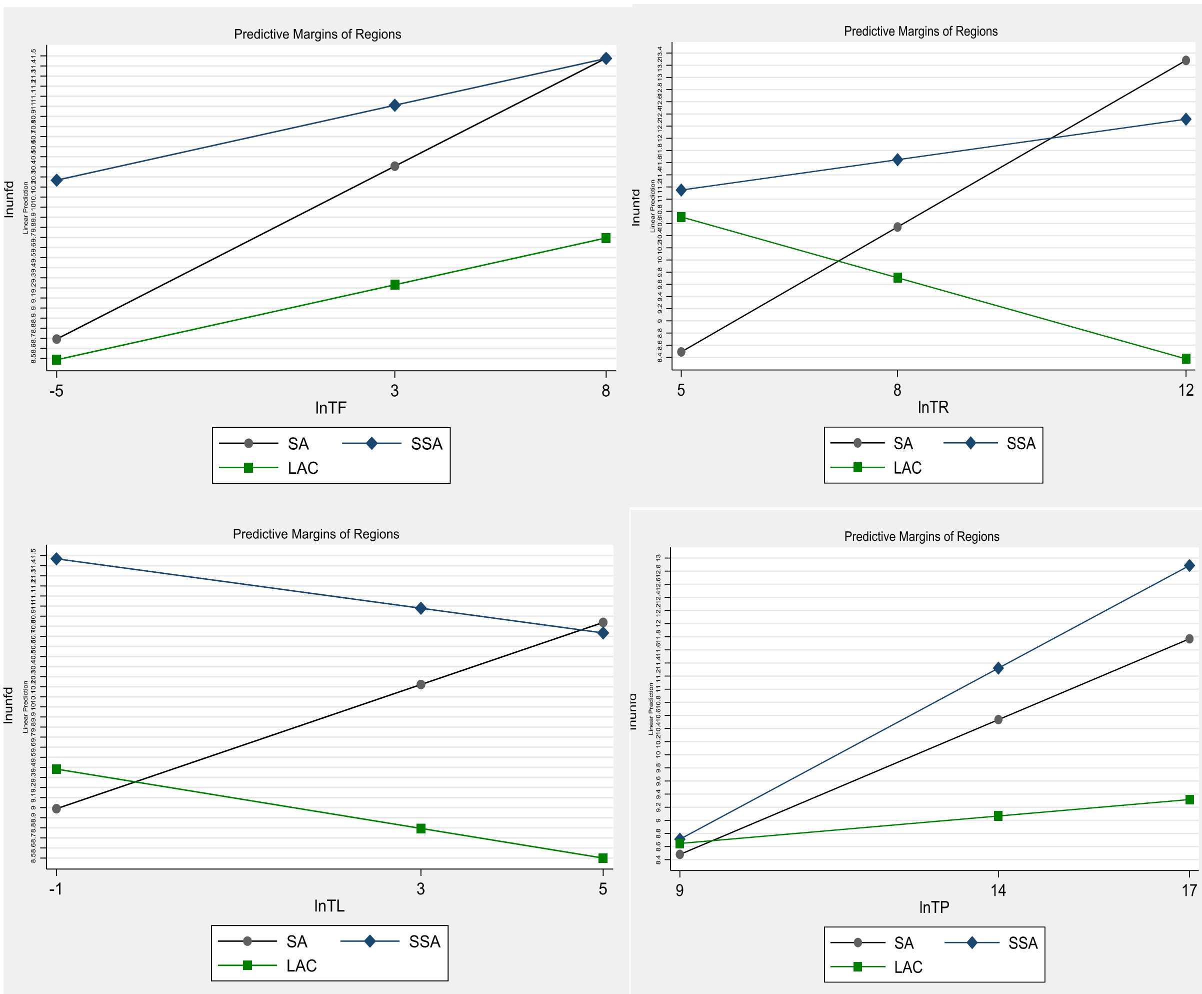

Fig 1g. Marginal effect of transport infrastructures on under-five mortality: Regional groupings

4.3. Robustness check results

The Driscoll-Kraay estimator is applied to check the robustness of the IV-GMM results. The results, presented in Tables 3A-3C, are consistent with the IV-GMM results presented in Tables 2A-2E. For instance, for the transport infrastructure variables, the estimates show that freight and rail coefficients are negative and statistically significant. On the other hand, the port connectivity and port traffic coefficients are positive and statistically significant. For the ICT infrastructure variables, while the estimate shows that telephone and ICT goods penetration have a neutral effect on human development, the coefficients of broadband, internet, and mobile phone penetration are positive and statistically significant. Similarly, the impact of the transport and ICT variables on human capital (see Models 10-18 of Table 3A), life expectancy (see Models 1-9 of Table 3B), under-five mortality (see Models 10-18 of Table 3B), and maternal mortality (see Models 1-9 of Table 3C) are not different from the IV-GMM results in terms of signs and significance levels. The consistency of the results shows that our findings are reliable for informing the design and implementation of infrastructure and human development policies in developing regions.

