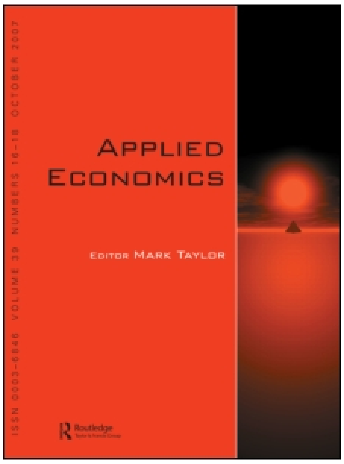

Applied Economics
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713684000

Telecommunications and economic growth: an empirical analysis of sub-Saharan Africa

Sang H. Lee[a]; John Levendis[b]; Luis Gutierrez[c]
[a] Department of Business Administration and Finance, Southeastern Louisiana University, Hammond, LA 70402, USA [b] Department of Economics, Loyola University New Orleans, New Orleans, LA 70118, USA [c] Department of Economics, Universidad del Rosario, Bogota, Colombia

First published on: 11 January 2011

To cite this Article Lee, Sang H. , Levendis, John and Gutierrez, Luis(2011) 'Telecommunications and economic growth: an empirical analysis of sub-Saharan Africa', Applied Economics,, First published on: 11 January 2011 (iFirst)
To link to this Article: DOI: 10.1080/00036846.2010.508730
URL: http://dx.doi.org/10.1080/00036846.2010.508730

Applied Economics, 2011, 1–9, iFirst

Routledge
Taylor & Francis Group

Telecommunications and economic growth: an empirical analysis of sub-Saharan Africa

Sang H. Lee[a,*], John Levendis[b] and Luis Gutierrez[c]

[a]*Department of Business Administration and Finance, Southeastern Louisiana University, Hammond, LA 70402, USA*
[b]*Department of Economics, Loyola University New Orleans, New Orleans, LA 70118, USA*
[c]*Department of Economics, Universidad del Rosario, Bogota, Colombia*

We examine the effect of mobile cellular phones on economic growth in sub-Saharan Africa where a marked asymmetry is present between land line penetration and mobile telecommunications expansion. This study extends previous research along two important dimensions. First, we allow for the potential endogeneity between economic growth and telecommunications expansion by employing a special linear Generalized Method of Moments (GMM) estimator. Second, we explicitly model for varying degrees of substitutability between mobile cellular and land line telephony, so that greater expansion of mobile telecommunications can have a different impact whenever the level of land line penetration differs. We find that mobile cellular phone expansion is an important determinant of the rate of economic growth in sub-Saharan Africa. Moreover, we find that the contribution of mobile cellular phones to economic growth has been growing in importance in the region, and that the marginal impact of mobile telecommunication services is even greater wherever land line phones are rare. Given the low cost of mobile telecommunications technology relative to other broad infrastructure projects, especially land line infrastructure, we advocate that mobile telecommunication services be encouraged in the area.

I. Introduction

Mobile and land-line (fixed-line) telephones offer great promise for improving economic well-being in Africa. When a farmer in a remote village can get quicker information of the prices of his products in two different towns, he can put resources where they are most needed and most valued. Resources can be better coordinated between sectors and across geographies. Better information also allows for better long-term planning, as local producers can better assess global resource demands.

The two technologies, however, are imperfect substitutes, offering different types of services. Clearly, mobile phones offer most, and possibly all, of the services of land-line telephones. The opposite statement is less true. Land-line telephones do not offer text message services or mobile internet access.

*Corresponding author. E-mail: slee@selu.edu

Applied Economics ISSN 0003–6846 print/ISSN 1466–4283 online © 2011 Taylor & Francis
http://www.informaworld.com
DOI: 10.1080/00036846.2010.508730

Often, all that is required for an efficient decision to be made is a price quote. In this regard, a simple text message is far more cost-effective.

In this article, we investigate the different effects that mobile and land-line phones may have on economic development, accounting for the possibility that causation may run in both directions.

