ICT, economic performance and governance in developing countries

Background Paper

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Pathways for Prosperity Commission
Technology & Inclusive Development

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1. Executive Summary

The Information Age has sharpened the ability of individuals, firms and governments to effectively utilise the fruits of earlier eras of civilisation – such as the industrial revolution – towards greater prosperity. The previous phases of civilisation of the modern era produced significant divergence in income between the Global North and the Global South (Baldwin et al. 2001). Whether the new era of information and communications technology (ICT) helps developing countries catch up remains an open question. The dizzying progress in ICT and the associated decrease in the prices of technological products and services have certainly made information vastly more accessible in the developing world. That said, it is not always clear how developing countries can leverage this change to boost economic growth and bring about social and political progress.

This paper aims to shed light on the link between ICT, economic performance and quality of government in the developing world. We employ quantitative data from low and lower-middle income countries to highlight the potential causes and consequences of cross-country variations in ICT access and use. We mainly focus on mobile telephony and broadband internet as two of the most common pillars of ICT. We consider a series of sectoral and aggregate economic indicators to measure economic performance. We also look at measures of political participation and government quality to assess governance outcomes. Our analysis covers the two-and-a-half decades between 1990 and 2015 where computing and information technologies have mushroomed and spread rapidly across the globe. In Section 4, we also present tentative results on the potential causes and consequence of subnational variations in ICT access and use in selected African countries.

The potential effects of ICT on economic growth could take place through a number of transmission channels occurring on both the supply and demand sides (Andrianaivo and Kpodar 2011). At the most basic level, the growth of the ICT sector itself directly contributes to the growth of output and employment in ICT-enabled activities. The direct effect of ICT is further enhanced by its impact on government revenue through taxation, as well as balance of payments through attracting foreign direct investment. However, it should be noted that, as the sector gets more sophisticated, ICT-intensive business activities might become difficult to tax for many governments. On the demand side, there is substantial evidence that access to ICT can improve firm productivity (Cardona et al. 2013). ICT can contribute to the creation of larger and more integrated markets by reducing search cost, i.e. the time, energy and money expended by a consumer or a firm which is searching a product or service for purchase. ICT can also increase financial inclusion by providing cheaper and easier access for small businesses and households to different forms of financial instruments.

As an outcome that requires substantial investment and knowhow, the spread of ICT is likely to depend on the level of economic and technological development of countries. The take-up and diffusion of technologies such as fixed broadband is path-dependent because the current rate of expansion is determined by the availability of earlier technologies and infrastructure. The adoption of less path-dependent technologies, such as mobile telephony, which do not depend heavily on existing infrastructure and do not require substantial technical knowhow, might be affected by external factors such as topography. To the extent that ICT is a private good exchanged in the marketplace, the market structure (defined by the nature of competition/concentration and pricing) is likely to influence the spread of technologies.

In this paper, we use data from multiple sources to build a panel dataset of mobile and broadband coverage, internet use, use of secure servers as well as a number of relevant economic, geographical and political indicators across countries classified as low and lower-middle income. The quantitative analysis in subsequent sections is aimed at providing an overview of a series of key correlations rather than proving the causal link between a few specific relationships.

Summary of the key findings:

1. Our analysis indicates that wealthier and more urbanised countries have been in a better position to take advantage of the mobile telephony revolution. This is despite the finding that countries with poorly developed fixed telephone infrastructures can 'leapfrog' by expanding access to mobile telephony. The role of initial conditions is not limited to economic and technological factors. Political rights are found to be a critical predictor of the rate of mobile subscriptions in Africa.

2. The path-dependent nature of broadband technology is demonstrated in the strong association between contemporary broadband subscriptions and fixed phone subscriptions in the past. The predictive power of fixed phone subscriptions is strong enough that it absorbs the whole effect of per capita income on broadband subscriptions.

3. The rate of broadband subscriptions is a more accurate predictor of individual internet usage and the use of secure servers by businesses than the more generic indicator of mobile subscriptions. This is particularly true in Africa. Although the use of secure servers is often intended to facilitate online transactions, there is an indication that the size of the traditional financial sector might not be a good predictor of the adoption of secure servers in low and lower-middle income countries.

4. The expansion of mobile subscriptions is positively associated with an increase in per capita income. The source of this relationship at an aggregate level can be partly traced to the sector-level correlations between mobile subscriptions, and per capita value addition in the agricultural and service sectors. One way the expansion of mobile subscriptions may affect service sector growth is through its relationship with service sector exports such as tourism earnings. Most of the associations are lower in magnitude, or even negative in the case of African countries. This is probably because a number of complementary factors, such as relevant human capital, that may need to be available for mobile telephony to have an economically meaningful impact, are missing in many African countries.

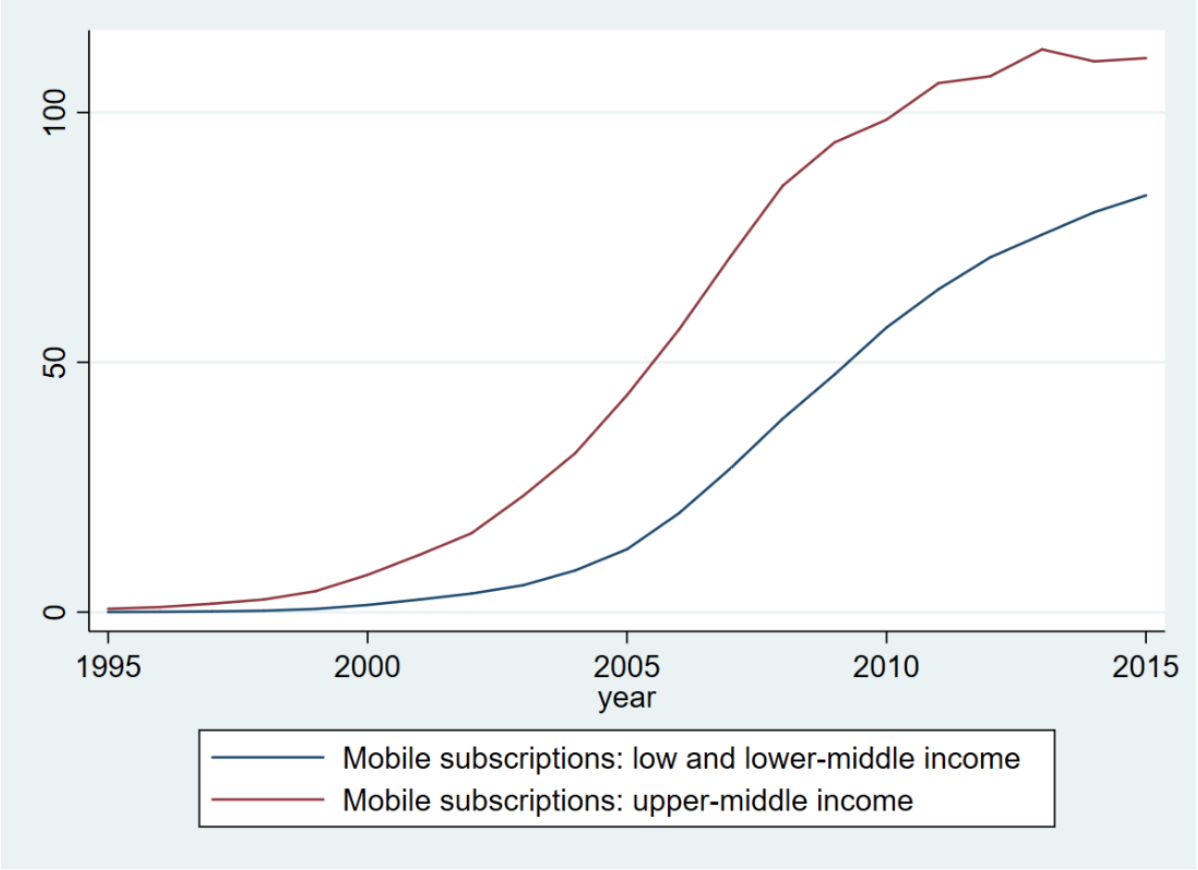
5. The relatively poor expansion of fixed broadband technology in low and lower-middle income countries seems to have weakened its link statistically with economic outcomes compared to mobile telephony. The positive correlation between broadband subscriptions and agricultural value added is an indication that the level of fixed broadband expansion may serve as a proxy for the potential of technology transfer. Even if the rate of broadband subscriptions does not seem to have a discernible link with service sector performance, the number of internet users, (including mobile internet), has a statistically significant positive relationship with service sector growth.