5. Conclusion and policy suggestions

Recent scholarly and policy discussions have focused on whether ICT and transport infrastructure enhance human development outcomes in developing countries. To contribute to the knowledge and policy, this study explores the impact of investment in transport and ICT infrastructures on human development using comprehensive panel data for 79 countries from South Asia (SAR), Sub-Saharan Africa (SSA) and Latin America-Caribbean (LAC) from 1990 to 2018. Applying the two-step IV-GMM to handle endogeneity, the results that emanated from this study are summarised as follows:

1 For transport infrastructure, our results revealed that freight and rail neither improve under-five mortality nor human development as a whole. Similarly, port traffic does not improve under-five mortality. However, port connectivity and port traffic enhance human development, and freight, rail, and port connectivity enhance human capital. In addition, rail and port connectivity were found to improve maternal mortality, and port connectivity also enhances life expectancy. We also found neutral effects of freight, rail and port traffic on life expectancy, port traffic on human capital, port connectivity on under-five mortality, and freight and port traffic on maternal mortality.

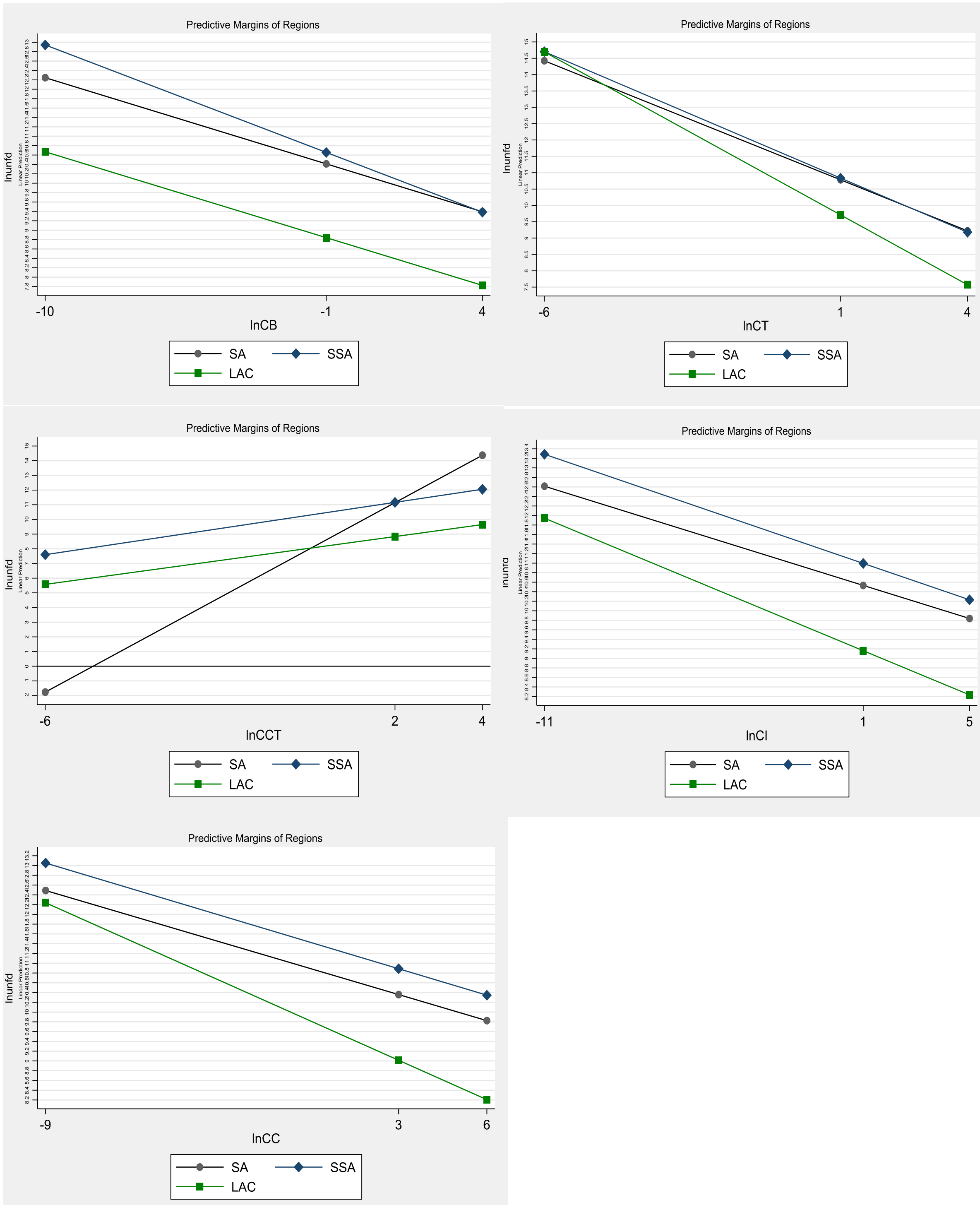

Fig 1h. Marginal effect of ICT infrastructures on under-five mortality: Regional groupings

2 For ICT infrastructure, our findings indicated that broadband, internet, mobile phone and telephone penetration improve human capital, life expectancy and under-five mortality. Similarly, broadband and internet penetration improve maternal mortality and human development as a whole. The results further reveal that maternal mortality can be improved by telephone penetration while human development can be improved by mobile phone penetration. It was also revealed that ICT goods penetration does not improve life expectancy and under-five mortality, while having a neutral effect on human development, human capital, and maternal mortality. Also, we found neutral effects of telephone penetration on human development, and mobile phone penetration on maternal mortality.