Since a seminal paper by Hardy (1980) investigated the impact of telephones *per capita* on economic growth, a growing number of studies have attempted to identify telecommunications as an essential component of the economic infrastructure, fostering productivity and economic growth. The received implications of telecommunications infrastructure for economic development have evolved out of both direct and indirect benefits to economic growth of telecommunications expansion. For example, more efficient flow of information reduces communication and transaction costs, and accelerated information diffusion enhances market efficiency and competition as well as the potential for technological catch-up.[1]

In literature, the relationship between telecommunications investment and economic growth has been examined in various ways. Several studies have employed time series analysis such as Granger causality tests and modified Sims tests, and have focused on the strength and direction of the causal relationship between telecommunication infrastructure investment and economic growth. For instance, Cronin *et al.* (1991, 1993b) and Wolde-Rufael (2007) confirmed a two-way causal relationship in the US between telecommunications infrastructure investment and economic growth. In a similar study, however, Beil *et al.* (2005) conducted Granger–Sims causality tests for a time series of 50 years in the US, and suggested a one-way causality from economic growth to telecommunications investment. Dutta (2001) applied Granger causality tests for a cross-section of 30 developing and industrialized countries in three different years, and found a bi-directional causality for both developing and industrialized countries. Perkins *et al.* (2005) also identified a bi-directional causality in South Africa using a PSS *F*-test (Pesaran *et al.*, 2001).

On the other hand, a few studies have attempted to quantify the impact of telecommunications on economic growth by incorporating telecommunications infrastructure investment explicitly into a macro (aggregate) production function or a cross-country growth framework. Madden and Savage (2000) extended Mankiw *et al.* (1992) to develop a supply-side growth model where teledensity (the number of main telephone lines per 100 persons) and the share of telecommunications investment in national income were controlled for as telecommunications capital proxies. Their results from data on 43 countries over the period 1975 to 1990 suggested a significant positive cross-country relationship between telecommunications capital and economic growth. In another study, Röller and Waverman (2001) endogenized telecommunications infrastructure into aggregate economic activity. They first specified a micro model of the demand for and supply of telecommunications infrastructure, and jointly estimated the micro model with the macro production function. They found a significant causal relationship between telecommunications infrastructure and aggregate output. More recently, Datta and Agarwal (2004) extended the cross-country growth framework of Barro (1991) and Levine and Renelt (1992) to examine the effects of telecommunications infrastructure on economic growth. In a dynamic panel model built upon Islam (1995), they controlled for lagged real Gross Domestic Product (GDP) *per capita* to test for convergence while testing separately the direction of causality between the teledensity and economic growth, using the first-lagged values of teledensity.

While previous studies attested the fact that telecommunications infrastructure investment is positively correlated with economic growth, far fewer studies have investigated how *mobile* telecommunications specifically have played a role in economic growth, especially in a region where a disproportionate rate of growth of mobile telecommunications is present relative to the level of land-line telephony. The growth of mobile telephony in Africa, especially in sub-Saharan Africa, epitomizes such a case. Due to the high investment-intensive nature of land-line telecommunications infrastructure deployment, Africa accounted for less than 2% of the main telephone lines worldwide in 2006, while Asia had a 48% share (International Telecommunication Union (ITU), 2007). However, the breakthroughs in mobile phone technology in the last decade, combined with relatively cheap mobile phone infrastructure, have led Africa to achieve a significant annual growth in mobile telephone penetration. For instance, the number of mobile subscribers in Africa passed the number of landlines in 2001 (Gray, 2006) and the number of mobile subscribers in the region increased by 46.2% between 2001 and 2005 (ITU, 2007). In addition, mobile penetration in Africa by the end of 2006 was 22.0 subscribers per 100 persons while Asia had 29.3, and Africa was the

[1] For discussions on direct and indirect benefits to economic growth of telecommunications sector, see Tisdell (1981), Leff (1984), Antonelli (1991), Cronin *et al.* (1993a) and Greenstein and Spiller (1995).