6. Our analysis of subnational data from 17 African countries shows that the spatial distribution of mobile access and use within countries tends to become more equitable as the overall rate of access and use increases. This can be interpreted as suggesting that the rising tide of overall mobile expansion lifts all boats. Access to mobile phones is shown to be a good predictor of internet use in small towns and rural areas. This also indicates the importance of mobile phones in creating equitable internet access. Finally, the association between mobile subscriptions and per capita income is stronger in countries where the subnational distribution of mobile access and use is more equitable.

2. Macro-level correlates of ICT access and use

Across the developing world, there is a clear trend showing an exponentially increasing rate of mobile telephone subscriptions.

Figure 1 - Trends of mobile subscription in groups of developing countries



Source: World Development Indicators

Figure 1 shows that the average number of mobile subscriptions per 100 people in low and lower-middle income countries has more than doubled in the years between 2008 and 2015. However, there is a growing divergence of mobile coverage between within the group of low and lower-middle income countries. In the period from 1995 to 2015, the standard deviation of mobile subscriptions increased consistently until it peaked in 2012. We attempt to explore factors that may be driving this divergence by analysing the antecedent correlates of mobile subscription in 2012.

Table 1 - Correlates of mobile subscriptions in developing countries: OLS estimates

Dependent variable: mobile subscriptions per 100 people in 2012	Full sample of low and lower-middle income countries			Africa sample		
	1	2	3	4	5	6
Fixed phone subscriptions (1995)	1.40*	4.31**	0.342	3.47	4.49	-1.23
	(1.82)	(2.02)	(0.33)	(1.12)	(1.43)	(-0.3)
Fixed phone subscriptions squared (1995)		-0.256*			-1.86*	
		(-1.79)			(-1.72)	
GDP per capita, log (1995)	13.96***	11.41***	10.72*	13.75***	11.73***	11.24**
	(3.48)	(2.73)	(1.82)	(3.26)	(2.68)	(2.56)
Topographic ruggedness (population weighted)	-2.79	-3.63	-8.12	0.770	0.034	-5.51
	(-0.57)	(-0.69)	(-1.25)	(0.18)	(0.01)	(-0.99)
Private investment in telecom, log (2000-05)	0.929	1.16	0.055	1.34	1.77	1.61
	(0.47)	(0.65)	(0.03)	(0.55)	(0.74)	(0.63)
Political rights index (2000)	-0.178	-0.086	-0.926	4.45**	4.42**	3.57*
	(0.09)	(0.04)	(0.38)	(2.10)	(2.08)	(1.73)
Population density (1995)	0.029	0.028	0.030	0.088	0.090	0.134
	(1.05)	(1.04)	(1.00)	(1.31)	(1.29)	(1.63)
Urbanisation (1995)	0.690***	0.603**	0.539**	1.05***	1.04***	1.04***
	(2.95)	(2.42)	(2.00)	(3.44)	(3.43)	(3.44)
Average mobile subscriptions in neighbouring countries (2005)			0.613*			0.651*
			(1.7)			(1.86)
R-squared	0.50	0.52	0.54	0.7	0.72	0.75
N	61	61	55	35	35	33

Note: t-values are given in parenthesis. ***, ** and * represent 1%, 5% and 10% statistical significance, respectively.

Source: Author's computation of OLS

Table 1 shows the results of an Ordinary Least Squares regression of mobile subscriptions in 2012 on a set of economic, technological, geographic and political factors. We fix most of the correlates at the beginning of the period under consideration (1995) in an attempt to reduce the effect of confoundedness (i.e. the possibility of both the dependent and explanatory variable being caused by some common unobserved factor) as much as possible. However, the indicator of political rights is from 2000 because many countries were still undergoing the Third Wave of democratisation in the 1990s. Likewise, private investment in telecommunications is averaged over 2000 to 2005 to capture data on as many countries as possible and to smooth out annual fluctuations.

Table 1 shows that the rate of mobile subscriptions in 2012 is strongly correlated with average income in 1995. There is some indication that the degree of fixed phone coverage in 1995 might predict current mobile subscriptions. Although the two modes of telephony are generally considered substitutes, the expansiveness of the fixed phone network in the 1990s could serve as an indicator for the development of the telecommunications sector. Since we do not expect mobile subscriptions to increase linearly with the size of the fixed phone network beyond the attainment of a minimum level of telecommunications development, we test for nonlinearity in the relationship. Accordingly, column 2 includes a quadratic term of fixed telephone subscription in 1995. This shows that the positive correlation between contemporary rates of mobile subscriptions and past landline network diminishes once a certain level of telecommunications development has been attained.