3 The results also suggest that SSA countries have lower human development, human capital, and life expectancy, but higher under-five and maternal mortality, when compared to SAR countries. Also, relative to SAR countries, LAC countries have lower human development index, human capital, under-five mortality and maternal mortality, but higher life expectancy.

4 In explaining how transport infrastructure contributes to the difference in human development outcomes across regions, our marginal

Regional effects of ICT and transport infrastructure on maternal mortality: marginal analysis

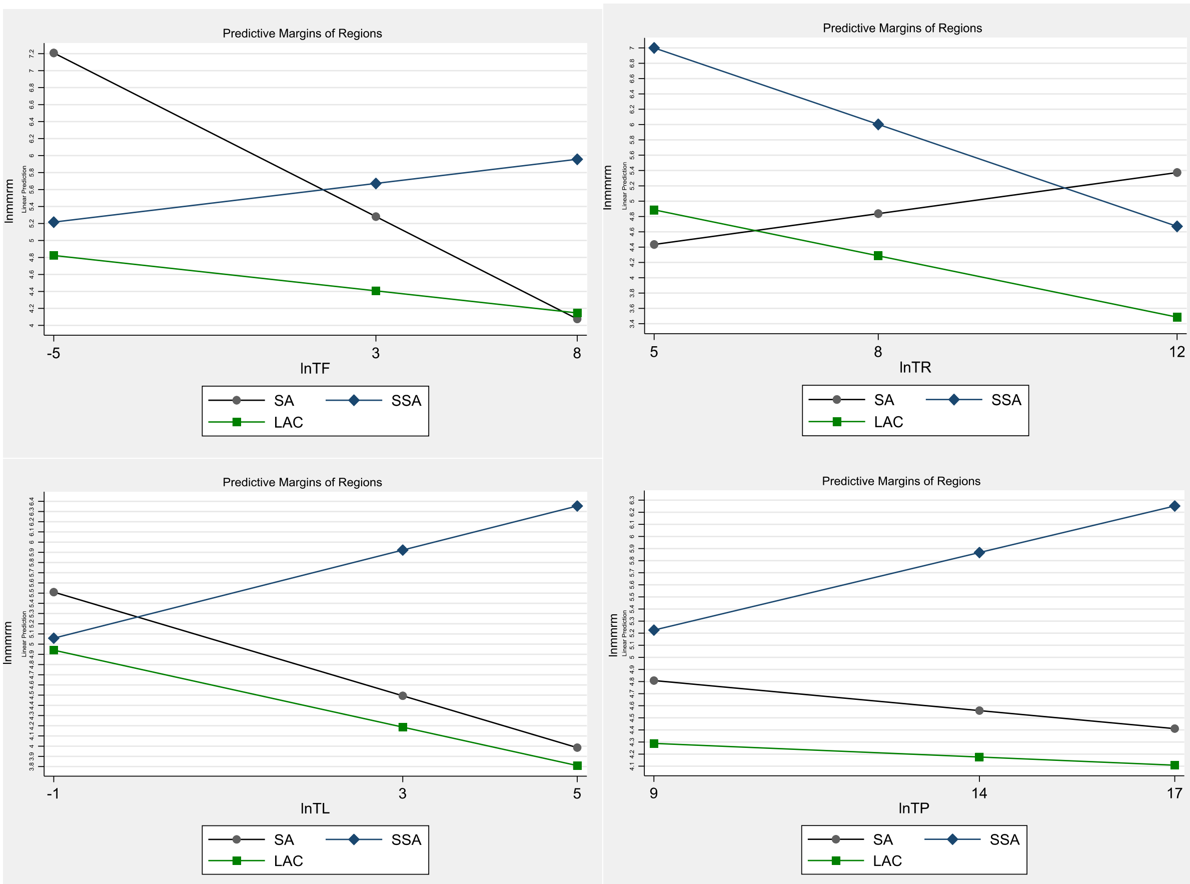

Fig 1i. Marginal effect of transport infrastructures on maternal mortality: Regional groupings

analysis indicated that port connectivity and port traffic improve human development in all the regions, but freight does not. It was also revealed that rail improves human development in LAC countries, but not in SAR and SSA countries. With regards to ICT infrastructure, we found that broadband, telephone, internet, and mobile phone penetration enhance human development in all regions. However, ICT goods penetration worsens human development in SAR and LAC while improving it in SSA. These findings suggest that the magnitude of the effect of the transport and ICT infrastructure variables on the human development outcomes differ among the regions.