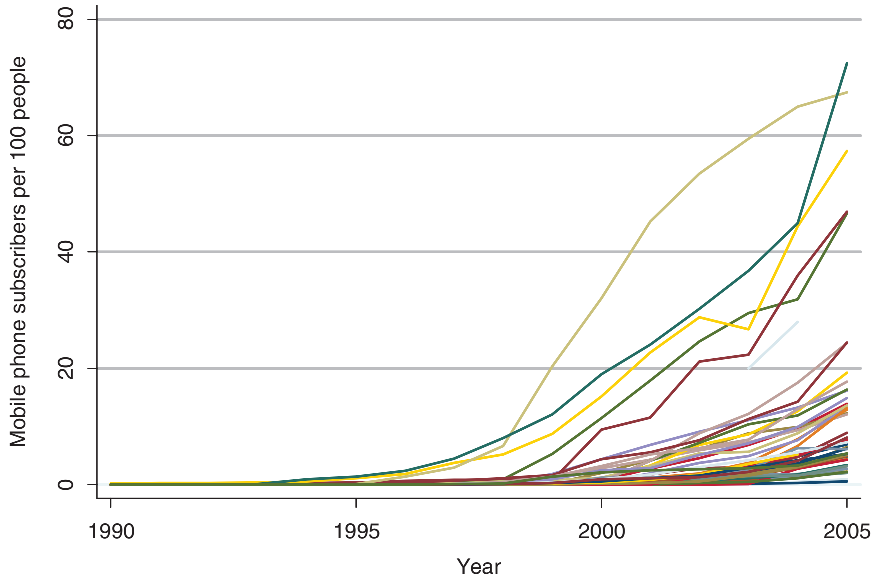

Fig. 1. Growth in mobile phone penetration in sub-Saharan Africa

only region where mobile telephone services generated more revenues than land-line telephone services in 2005, accounting for more than 60% of total telecommunications revenues in the region (ITU, 2007). The growth in mobile telephone subscriptions in sub-Saharan countries is shown in Fig. 1.

In the countries of sub-Saharan Africa, mobile telecommunications services emerged as a practical means of communication recently, relative to land-line telecommunications. Such marked asymmetry in the deployment of mobile and land-line telephones[2] in the region thus requires the use of more efficient econometric corrections as the observations in the region produces a panel data of both mobile and land-line telecommunication variables with only a few time periods and a large number of sample countries. This study draws upon recent developments in estimation methods such as a linear Generalized Method of Moments (GMM) estimator designed for fixed effects as well as potentially endogenous regressors in situations with small time periods and large individuals (Roodman, 2006).

To reiterate, this article departs from the existing studies in the literature in the following ways. First, we focus on the sub-Saharan countries – where cellular phones have expanded quickly, while the number of landlines has remained low – and investigate any causal links between these two different types of phones and economic growth in the region. Second, controlling for cellular and land-line phones separately, we attempt to examine the extent to which the effect on economic growth of cellular phones is pronounced when countries have relatively few landlines. Third, for methodological improvement, this study employs the linear GMM estimator of Arellano and Bover (1995) and Blundell and Bond (1998) that has become increasingly popular in situations where panel data is made up of few time periods and large number of individuals.

The rest of this article is organized as follows. In Section II, we introduce a macroeconomic growth model that accounts separately for the effects of cellular phones and landlines. In Section III, we explain the data and estimation procedure. We discuss the econometric approach, a two-step difference GMM estimator. In Section IV, we report the estimation results. Section V concludes with a discussion of the results and their policy implications.

II. A Macroeconomic Growth Model

In this study, we closely follow the cross-country growth framework of Datta and Agrwal (2004),

[2] Throughout the rest of the article, we opt for more commonly used terminologies, such as cellular phones and land-line phones, rather than the more formal but cumbersome 'mobile telecommunications services' and 'land-line telecommunications services'.