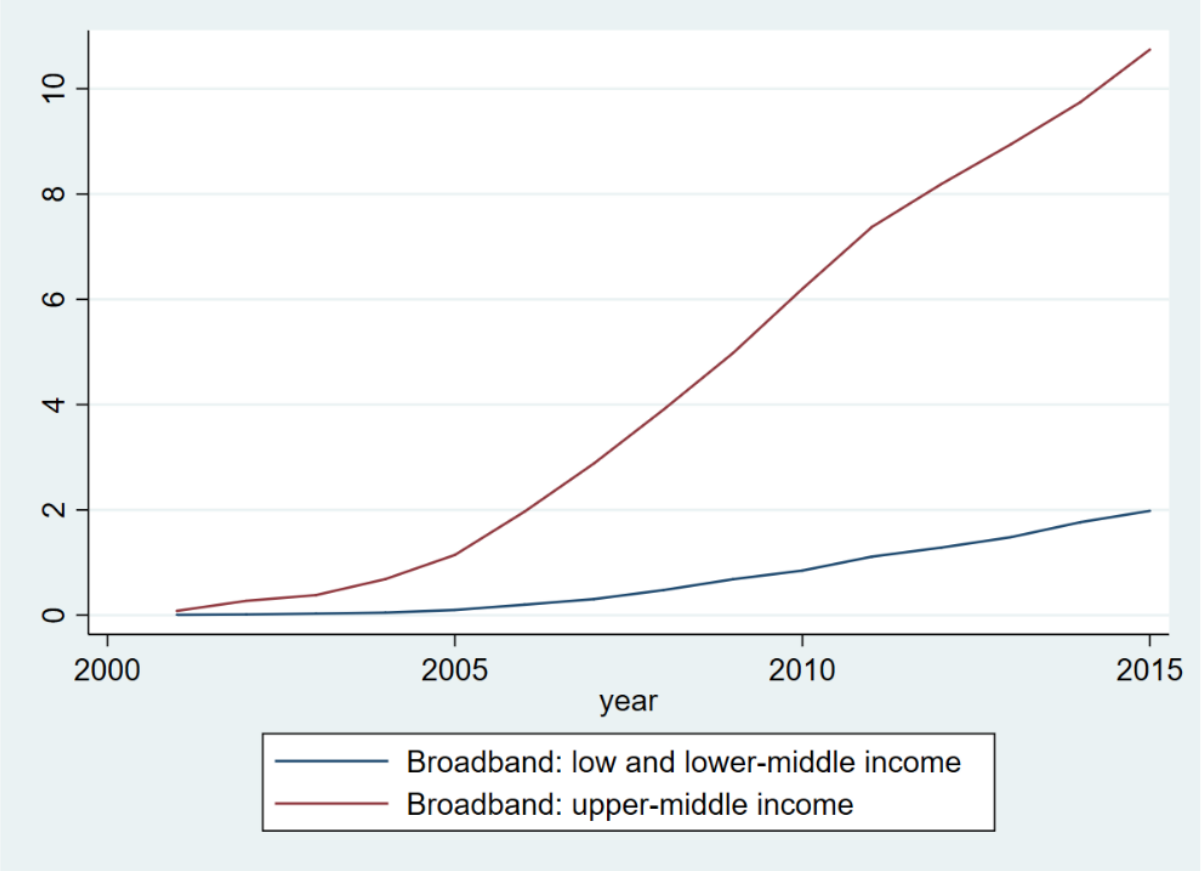
The rate of urbanisation in 1995 is positively correlated with the rate of mobile subscriptions in 2012, independent of level of income. The existence of sufficient urban centres appears to be a more important predictor of mobile expansion than overall population density. Although Buys et al (2009) present evidence of a negative correlation between mobile tower location, elevation and slope, the average ruggedness of a country's terrain does not seem to have a statistically significant relationship with the spread of mobile telephony. There is also no meaningful relationship between the level of private investment in the telecommunications sector and the rate of mobile subscription.

Many of telecommunications companies providing mobile telephony services are multinational companies with regional concentration. This means there could be spatial diffusion of mobile technologies through multinational companies operating in neighbouring countries, potentially creating distinct clusters of telecommunication agglomeration. In column 3 of Table 1, we include the average rate of mobile subscription in contiguous countries in 2005 as a correlate. The results show that there is a marginally significant positive correlation between mobile subscriptions in a given country in 2012 and the average rate of subscription for its neighbours seven years ago.

Considering that Africa is the most underdeveloped region in the world where ICT presents significant opportunities, we estimate the predictors of mobile subscriptions in Africa by repeating the above analysis for a subsample consisting only of Africa countries. Column 4 shows that per capita income, as the most important predictor of mobile subscriptions, has almost the same coefficient in Africa as in the entire sample of low and lower-middle income countries. However, urbanisation has a significantly stronger correlation with the rate of mobile subscription in Africa than in the rest of the developing world. This is probably because, with a number of economies in Africa still reliant on agriculture, the more urbanised countries have comparatively dynamic service sectors. The assessment that many developing countries are leapfrogging earlier ICT by adopting mobile technologies seems more accurate in the case of African countries. This is indicated by

the insignificance of the fixed telephone coefficient in columns 4–6. One result that markedly distinguishes African countries from other developing countries is the positive correlation between political rights in 2000 and mobile subscriptions in 2012. There are a number of potential channels through which political freedom may influence the expansion of new technologies. The desire of repressive regimes to restrict the flow of information might lead them to deliberately stifle the growth of the sector.[1]

Figure 2 - Trends of broadband subscription in groups of developing countries



Source: World Development Indicators

The rate of fixed broadband subscriptions has grown substantially in low and lower-middle income countries since the start of the millennium. However, as Figure 2 shows, there is a growing divergence between the spread of broadband subscriptions in lower and lower-middle income countries and upper-middle income countries. This divergence appears even larger than that of mobile telephone subscriptions in Figure 1. Considering that fixed broadband is more widely used in businesses than mobile broadband, this divergence could have implications for the competitiveness of low and lower-middle income countries. As far as group divergence is concerned, the standard deviation of fixed broadband subscriptions is growing in both groups of countries.

[1] One example that shows the extent repressive regimes might go to in restricting basic telecom services is that the Ethiopian government shut down the short message service (SMS) across the entire nation for more than two years following the 2005 post-elections crisis.

Table 2 - Correlates of fixed broadband subscriptions in developing countries: OLS estimates

Dependent variable: fixed broadband subscription per 100 people in 2015	Full sample of low and lower-middle income countries			Africa sample		
	1	2	3	4	5	6
Fixed phone subscriptions (2005)	0.516***	0.397***	0.544***	0.311***	0.282***	0.373***
	(7.28)	(4.39)	(7.54)	(5.62)	(7.69)	(5.32)
Fixed phone subscriptions squared (2005)		0.016			0.116***	
		(1.43)			(3.65)	
GDP per capita, log (2000)	-0.177	0.227	-0.277	-0.010	0.125	-0.093
	(-0.53)	(0.63)	(-0.6)	(-0.06)	(1.00)	(-0.51)
Distance to coast	0.529	0.669	0.544	0.257	0.021	0.388*
	(0.75)	(0.97)	(0.72)	(1.33)	(0.14)	(1.92)
Private investment in telecom, log (2000-05)	-0.089	-0.081	-0.114	0.164	0.120	0.171*
	(-0.62)	(-0.6)	(-0.71)	(1.77)	(1.2)	(1.76)
Political rights index (2000)	-0.068	-0.093	-0.037	0.009	0.006	0.013
	(-0.65)	(-0.97)	(-0.3)	(0.2)	(0.16)	(0.26)
Population density (2000)	0.002*	0.002**	0.002	0.000	0.000	0.000
	(1.75)	(2.49)	(1.27)	(0.06)	(0.29)	(-0.05)
Urbanisation (2000)	0.010	0.009	0.020	0.009	0.007	0.012
	(0.620	(0.62)	(1.19)	(1.2)	(1.11)	(1.28)
Average broadband subscription in neighbouring countries (2010)			-0.307**			-0.130
			(-2.62)			(-1.17)
R-squared	0.73	0.74	0.75	0.88	0.90	0.89
N	59	52	52	33	33	30

Note: t-values are given in parenthesis. ***, ** and * represent 1%, 5% and 10% statistical significance, respectively.
Source: Author's computation based on World Development Indicators data

In Table 2, we present coefficients of an OLS regression of broadband subscriptions in 2015 as a function of roughly the same set of variables as for mobile subscriptions. The only exception is that the geography variable that is deemed relevant for broadband coverage is 'average distance to coast'. This is because 99% of international data is transmitted through submarine cables.[2]

Table 2 shows that fixed telephone subscription, as might be expected, is strongly correlated with fixed broadband subscription in all specifications. As the main infrastructure used for downstream distribution of broadband internet, the expansiveness of the landline network is a key predictor of a country's ability to take advantage of broadband internet. Interestingly, per capita income in 2000 does not have any statistically significant relationship with broadband subscriptions in 2015, apart from its effect through the underlying infrastructure. Unlike mobile subscriptions, urbanisation is not associated with the spread of broadband subscriptions. However, there is some evidence suggesting that overall population density could be a predictor of broadband development in low and lower-middle income countries. Column 3 presents a curious result showing that average broadband subscriptions in neighbouring countries in 2010 is negatively correlated with broadband expansion in a given country. This indicates that, at best, there is no regional agglomeration in the fixed broadband market.