In conclusion, we argue that infrastructure investment is vital for enhancing human development outcomes in developing regions. However, ICT infrastructure has been very effective in promoting human development in developing regions compared to transport infrastructure. We further argue that differences in human development outcomes across developing regions are partly explained by differences in transport and ICT infrastructure. These results and conclusions are robust to an alternative econometric estimator.

From a policy perspective, these findings have important implications for policymakers in developing regions to enhance human development outcomes. Our results consolidate the need to improve investment in transport and ICT infrastructure to improve human development outcomes. Currently, developing regions suffer from colossal infrastructure deficits. Closing the infrastructure deficits in developing countries requires substantial financial resources. For instance, the SAR region needs approximately US$5 trillion by 2030 to close its infrastructure gap, which translates into US$ 423 billion per annum (Kumar & Arora, 2019). For SSA, it is estimated that approximately US$93 billion is required annually to close the infrastructure deficit, of which about US$60 billion is needed for building new infrastructure and US$30 billion for maintaining existing infrastructure (Pottas, 2014). Similarly, Inter-American Development Bank has estimated that about US$150 billion is needed annually to close the infrastructure deficit in LAC. Most of the physical infrastructure investments in these regions are public; however, public investment in these regions is challenged by high accumulated public debt levels and fiscal constraints.

It is recommended that policymakers form partnerships with the private sector to expand the infrastructure needs in these regions. Using public-private partnership (PPP) to boost infrastructure development in these regions requires policymakers to design and implement a clear institutional policy framework for the partnership. According to Serebrisky and Suárez-Alemán (2021), attracting the private sector to boost infrastructure development requires policymakers to improve infrastructure planning and prioritisation, enhance project preparation facilities to speed efficient and sustainable project delivery, and align infrastructure development plans and programs with investors incentives.

Also, this study has demonstrated that ICT infrastructure plays a substantial role in enhancing human development outcomes in developing regions. However, using ICT in these developing regions is costly, limiting their usage among the larger population. Therefore, policymakers need to design and formulate policies to ensure universal access to ICT through low pricing.