Table 1. List of the sample countries

Angola	Congo (Republic)	Lesotho	Senegal
Benin	Cote d'Ivoire	Madagascar	Seychelles
Botswana	Equatorial Guinea	Malawi	Sierra Leone
Burkina Faso	Eritrea	Mali	South Africa
Burundi	Ethiopia	Mauritania	Sudan
Cameroon	Gabon	Mauritius	Swaziland
Cape Verde	Gambia	Mozambique	Tanzania
Central African Republic	Ghana	Namibia	Togo
Chad	Guinea	Niger	Uganda
Comoros	Guinea-Bissau	Nigeria	Zambia
Congo (Democratic Republic)	Kenya	Rwanda	Zimbabwe

which was built upon Barro (1991) and Levine and Renelt (1992) as follows:

$$\text{GDPPCGR}_{it} = \alpha\text{GDPPCGR}_{it-1} + \mathbf{X}'_{it}\boldsymbol{\beta} + \mu_i + \upsilon_{it}$$

where

$$\mathbf{X}'_{it} = [\text{GDPPC}_{it-1}, \text{TRADE/GDP}_{it}, \text{GDI/GDP}_{it}, \text{GC/GDP}_{it}, \text{POPGR}_{it}, \text{LANDPHONES100}_{it}, \text{CELLPHONES100}_{it}, \text{LANDPHONES100}_{it} \times \text{CELLPHONES100}_{it}]$$

and

$$E[\mu_i] = E[\upsilon_{it}] = E[\mu_i \upsilon_{it}] = 0$$

In the above growth equation, μ_i and ν_{it} are the unobserved country-specific effects and idiosyncratic shocks, respectively. GDPPC is GDP *per capita* and GDPPCGR is the growth rate of GDP *per capita*. Assuming a dynamic process in which the current value of the dependent variable may be influenced by past ones, the lagged value of GDPPCGR is controlled for on the right-hand side. As a standard measure to test for convergence, the lagged value of GDPPC is also included. TRADE/GDP is a country's trade volume as a share of its GDP and is a proxy for the degree of openness of a country's economy. POPGR is the Growth Rate of Population (POPGR) and GDI/GDP is the Gross Domestic Investment as a share of GDP. GC/GDP is a government consumption expenditure for goods and services as a share of GDP. GC/GDP is included to estimate the effect on economic growth of the proportion of GC expenditure relative to GDP. As widely evidenced in the economic growth literature, negative coefficients are expected for POPGR, the lagged values of GDPPCGR, and GDPPC while positive coefficients for TRADE/GDP and Gross Domestic Investment (GDI)/GDP. LANDPHONES100 is the number of main telephone lines per 100 people and serves as an indicator of the penetration of conventional land-line telephony. Similarly, CELLPHONES100 is defined as the number of mobile phone subscribers per 100 people. Both LANDPHONES100 and CELLPHONES100 are expected to be positively correlated with economic growth. Finally, we include an interaction term between LANDPHONES100 and CELLPHONES100. The interaction term is included in order to allow the marginal impact of cellular phones to vary with the level of landlines that are already in place. In a region like sub-Saharan Africa where cellular phone penetration far exceeds that of landlines, a negative coefficient is expected. This implies that the impact on economic growth of mobile telecommunications is more pronounced when the penetration of landlines is relatively low.

III. The Data and Estimation Procedure

Examining the relationship between the telecommunications infrastructure investments and economic growth, this study focuses on 44 sub-Saharan countries, as marked asymmetry has been witnessed between the conventional land-line penetration and mobile phone service expansion in the region. All the data are from the *World Development Indicators* 2008 of the World Bank. The data cover 44 sub-Saharan countries over the years 1975 to 2006. The sample countries in the sub-Saharan Africa are listed in Table 1 and the descriptive statistics of the panel data used in this study are summarized in Table 2.

An issue of the uttermost pertinence is whether there is a causal relationship between telecommunications infrastructure and economic growth. Although many early cited time-series studies of causality found evidence of a one-way or two-way causation between telecommunications investment

Table 2. Descriptive statistics

Variable		Mean	SD	Observations
GDPPCGR	Overall	0.75	7.35	1361
	Between		2.62	47
	Within		6.96	
GDPPC	Overall	2352.51	2733.22	1320
	Between		2539.80	44
	Within		1018.34	
TRADE/GDP	Overall	71.76	38.77	1330
	Between		34.50	46
	Within		17.82	
GDI/GDP	Overall	19.69	10.43	1236
	Between		8.17	46
	Within		7.25	
GC/GDP	Overall	16.14	7.90	1294
	Between		7.17	46
	Within		4.93	
POPGR	Overall	2.57	1.27	1500
	Between		0.51	48
	Within		1.17	
LANDPHONES100	Overall	15.73	36.21	1348
	Between		28.33	47
	Within		21.80	
CELLPHONES100	Overall	14.90	60.76	1446
	Between		39.65	48
	Within		55.72	

and economic growth, such evidence does not necessarily imply that a change in telecommunications investment will cause a subsequent change in the rate of economic growth and *vice versa*. Some studies attempted to identify a causal link by controlling for either the initial year's stock of land-line phones (Norton, 1992) or the previous year's teledensity as a proxy for telecommunications investment (Datta and Agarwal, 2004).