Columns 4 to 6 in Table 2 present results for the Africa subsample. One indication that African countries might still benefit from investing in the underlying infrastructure for broadband internet is that fixed phone subscriptions in 2000 have a non-linear relationship with broadband subscriptions in 2015. In other words, the correlation between fixed phone subscriptions and broadband subscriptions grows stronger as the size of the fixed phone network increases. Moreover, the results show that there is marginally significant correlation between the level of private sector investment in telecommunications and broadband subscriptions in Africa. Considering that the broadband infrastructure is often dominated by current or former monopolies, private sector involvement may have a more meaningful effect on broadband subscriptions than on mobile subscriptions (which is often more competitive than broadband).

Having established some of the most important correlates of mobile and fixed broadband subscriptions, we now briefly analyse the determinants of internet use in low and lower-middle income countries. We employ two indicators of internet usage:

- the percentage of individuals using the internet
- the number of secure internet servers per 1 million people.[3]

While individual usage captures day-to-day use on the consumer side of the economy, the number of secure internet servers using encryption technology can be a proxy for internet use on the producer or business side of the economy.

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[2] See NEC 'Secrets of submarine cables – Transmitting 99 percent of all international data!' at: https://www.nec.com/en/global/about/mitatv/02

[3] According to World Development Indicators' definition, internet users are individuals who have used the internet (from any location) in the last three months. The internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV, and so on.

Table 3 - Predictors of internet use in developing countries: OLS estimates

	Dependent variable: Internet users per 100 people in 2015		Dependent variable: Secure internet servers per 1 million people in 2015	
	Full sample	Africa	Full sample	Africa
Mobile subscriptions (2015)	0.129***	0.071	-0.044	0.008
	(4.06)	(1.22)	(-0.71)	(0.32)
Fixed broadband subscriptions (2015)	1.74**	1.95**	3.63***	0.925
	(2.51)	(2.29)	(8.31)	(0.57)
GDP per capita, log (2010)	5.66***	2.21	6.40**	3.47*
	(3.08)	(0.72)	(2.28)	(1.90)
Educational attainment ages 15-34 (2015)	1.05**	1.45*		
	(2.03)	(1.70)		
Credit to GDP ratio (2015)			-0.039	0.073
			(-0.56)	(0.53)
R-squared	0.73	0.64	0.66	0.33
N	74	34	65	34

Note: t-values are given in parenthesis. ***, ** and * represent 1%, 5% and 10% statistical significance, respectively.

Source: World Development Indicators

Table 3 presents the results of an OLS model of internet usage as a function of a combination of contemporaneous and lagged variables. Per capita gross domestic product (GDP) is lagged by five years in an attempt to control for historical differences in economic and technological factors. We incorporate mobile and fixed broadband subscriptions as predictor variables because they are the most important modes for accessing the internet. Also, in the case of individual internet use, we control for the educational attainment of the population aged between 15 and 34 years. For secure internet servers, we attempt to take account of the potential size of encrypted internet transactions by incorporating a proxy for the development of the domestic financial sector. We use the ratio of bank credit to GDP as a proxy.

Although mobile and broadband subscriptions are statistically significant predictors of individual internet use, the size of the broadband coefficient is multiple times higher than that of mobile. A one standard deviation increase in broadband subscriptions is associated with 13 points increase in the percentage of internet users, whereas one standard deviation increase in mobile subscriptions

is only associated with 4.3 points increase in internet usage. This is to be expected since a large number of mobile subscribers may not be able (or inclined) to use their mobile phones to access the internet. Internet use via mobile phones can sometimes be measured inaccurately as some users fail to realise that they are using the internet when they access social media and other applications on their phones.[4] In the case of the Africa subsample, the rate of mobile subscriptions is not even a statistically significant predictor of individual internet use. This is probably due to the early stage of development of 3G and 4G mobile internet in most African countries.

Theoretically, we expect education to be a key predictor of the uptake of technologies such as the internet. Our results confirm that the average educational attainment of the population aged between 15 and 34 years is positively correlated with individual internet use in the full sample of low and lower-middle income countries. However, in Africa, average education is a less precise predictor of individual internet use.

On the business side of internet use, the number of secure internet servers per 1 million people is strongly correlated with the rate of fixed broadband subscriptions in the full sample of low and lower-middle income countries. On the contrary, the rate of mobile subscriptions does not have any signification association with the number of secure servers. This suggests that a significant portion of mobile phones in those countries are not used to access the internet, let alone perform secure transactions online. Per capita income is another predictor of the use of secure servers for internet transactions. However, financial depth proxied by bank credit to GDP ratio does not have any correlation with the use of encrypted servers once per capita income is controlled for. In Africa, none of the correlates, except for per capita income, have a statistically significant correlation with the number of secure servers. This is likely because the number of secure internet servers in most low or lower-middle income countries in Africa is relatively small and there is little variation to be explained by anything other than income.

[4] Quartz has compiled evidence from a number of countries proving the existence of measurement errors in self-reported use of the internet. See Mirani, L. 'Millions of Facebook users have no idea they're using the internet' at: https://qz.com/333313/milliions-of-facebook-users-have-no-idea-theyre-using-the-internet.

3. ICT, economic performance and governance

This section provides an overview of the correlations between access to different modes of ICT and a selected set of key economic and governance indicators. In the economic realm, we consider both aggregate and sectoral outcomes that may be affected by ICT use. In terms of governance, we consider composite quality of government as well as political participation. As each of the outcome indicators we consider are characterised by complex systems of causation that are beyond the scope of this paper, we do not attempt to estimate full specifications with complete sets of control variables. Instead, we simply provide estimates of linear regressions on the relevant ICT indicator with time and country fixed effects. The panel dataset covers the period between 1990 and 2015 for all low and lower-middle income countries for which data is available.

3.1 Mobile telephony subscriptions

Table 4 shows that the rate of mobile subscriptions (lagged by one year) has a statistically significant positive correlation with GDP per capita in low and lower-middle income countries.