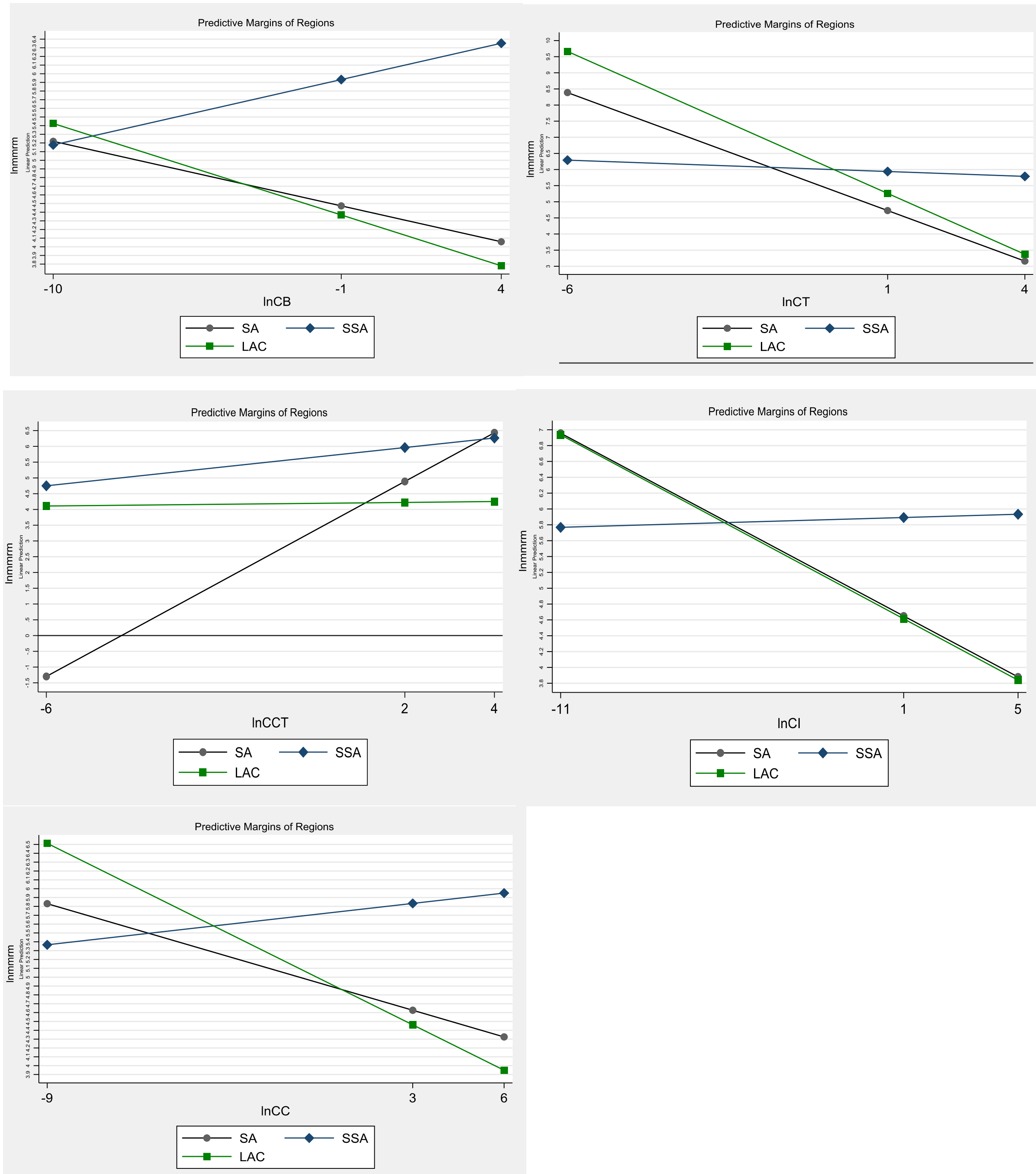

Fig 1j. Marginal effect of ICT infrastructures on maternal mortality: Regional groupings

This study's outcome is very important to attaining the Sustainable Development Goals (SDGs) of the United Nations. The entire SDGs can be pictured from two strands: i) economic and social development and ii) environmental sustainability. As attainment of the economic and social development strand leads to economic (income) and educational empowerment, the environmental sustainability strand improves health and life expectancy. Hence, the underlying agenda of the SDGs is to improve human development (wellbeing) on the fronts of income, education and health (including life expectancy). The results of this paper generally show that improvement in physical infrastructure (transport and ICT) ceteris paribus could improve human development. Therefore, physical infrastructure plays a pivotal role in achieving the 2030 agenda for sustainable development. As a result, important physical infrastructure to facilitate the transitioning to sustainable development is compelling, especially in developing countries with the largest infrastructural development investment deficits.

Empirical studies are usually fraught with limitations, and our study is no exception. The major limitation of our study was data availability. The sample focus of our study made this very apparent. Many developing countries have data availability and access challenges. In this study, considering all the variables employed, we arrived at 79 countries from 1990 to 2018. With more comprehensive access to data in the future, we suggest further studies be conducted on extended years and countries sample for a more constructive conclusion on the impact of physical infrastructure on human development. Future studies can also consider measuring infrastructure more broadly to include other

Table 3A
Driscoll-Kraay results for using composite human development index and human capital as dependent variables
Robustness Check

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Human Development									**Human capital**								
lnY	0.182***	0.077*	0.064***	0.100***	0.109***	0.105**	0.128***	0.097***	0.104***	0.176***	0.204***	0.187***	0.198***	0.172***	0.144***	0.187***	0.159***	0.167***
	(0.024)	(0.039)	(0.004)	(0.021)	(0.007)	(0.042)	(0.003)	(0.020)	(0.020)	(0.006)	(0.010)	(0.011)	(0.003)	(0.010)	(0.014)	(0.009)	(0.004)	(0.005)
lnTRA	0.038	0.047	0.071***	0.097***	0.077***	0.078***	0.085***	0.058**	0.033	0.140***	0.116***	0.071***	0.081***	0.119***	0.129***	0.100***	0.099***	0.092***
	(0.030)	(0.064)	(0.006)	(0.010)	(0.020)	(0.024)	(0.020)	(0.021)	(0.022)	(0.014)	(0.011)	(0.003)	(0.003)	(0.005)	(0.009)	(0.005)	(0.007)	(0.014)
lnUR	0.004	0.216**	0.105***	0.037	0.138***	0.119*	0.163***	0.154***	0.144***	-0.086***	-0.120**	-0.089***	-0.090***	0.016**	-0.016	0.005	-0.013	-0.032
	(0.041)	(0.089)	(0.024)	(0.030)	(0.012)	(0.058)	(0.012)	(0.030)	(0.035)	(0.018)	(0.051)	(0.007)	(0.012)	(0.006)	(0.032)	(0.020)	(0.028)	(0.043)
lnFDI	0.001	0.014	-0.031***	-0.020**	-0.019***	0.003	-0.018*	-0.008*	-0.013***	0.003	-0.002	-0.004*	-0.003	-0.006*	0.008***	-0.005	0.000	-0.002
	(0.005)	(0.012)	(0.004)	(0.009)	(0.004)	(0.003)	(0.009)	(0.005)	(0.004)	(0.005)	(0.004)	(0.002)	(0.003)	(0.003)	(0.002)	(0.005)	(0.004)	(0.003)
lnFD	0.013	-0.013	-0.059***	-0.070***	-0.021***	-0.009	0.002	-0.014	-0.010	-0.007	-0.017	-0.018***	-0.018**	-0.003	-0.016	0.011	-0.009*	-0.008
	(0.008)	(0.032)	(0.004)	(0.003)	(0.006)	(0.017)	(0.003)	(0.011)	(0.009)	(0.011)	(0.024)	(0.004)	(0.007)	(0.007)	(0.015)	(0.008)	(0.005)	(0.009)
lnRE	0.010***	0.003	-0.007**	-0.003	0.006***	0.005	0.008***	-0.001	-0.002	0.010*	-0.007	-0.004	-0.002	0.007	0.004	0.004	-0.001	-0.001
	(0.003)	(0.003)	(0.003)	(0.002)	(0.001)	(0.004)	(0.001)	(0.002)	(0.002)	(0.005)	(0.005)	(0.004)	(0.003)	(0.005)	(0.005)	(0.006)	(0.004)	(0.004)
lnEC	-0.043**	-0.078**	-0.192***	-0.154***	-0.103***	-0.055*	-0.077***	-0.087**	-0.074**	-0.034***	-0.053**	-0.028**	-0.031**	-0.035***	-0.030***	-0.019	-0.040***	-0.037***
	(0.016)	(0.035)	(0.009)	(0.027)	(0.014)	(0.028)	(0.017)	(0.032)	(0.033)	(0.009)	(0.020)	(0.011)	(0.013)	(0.003)	(0.003)	(0.012)	(0.005)	(0.005)
SSA	-0.150***	-0.170***	-0.169***	-0.120***	-0.217***	-0.168***	-0.225***	-0.227***	-0.216***	-0.131***	-0.217***	-0.167***	-0.186***	-0.183***	-0.169***	-0.195***	-0.196***	-0.196***
	(0.021)	(0.029)	(0.020)	(0.009)	(0.032)	(0.039)	(0.023)	(0.019)	(0.030)	(0.023)	(0.029)	(0.020)	(0.033)	(0.051)	(0.021)	(0.030)	(0.018)	(0.019)
LAC	-0.117***	-0.192***	-0.057***	-0.051**	-0.201***	-0.154***	-0.213***	-0.192***	-0.179***	-0.012	-0.115**	-0.069***	-0.089***	-0.139***	-0.116***	-0.136***	-0.128***	-0.115***
	(0.016)	(0.021)	(0.018)	(0.019)	(0.030)	(0.042)	(0.015)	(0.025)	(0.030)	(0.008)	(0.054)	(0.002)	(0.012)	(0.018)	(0.023)	(0.009)	(0.022)	(0.024)
lnTF	-0.014***									0.006								
	(0.004)									(0.004)								
lnTR		-0.023									0.020**							
		(0.017)									(0.008)							
lnTL			0.094***									0.028*						
			(0.014)									(0.013)						
lnTP				0.030***									0.007					
				(0.010)									(0.006)					
lnCB					0.008***									0.007***				
					(0.002)									(0.001)				
lnCT						0.024									0.028*			
						(0.022)									(0.014)			
lnCCT							0.003									-0.007		
							(0.009)									(0.010)		
lnCI								0.019***									0.018***	
								(0.004)									(0.003)	
lnCC									0.020***									0.015***
									(0.004)									(0.002)
Constant	-2.120***	-1.945***	-0.347**	-1.038***	-1.388***	-2.024***	-1.914***	-1.497***	-1.385***	-1.008***	-0.562***	-0.352	-0.559***	-0.927***	-0.907***	-0.965***	-0.609***	-0.573**
	(0.113)	(0.189)	(0.143)	(0.265)	(0.236)	(0.253)	(0.306)	(0.303)	(0.249)	(0.197)	(0.155)	(0.217)	(0.141)	(0.133)	(0.248)	(0.092)	(0.115)	(0.244)
N	618	281	385	394	451	773	510	692	729	649	294	385	394	451	804	513	710	749
R2	0.612	0.432	0.612	0.567	0.641	0.597	0.656	0.635	0.612	0.686	0.713	0.741	0.722	0.689	0.689	0.705	0.709	0.688