Table 4 - Mobile telephony, economic and governance outcomes: linear regressions with country and year fixed effects

Dependent variable	Explanatory variable (1-year lag)	1	2	3
GDP per capita, log	Mobile subscriptions	0.002***	0.003***	0.002***
		(7.52)	(6.29)	(8.13)
	Mobile subscriptions, squared		0	
			(-2.15)	
	Mobile subscriptions X Africa dummy			-0.001***
				(-6.12)
	R-squared	0.49	0.49	0.5
	N	1,920	1,920	1,909
Agriculture, per capita value added, log	Mobile subscriptions	0.002***	0.001***	0.002***
		(8.46)	(4.26)	(8.71)
	Mobile subscriptions, squared		0	
			(0.99)	
	Mobile subscriptions X Africa dummy			-0.001
				(-4.24)
	R-squared	0.17	0.17	0.18
	N	1,657	1,657	1,651

Industry, per capita value added, log	Mobile subscriptions	-0.0002	0.0009	1.34
		(-0.67)	(1.34)	(-0.41)
	Mobile subscriptions, squared		0	
			(-2.17)	
	Mobile subscriptions X Africa dummy			-0.002***
				(-5.53)
	R-squared	0.33	0.33	0.34
	N	1,657	1,657	1,651
Service sector, per capita value added, log	Mobile subscriptions	0.001***	0.002***	0.0014***
		(4.34)	(4.98)	(4.60)
	Mobile subscriptions, squared		0	
			(-2.97)	
	Mobile subscriptions X Africa dummy			-0.0016***
				(-5.94)
	R-squared	0.61	0.61	0.61
	N	1,638	1,638	1,632
Service sector exports, log	Mobile subscriptions	0.004****	0.006***	0.004***
		(4.34)	(4.83)	(4.68)
	Mobile subscriptions, squared		0	
			(-2.79)	
	Mobile subscriptions X Africa dummy			-0.003***
				(-4.31)
	R-squared	0.64	0.64	0.64
	N	1,701	1,701	1,692
Quality of government index	Mobile subscriptions	0	0.0001	0
		(0.06)	(0.69)	(0.48)
	Mobile subscriptions, squared		0	
			(-0.81)	
	Mobile subscriptions X Africa dummy			-0.0003***

				(-3.88)
	R-squared	0.19	0.19	0.2
	N	1,353	1,353	1,353
Political participation index	Mobile subscriptions	-0.0001	-0.001***	-0.0001
		(-1.17)	(-4.31)	(-1.00)
	Mobile subscriptions, squared		0	
			(4.54)	
	Mobile subscriptions X Africa dummy			-0.0001
				(-1.37)
	R-squared	0.16	0.17	0.16
	N	1,933	1,933	1,927

Note: t-values are given in parenthesis. Fractions with more than 4 decimal points are rounded off to zero. ***, ** and * represent 1%, 5% and 10% statistical significance, respectively.

As expected for such a catch-all indicator as GDP per capita, the magnitude of the coefficient is rather small. A one standard deviation increase in mobile subscription is associated with only 0.08 points increase in log per capita income. However, as far as within case variation (net of country fixed effects) is concerned, change in mobile subscriptions explains nearly half of the variation in per capita income. We also test if the size of the correlation between mobile subscriptions and average income increases with rate of mobile subscriptions in line with the hypothesis that the benefits of ICT are maximised after a certain level of network density is attained.[5] There is no evidence of increasing returns to network density. Finally, our results show that the correlation between mobile subscriptions and per capita income is much lower for African countries, although the coefficient generally remains positive.

The contribution of ICT to aggregate output occurs in the form of contributions to specific sectors of the economy. The widespread use of mobile phones may contribute to boosting agricultural production. It can do this by making weather and market information more accessible, as well as providing extension support (such as expert advice on the use of agricultural inputs). We use per capita real agricultural value added as an indicator of agricultural production. Table 4 shows that there is a positive correlation between agricultural value added and mobile subscriptions. However, the magnitude of the correlation is small, indicating that much of the variation in agricultural production between countries is mainly attributed to factors other than mobile subscriptions. Also, African countries may not be benefitting as much from mobile telephony in growing their agricultural sectors. This is shown by the reduced size of correlation for that particular group of countries.

[5] Kathuria et al. (2009) show, using a study of Indian states, that there is a critical mass of mobile diffusion above which mobile penetration begins to have a significant positive effect on economic growth.

As expected, the rate of mobile subscriptions does not have a statistically significant correlation with per capita industrial value added in any meaningful way. On the contrary, mobile telephony is expected to have an impact on the service sector, even at low levels of development. First, the expansion of mobile telephony services is counted directly as part of the service sector. Second, mobile technology is expected to catalyse activities in the trade and financial sectors in developing countries. Table 4 shows that the rate of mobile subscriptions is positively correlated with service sector growth. A one standard deviation increase in the rate of mobile subscriptions is associated with almost 5% increase in per capita value added in the service sector. However, this correlation is more pronounced at the early stages of mobile telephony expansion. It is curious that there is no network density effect influencing the relationship between mobile subscriptions and service sector value added. The positive correlation between mobile subscriptions and service sector value added is negative in the case of African countries.

Mobile telephony is expected to facilitate transactions in export-oriented service activities such as tourism and hospitality. For instance, one of the factors determining the attractiveness of a country for international tourists is the ease of acquiring a mobile SIM card and the extent of network coverage in tourist destinations. Our results show that an increase in the rate of mobile subscriptions is associated with a small but statistically significant rise in service exports in low and lower-middle income countries.

As in the case of overall value added in the service sector, the positive correlation between mobile subscriptions and service exports is larger at the early stages of mobile expansion. However, there seem to be significant regional disparities in this relationship as well. The positive correlation almost disappears when we introduce an indicator variable for African countries.

We use International Country Risk Guide's composite indicator of government quality and Freedom House's overall measure of political participation to gauge the supply and demand sides of governance respectively. Table 4 shows that the rate of mobile subscriptions does not have any statistically significant relationship with the quality of government. When it comes to political participation, the correlation with mobile subscriptions appears to be negative when a nonlinear specification is assumed.

3.2 Fixed broadband subscriptions

Table 5 presents results on the relationship between fixed broadband subscriptions and economic and governance indicators. The rate of fixed broadband subscriptions is positively correlated with per capita GDP. However, the size of the correlation, per standard deviation change, is only 56% of the corresponding effect in the case of mobile telephony (i.e. 0.049 vs 0.088). The positive correlation completely vanishes in the case of African countries.

Table 5 - Fixed broadband, economic and governance outcomes: linear regressions with country and year fixed effects

Dependent variable	Explanatory variable (1-year lag)	1	2	3
GDP per capita, log	Fixed broadband subscriptions	0.010***	0.005	0.011***
		(3.45)	(1.26)	(4.07)
	Fixed broadband subscriptions, squared		0.001*	
			(1.87)	
	Fixed broadband subscriptions X Africa dummy			-0.032***
				(-4.04)
	R-squared	0.63	0.63	0.65
	N	796	796	796
Agriculture, per capita value added, log	Fixed broadband subscriptions	0.022***	0.027***	0.023***
		(6.57)	(5.99)	(6.56)
	Fixed broadband subscriptions, squared		-0.001	
			(-1.64)	
	Fixed broadband subscriptions X Africa dummy			-0.005
				(-0.53)
	R-squared	0.18	0.18	0.18
	N	736	736	736
Industry, per capita value added, log	Fixed broadband subscriptions	-0.018***	-0.034***	-0.015
		(-3.42)	(-4.85)	(-0.41)
	Fixed broadband subscriptions, squared		0.003***	
			(3.42)	

	Fixed broadband subscriptions X Africa dummy			-0.047***
				(-3.13)
	R-squared	0.36	0.37	0.37
	N	736	736	736
Service sector, per capita value added, log	Fixed broadband subscriptions	-0.001	-0.008*	0.001
		(-0.26)	(-1.89)	(0.27)
	Fixed broadband subscriptions, squared		0.002**	
			(2.54)	
	Fixed broadband subscriptions X Africa dummy			-0.031***
				(-3.18)
	R-squared	0.67	0.67	0.67
	N	735	735	735
Service sector exports, log	Fixed broadband subscriptions	0.004	-0.015	0.011
		(0.51)	(-1.19)	(1.33)
	Fixed broadband subscriptions, squared		0.003**	
			(2.09)	
	Fixed broadband subscriptions X Africa dummy			-0.170***
				(-6.72)
	R-squared	0.59	0.59	0.62
	N	804	804	801
Quality of government index	Fixed broadband subscriptions	-0.002**	-0.002*	-0.002**
		(-2.47)	(-1.82)	(-2.41)
	Fixed broadband subscriptions, squared		0	
			(0.11)	