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3B
Driscoll-Kraay results for using life expectancy and under-five mortality as dependent variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Life expectancy									**Under-five mortality**								
lnY	0.056***	0.040***	0.051***	0.059***	0.038***	0.031***	0.050***	0.046***	0.051***	-1.169***	-1.061***	-1.142***	-1.310***	-0.921***	-0.543***	-1.210***	-1.010***	-1.077***
	(0.007)	(0.003)	(0.004)	(0.003)	(0.003)	(0.007)	(0.005)	(0.003)	(0.003)	(0.110)	(0.168)	(0.076)	(0.051)	(0.039)	(0.158)	(0.088)	(0.052)	(0.064)
lnTRA	0.044***	0.010	0.034***	0.024***	0.014***	0.039***	0.032**	0.024***	0.016**	-1.787***	-0.960***	-1.581***	-1.658***	-1.510***	-1.924***	-1.647***	-1.574***	-1.445***
	(0.008)	(0.013)	(0.011)	(0.005)	(0.002)	(0.007)	(0.011)	(0.005)	(0.006)	(0.116)	(0.115)	(0.170)	(0.169)	(0.151)	(0.076)	(0.202)	(0.108)	(0.106)
lnUR	-0.052*	0.010	-0.071***	-0.105***	-0.081***	-0.042*	-0.068***	-0.055**	-0.056**	1.091***	0.674*	1.017***	1.577***	1.224***	0.767***	1.254***	1.096***	1.132***
	(0.029)	(0.024)	(0.010)	(0.008)	(0.008)	(0.022)	(0.009)	(0.021)	(0.020)	(0.384)	(0.342)	(0.199)	(0.111)	(0.070)	(0.234)	(0.172)	(0.170)	(0.151)
lnFDI	0.002	-0.001	0.002	0.005	0.002***	0.005	0.004***	0.003	-0.000	0.221***	0.204***	0.393***	0.325***	0.376***	0.208***	0.290***	0.314***	0.344***
	(0.005)	(0.006)	(0.001)	(0.003)	(0.000)	(0.005)	(0.001)	(0.003)	(0.004)	(0.029)	(0.058)	(0.041)	(0.055)	(0.029)	(0.022)	(0.058)	(0.033)	(0.034)
lnFD	0.010	-0.014*	0.007***	0.001	-0.003	-0.003	0.019***	0.004	0.006*	-0.188***	-0.020	-0.121***	-0.048	0.085	0.206*	-0.227***	0.010	-0.017
	(0.007)	(0.007)	(0.001)	(0.002)	(0.002)	(0.007)	(0.003)	(0.004)	(0.003)	(0.059)	(0.043)	(0.019)	(0.041)	(0.089)	(0.106)	(0.035)	(0.042)	(0.052)
lnRE	0.001	0.000	-0.010***	-0.008***	-0.010***	-0.001	-0.007**	-0.006	-0.005	0.147***	0.206***	0.294***	0.250***	0.281***	0.182***	0.249***	0.247***	0.235***
	(0.005)	(0.004)	(0.002)	(0.002)	(0.001)	(0.004)	(0.002)	(0.004)	(0.004)	(0.050)	(0.061)	(0.014)	(0.037)	(0.020)	(0.055)	(0.028)	(0.040)	(0.041)
lnEC	-0.011**	-0.019***	-0.016***	-0.005**	0.001	-0.012**	0.000	-0.016***	-0.016***	0.049	0.101	0.163***	0.174*	-0.013	-0.061	0.094	0.036	0.003
	(0.005)	(0.003)	(0.003)	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.122)	(0.072)	(0.026)	(0.095)	(0.081)	(0.042)	(0.057)	(0.043)	(0.036)
SSA	-0.172***	-0.239***	-0.191***	-0.175***	-0.170***	-0.168***	-0.201***	-0.193***	-0.194***	0.329**	0.575**	0.722***	0.470**	0.306**	0.065	0.550**	0.489***	0.545***
	(0.015)	(0.015)	(0.025)	(0.019)	(0.014)	(0.017)	(0.025)	(0.016)	(0.014)	(0.149)	(0.225)	(0.166)	(0.161)	(0.114)	(0.123)	(0.191)	(0.109)	(0.098)
LAC	0.042**	-0.009	0.029***	0.054***	0.046***	0.010	0.048***	0.014	0.013	-1.434***	-0.822**	-1.425***	-1.609***	-1.517***	-1.169***	-1.805***	-1.370***	-1.308***
	(0.017)	(0.020)	(0.005)	(0.006)	(0.009)	(0.014)	(0.005)	(0.009)	(0.014)	(0.221)	(0.310)	(0.087)	(0.083)	(0.162)	(0.182)	(0.140)	(0.050)	(0.142)
lnTF	0.002									0.113***								
	(0.006)									(0.011)								
lnTR		-0.002									0.249**							
		(0.004)									(0.098)							
lnTL			0.009									-0.085*						
			(0.006)									(0.043)						
lnTP				-0.007									0.139**					
				(0.006)									(0.056)					
lnCB					0.012***									-0.219***				
					(0.002)									(0.038)				
lnCT						0.026***									-0.580***			
						(0.008)									(0.110)			
lnCCT							-0.013									0.523***		
							(0.008)									(0.025)		
lnCI								0.011***									-0.200***	
								(0.003)									(0.040)	
lnCC									0.011***									-0.198***
									(0.002)									(0.027)
Constant	3.747***	3.977***	4.145***	4.238***	4.395***	3.921***	3.993***	4.078***	4.109***	15.381***	9.803***	7.711***	7.342***	5.061***	12.043***	10.446***	9.216***	9.129***
	(0.132)	(0.056)	(0.058)	(0.052)	(0.046)	(0.123)	(0.099)	(0.112)	(0.072)	(2.383)	(1.337)	(1.841)	(1.101)	(1.615)	(1.655)	(1.953)	(1.652)	(1.250)
N	649	294	385	394	451	804	513	710	749	649	294	385	394	451	804	513	710	749
R2	0.805	0.808	0.831	0.816	0.849	0.812	0.839	0.824	0.820	0.797	0.802	0.862	0.857	0.876	0.820	0.844	0.836	0.833

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3C
Driscoll-Kraay results for using maternal mortality as the dependent variable

	1	2	3	4	5	6	7	8	9
lnY	-0.638***	-0.346***	-0.502***	-0.629***	-0.531***	-0.273**	-0.615***	-0.518***	-0.567***
	(0.106)	(0.111)	(0.065)	(0.099)	(0.073)	(0.097)	(0.054)	(0.064)	(0.062)
lnTRA	-0.367**	-0.134	-0.299**	-0.286***	-0.086	-0.350***	-0.211***	-0.224***	-0.239**
	(0.136)	(0.200)	(0.122)	(0.063)	(0.056)	(0.088)	(0.054)	(0.074)	(0.094)
lnUR	0.672**	0.626**	0.530***	0.786***	0.787***	0.537***	0.717***	0.582***	0.739***
	(0.265)	(0.269)	(0.076)	(0.195)	(0.188)	(0.151)	(0.182)	(0.142)	(0.114)
lnFDI	-0.030	-0.058**	-0.002	-0.041	-0.022	-0.112***	-0.046	-0.052**	-0.071**
	(0.034)	(0.021)	(0.014)	(0.027)	(0.014)	(0.022)	(0.027)	(0.019)	(0.028)
lnFD	-0.096	-0.153*	-0.105***	-0.164***	-0.189***	-0.040	-0.234***	-0.145***	-0.163***
	(0.070)	(0.087)	(0.032)	(0.032)	(0.058)	(0.045)	(0.079)	(0.038)	(0.046)
lnRE	0.092***	0.135***	0.147***	0.158***	0.153***	0.145***	0.138***	0.145***	0.150***
	(0.032)	(0.022)	(0.013)	(0.023)	(0.017)	(0.028)	(0.024)	(0.020)	(0.018)
lnEC	0.004	-0.122	0.023	-0.134**	-0.197**	-0.018	-0.164*	-0.095*	-0.113*
	(0.100)	(0.093)	(0.045)	(0.055)	(0.071)	(0.061)	(0.088)	(0.050)	(0.059)
SSA	0.880***	0.639***	1.350***	1.225***	1.164***	0.889***	1.289***	1.151***	1.100***
	(0.155)	(0.088)	(0.118)	(0.061)	(0.104)	(0.176)	(0.104)	(0.185)	(0.127)
LAC	-0.508***	-1.212***	-0.381**	-0.383***	-0.373***	-0.201*	-0.432**	-0.279**	-0.399***
	(0.146)	(0.213)	(0.123)	(0.118)	(0.091)	(0.098)	(0.147)	(0.104)	(0.087)
lnTF	-0.016								
	(0.016)								
lnTR		-0.107***							
		(0.034)							
lnTL			-0.182***						
			(0.035)						
lnTP				-0.005					
				(0.031)					
lnCB					-0.074***				
					(0.013)				
lnCT						-0.294***			
						(0.064)			
lnCCT							0.088		
							(0.056)		
lnCI								-0.077***	
								(0.019)	
lnCC									-0.042**
									(0.015)
Constant	7.870***	6.285***	5.523***	6.275***	4.534***	6.208***	6.791***	6.396***	6.696***
	(1.657)	(1.476)	(0.913)	(0.601)	(0.601)	(0.969)	(0.463)	(0.904)	(0.706)
N	143	54	120	127	148	176	150	173	173
R2	0.795	0.816	0.819	0.800	0.799	0.788	0.806	0.787	0.776

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

infrastructure such as different energy sources.

CRediT authorship contribution statement

Alex O. Acheampong: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Eric Evans Osei Opoku:** Conceptualization, Methodology, Formal analysis, Writing – original draft. **Janet Dzator:** Conceptualization, Methodology, Formal analysis, Validation, Writing – review & editing. **Nana Kwabena Kufuor:** Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.techfore.2022.121725.

Appendix. Table 1: Countries included in the study

South-Asia countries
Maldives; Sri Lanka; Bhutan; Pakistan; India; Nepal; Bangladesh
Sub-Saharan Africa countries
Mauritius; Seychelles; Gabon; South Africa; Cabo Verde; Comoros; Equatorial Guinea; Sao Tome and Principe; Ghana; Cote d'Ivoire; Congo, Rep.; Eswatini; Cameroon; Nigeria; Senegal; Namibia; the Gambia, The; Botswana; Sudan; Zimbabwe; Angola; Ethiopia; Mauritania; Togo; Benin; Kenya; Guinea; Mali; Zambia; Lesotho; Sierra Leone; Madagascar; Guinea-Bissau; Mozambique; Tanzania; Congo, Dem. Rep.; Uganda; Central African Republic; Burkina Faso; Liberia; Rwanda; Niger; Malawi; Chad and Burundi.
Caribbean-Latin America countries
The Bahamas, The; Barbados; Costa Rica; Venezuela, RB; Antigua and Barbuda; Uruguay; Argentina; Mexico; Chile Trinidad and Tobago; Brazil; Ecuador; Colombia; Paraguay; Dominican Republic; Dominica; Grenada; Jamaica; El Salvador; Panama; Belize; Guatemala; Peru; Bolivia; Nicaragua; Honduras; Haiti

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