	Fixed broadband subscriptions X Africa dummy			-0.001
				(-0.39)
	R-squared	0.07	0.07	0.07
	N	603	603	603
Political participation index	Fixed broadband subscriptions	0.007***	0.005***	0.006***
		(5.90)	(3.18)	(5.28)
	Fixed broadband subscriptions, squared		0.0002	
			(1.10)	
	Fixed broadband subscriptions X Africa dummy			0.017***
				(4.96)
	R-squared	0.11	0.11	0.14
	N	821	821	815

Note: t-values are given in parenthesis. Fractions with more than four decimal points are rounded off to zero. ***, ** and * represent 1%, 5% and 10% statistical significance, respectively.

In terms of sectoral contributions, the results show that the rate of broadband subscriptions is positively associated with per capita value added in agriculture. The link between broadband connection and agricultural production is not obvious. However, it is conceivable that, in low and lower-middle income countries where agriculture is likely to be underdeveloped, even a general-purpose technology such as broadband internet might help in facilitating technology transfer. Another encouraging result is that there is no statistically significant difference between African countries and other low and lower-middle income countries regarding the link between agricultural value added and broadband subscription. When it comes to the industry sector, broadband subscriptions are negatively associated with per capita value added once country and year fixed effects are controlled for. The magnitude of the negative correlation grows as the rate of broadband subscriptions increases. Moreover, the negative relationship between broadband subscriptions and industrial valued added is four times stronger in African countries than in the rest of low and lower-middle income countries.

It is rather puzzling that there is no statistically significant correlation between broadband subscriptions and per capital value added in the service sector. There is even an indication that the relationship might be negative if a nonlinear specification is assumed. Likewise, service sector exports have no statistically significant relationship with broadband subscriptions. This seemingly counter-intuitive result is potentially attributable to the generally low level of broadband subscriptions in low and lower-middle income countries as compared to mobile subscriptions.

Table 5 shows that the indicator of quality of government is negatively correlated with broadband subscriptions. This suggests a tenuous link, at best, between broadband coverage and the supply side of good governance. However, on the demand side, there is a positive correlation between broadband subscriptions and political participation. Interestingly, the positive correlation is more than three times stronger in African countries than in the rest of low and lower-middle income countries.

3.3 Internet use

Table 6 presents linear regression coefficients with respect to the number of internet users.

Table 6 - Internet use, economic and governance outcomes: linear regressions with country and year fixed effects

Dependent variable	Explanatory variable (1-year lag)	1	2	3
GDP per capita, log	Internet users per 100 people	0.006***	0.011***	0.007***
		(9.09)	(10.12)	(9.52)
	Internet users per 100 people, squared		-0.0001***	
			(-5.40)	
	Internet users per 100 people X Africa dummy			-0.003***
				(-2.84)
	R-squared	0.51	0.52	0.52
	N	1580	1580	1578
Agriculture, per capita value added, log	Internet users per 100 people	0.006***	0.008	0.007***
		(8.83)	(-1.48)	(9.15)
	Internet users per 100 people, squared		0	
			(-2.54)	
	Internet users per 100 people X Africa dummy			-0.002**
				(-2.53)
	R-squared	0.16	0.16	0.16
	N	1401	1401	1401
Industry, per capita value added, log	Internet users per 100 people	-0.001	0.001	0.0003
		(-0.60)	(0.86)	(0.25)

	Internet users per 100 people, squared		-0.0001	
			(-1.64)	
	Internet users per 100 people X Africa dummy			-.003**
				(-2.18)
	R-squared	0.32	0.33	0.33
	N	1401	1401	1401
Service sector, per capita value added, log	Internet users per 100 people	0.003***	0.007***	0.004***
		(3.86)	(5.63)	(4.49)
	Internet users per 100 people, squared		-0.0001***	
			(-4.09)	
	Internet users per 100 people X Africa dummy			-0.002**
				(-2.42)
	R-squared	0.62	0.62	0.62
	N	1,387	1,387	1,387
Service sector exports, log	Internet users per 100 people	0.006***	0.013***	0.009***
		(3.09)	(3.91)	(4.22)
	Internet users per 100 people, squared		-0.0002**	
			(-2.52)	
	Internet users per 100 people X Africa dummy			-0.009***
				(-3.73)
	R-squared	0.65	0.65	0.65
	N	1445	1445	1442
Quality of government index	Internet users per 100 people	0	0.0002	0.0001
		(-0.04)	(0.58)	(0.39)
	Internet users per 100 people, squared		0	
			(-0.76)	
	Internet users per 100 people X Africa dummy			-0.0004

				(-1.37)
	R-squared	0.21	0.21	0.22
	N	1148	1148	1148
Political participation index	Internet users per 100 people	0.0004*	-0.0005	0.0004*
		(1.78)	(-1.50)	(1.92)
	Internet users per 100 people, squared		0	
			(3.47)	
	Internet users per 100 people X Africa dummy			-0.0002
				(-0.73)
	R-squared	0.15	0.16	0.15
	N	1593	1593	1590

Note: t-values are given in parenthesis. Fractions with more than four decimal points are rounded off to zero. ***, ** and * represent 1%, 5% and 10% statistical significance, respectively.

As in the cases of mobile telephony and fixed broadband subscriptions, the number of internet users is positively correlated with per capita GDP. Again, this relationship holds more strongly when the number of internet users is low, rather than at more advanced stages. Although the sign of the relationship remains positive, the magnitude of the correlation is weaker in the case of Africa countries.

There is a positive correlation between per capita agricultural value added and number of internet users. This is possibly relates to technology transfer, as in the case of fixed broadband subscriptions. The size of the correlation is smaller in African countries. Contrary to the lack of statistical relationship between broadband subscriptions and service sector value added, there is a positive and significant correlation between internet use and service sector value added. This discrepancy is probably because a significant portion of economically meaningful internet connectivity in low and lower-middle income countries takes place via modes other than fixed broadband. The pattern of relationships for service sector exports is similar to per capita value added. In both cases, there is significant regional heterogeneity in the potential effect of internet use. The positive correlation is significantly reduced for African countries in the case of service sector value added, whereas the net coefficient turns negative in the case of service sector exports.

4. Subnational variations in ICT use and in selected African countries

In this section, we look at household data on ICT access and use from 17 African countries collected between 2007 and 2008. We use the data to profile the distributions of mobile telephony and internet use across major urban areas, small towns and rural areas in each country.[6] We then juxtapose the relevant country-level summary statistic with a selected set of economic outcomes to provide descriptive evidence on the relationship between spatial inequality in ICT use and economic performance.

We computed the proportions of individuals with a working mobile phone and those who have ever used the internet in major urban areas, small towns and rural areas. We weighted the summary measures by the relevant sampling weight to find the population estimate. The results show that there is significant variation in the spatial distribution of mobile telephony and internet use across the 17 countries. Ethiopia features the highest disparity between major urban and small town/rural locations in terms of mobile telephony use, whereas Mozambique features the highest disparity in internet use. In contrast, Nigeria has the most spatially equitable distribution of mobile telephony use, whereas Senegal is the most equitable in internet use.

Figure 3 – Spatial distribution of mobile telephony utilization in a sample of African countries

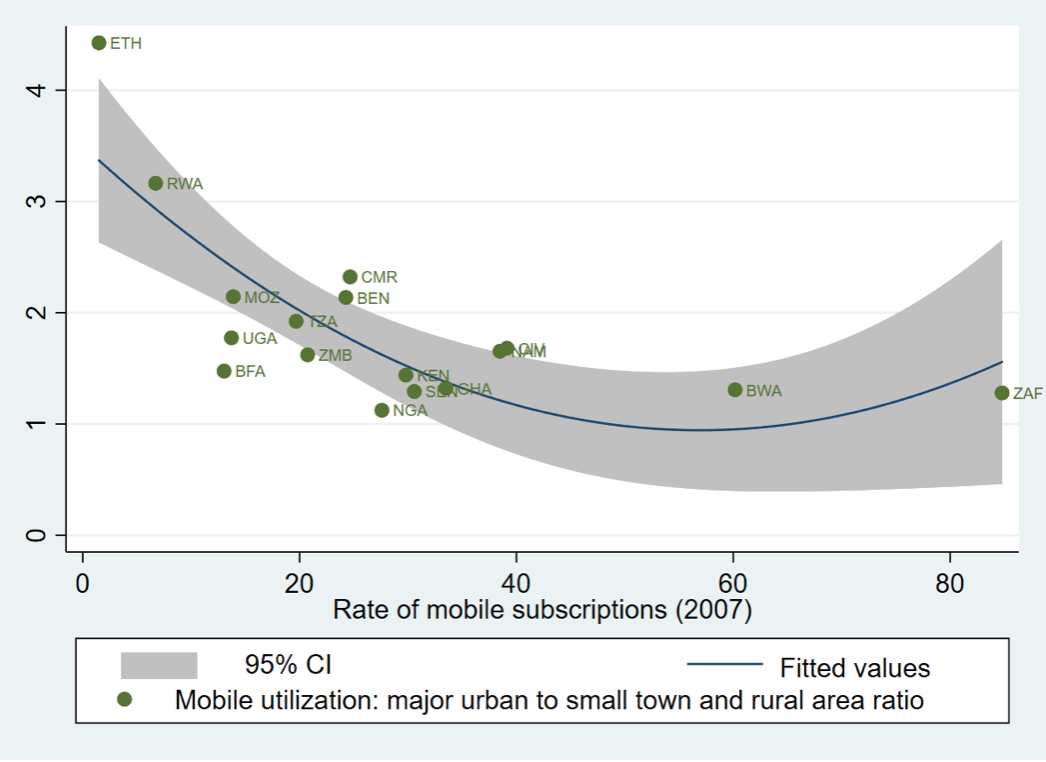
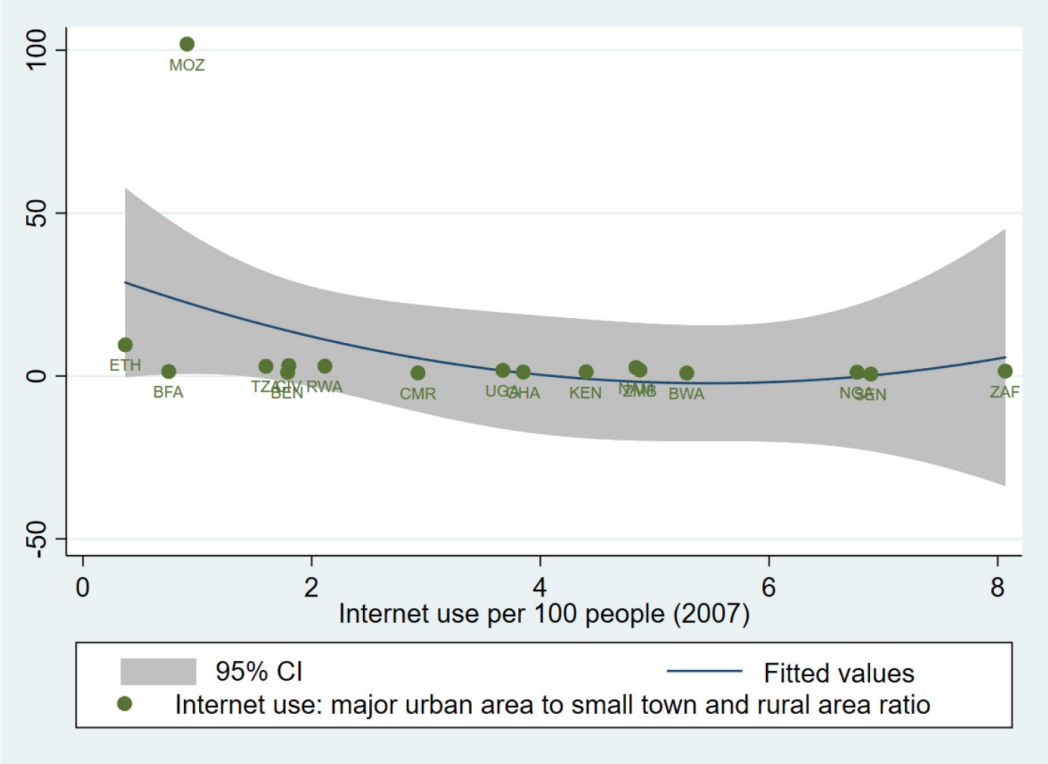


Figure 3 shows that the spatial distribution of mobile telephony becomes more equitable as the overall rate of mobile subscriptions increases. However, this relationship seems to hold only until a certain level of mobile subscriptions is achieved.

[6] The countries are Benin, Botswana, Burkina Faso, Cameroon, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Uganda and Zambia.

Figure 4 – Spatial distribution of Internet utilization in a sample of African countries



On the contrary, Figure 4 shows that there is no discernible relationship between the spatial distribution of internet use and the overall rate of internet use.

Table 7: Correlates of mobile telephony and internet utilization in small towns and rural areas in Africa

	Mobile telephony utilization in small towns (2007/08)	Mobile telephony utilization in rural areas (2007/08)	Internet use in small towns and rural areas (2007/08)
GDP per capita (2000)	0.174***	0.174**	0.010
	(3.13)	(2.39)	(0.42)
Political rights index (200)	0.038**	0.021	-0.008
	(2.53)	(1.08)	(-0.56)
Mobile subscriptions (2000)	-0.023**	-0.015	
	(-2.28)	(-1.10)	
Mobile utilization in small towns and rural areas			0.285**
			(2.23)
R-squared	0.67	0.55	0.36
N	17	17	17

Note: t-values are given in parenthesis.

In Table 7, we further analyse the historical correlates of mobile telephony and internet use in small towns and rural areas. Per capita income in 2000 stands out as the strongest predictor of mobile use in small towns and rural areas in 2007/08. Interestingly, political freedom is positively correlated with the rate of mobile telephony use in small towns, whereas there is no such relationship at conventional levels of statistical significance in rural areas. When it comes to internet use in small towns and rural areas, per capita income in the past does not seem to be a significant predictor. Rather, the contemporaneous rate of of mobile telephony use is strongly correlated with internet use in small towns and rural areas. This result suggests that mobile telephones are crucial in allowing individuals get access to the internet in small towns and rural areas in Africa.

Finally, we provide some suggestive evidence regarding the link between the spatial distribution of mobile telephony and internet use on the one hand and the effect of the respective technology on economic performance on the other hand. First, we compute the predicted value of the outcome variable conditional on either mobile subscriptions or internet use, based on the full sample fixed effects estimations presented in Tables 4 and 6. Then, we map the average predicted values for the 17 African countries in our sample (years 2008–2010) on the relevant indicator of spatial distribution of ICT use.

Figure 5 – The spatial distribution of mobile use against the correlation of mobile subscriptions and per capita income

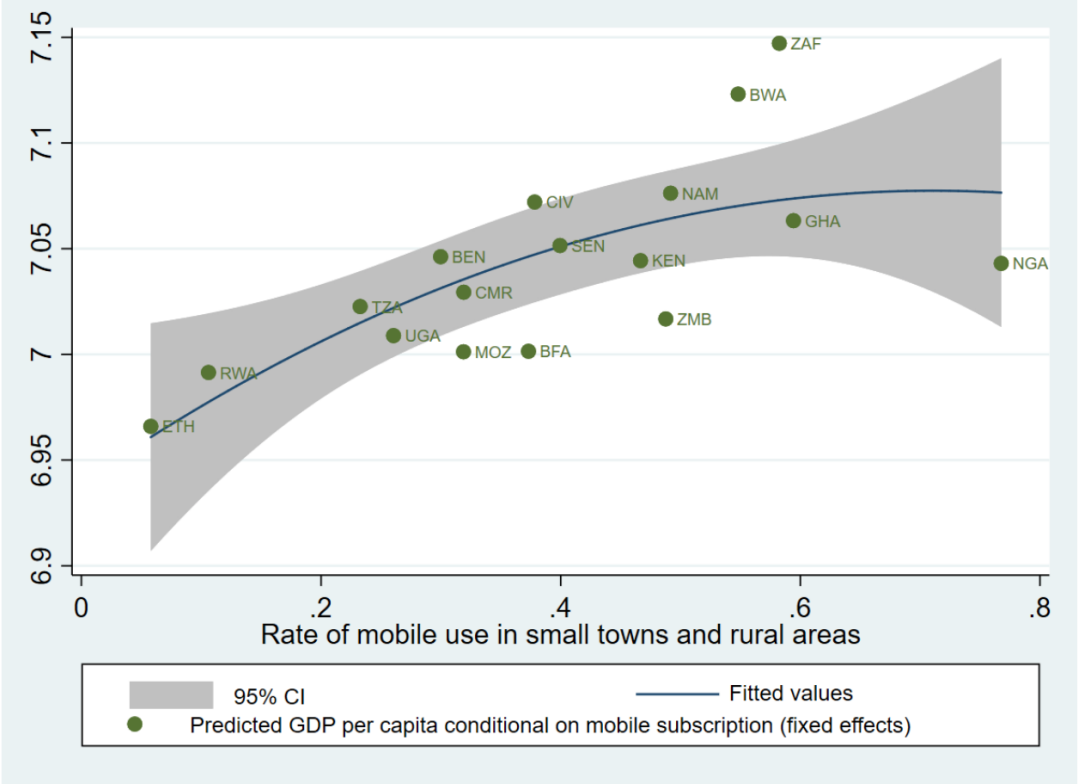


Figure 5 shows that the predicted value of per capita income conditional on mobile subscriptions is positively correlated with the rate of mobile telephony use in small towns and rural areas. In particular, the fitted relationship captures the correlation fairly accurately in the middle part of the distribution where most cases fall.

Figure 6 - The spatial distribution of internet use against the correlation of internet use and per capita income

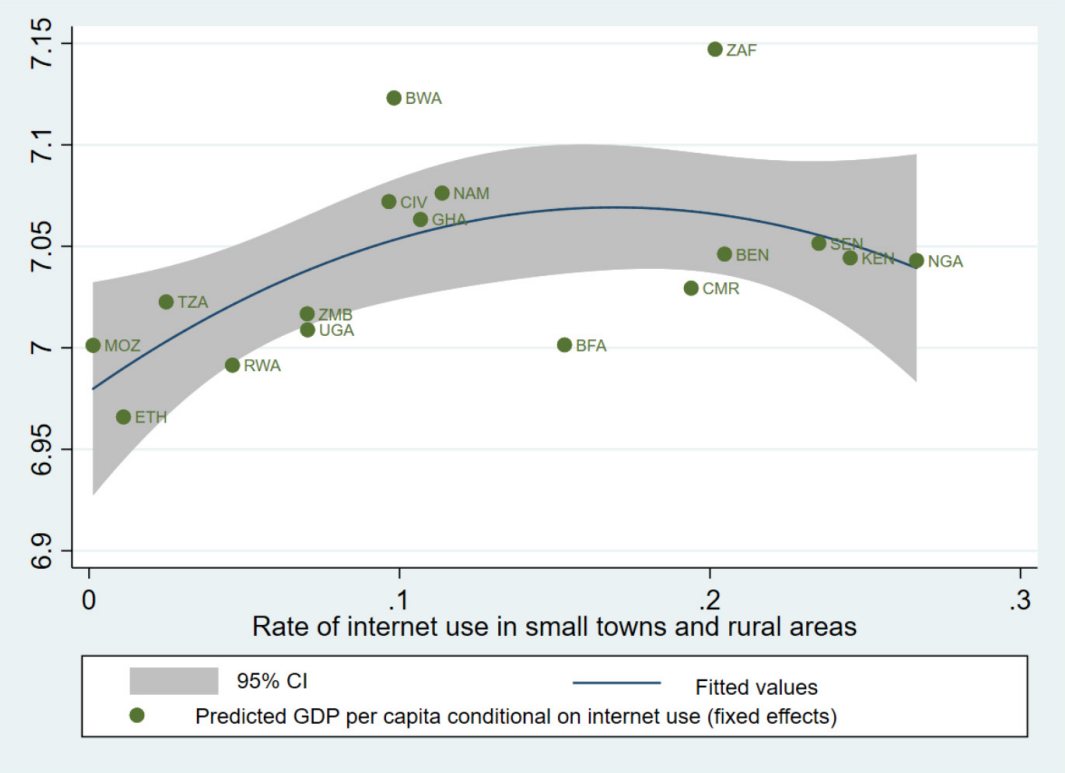


Figure 6 shows that the relationship between predicted GDP per capita and internet use in small towns and rural areas is upward slopping until a certain level of internet use outside major urban centres is achieved. Internet use in small towns and rural areas ceases to have a positive association with predicted per capita income in countries with fairly widespread internet access.

5. Conclusion

The past two-and-a-half decades have seen great advancements in ICT combined with significant increase in the accessibility of such technologies. This development is symbolised by the current availability in the average consumer's pocket of the kind of computing power that would not have been accessible to most organisations only a few decades ago. Regardless, initial conditions in national wealth and underlying infrastructure have been instrumental in rendering some countries more successful in using ICT than others. Contemporary rates of ICT access and use are shown to be positively correlated with key economic indicators such as per capita income and value addition in the agricultural and service sectors. However, significant regional inequalities seem to prevail, as shown by the much weaker and sometimes counter-intuitive relationships in African countries. A more equitable distribution of access and use of mobile and internet technologies has the potential to enhance the effect of those technologies on economic outcomes.

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