In order to address the issue of reverse causality, this study uses the two-step difference GMM estimator of Arellano and Bover (1995)/Blundell and Bond (1998). The Arellano and Bover (1995)/Blundell and Bond (1998) difference GMM estimator allows the modification of several key assumptions of panel data approach.[3] First, the estimator is designed to accommodate not only (potentially) endogenous independent variables but also independent variables that are not strictly exogenous. In fact, this study assumes that all telecommunications variables are potentially endogenous, meaning that higher economic growth can be the result of higher telecommunications infrastructure investments and *vice versa*. In the Arellano and Bover (1995)/Blundell and Bond (1998) difference GMM estimator (potentially) endogenous independent variables are treated as follows. Applying the first-difference transform to the previous cross-country growth framework, we obtain

$$\Delta\text{GDPPCGR}_{it} = \alpha\Delta\text{GDPPCGR}_{it-1} + \Delta\mathbf{X}'_{it}\boldsymbol{\beta} + \Delta\upsilon_{it}$$

Let x^j_{it}, the jth variable in $\mathbf{X}$, be an endogenous regressor. While the first-difference purges out the fixed effects, x^j_{it} in $\Delta x^j_{it} = x^j_{it} - x^j_{it-1}$ still correlates with υ_{it} in $\Delta\upsilon_{it} = \upsilon_{it} - \upsilon_{it-1}$. To work around this dynamic panel bias, the Arellano and Bover (1995)/Blundell and Bond (1998) two-step difference GMM estimator instrument levels with differences. Thus, for an endogenous variable x^j_{it}, Δx^j_{it-2} can be used as an instrument if υ_{it} is not serially correlated of order 1 since $\Delta x^j_{it-2} = x^j_{it-2} - x^j_{it-3}$ is not correlated with $\Delta\upsilon_{it} = \upsilon_{it} - \upsilon_{i\,t-1}$. If, however, υ_{it} is serially correlated of order 1, Δx^j_{it-2} is no longer a valid instrument and thus a proper instrument needs to be restricted to the third lagged values or more (Δx^j_{it-s} for $s \geq 3$). In this study, we assume that telecommunications variables are potentially endogenous and thus valid instruments are determined according to the Arellano and Bond (1991) test for autocorrelation.

[3] Roodman (2006) provides with a full discussion on the derivation of the Arellano and Bover (1995)/Blundell and Bond (1998) difference GMM estimator. Our discussions on the modification of key assumptions about panel data approach draws heavily upon Roodman (2006).

Table 3. Two-step difference GMM estimation results

Variable	Regression (1) (1975 to 2006)	Regression (2) (2000 to 2006)	Regression (3) (1975 to 2006)	Regression (4) (2000 to 2006)
$GDPPCGR_{t-1}$	0.0462	−0.1931	0.0431	0.1641
	(0.1006)	(0.1335)	(0.0630)	(0.1305)
$GDPPC_{t-1}$	−0.0022***	−0.0025***	−0.0012**	−0.0022***
	(0.0006)	(0.0003)	(0.0005)	(0.0004)
TRADE/GDP	0.0376*	0.0539*	0.0342	0.0503*
	(0.0225)	(0.0328)	(0.0239)	(0.0263)
GDI/GDP	0.1254**	0.0731	0.1237**	0.1129
	(0.0535)	(0.0727)	(0.0568)	(0.0816)
GC/GDP	−0.2406*	−0.1122	−0.2129**	−0.1328
	(0.1281)	(0.1207)	(0.1037)	(0.1242)
POPGR	−0.1627	0.2298	−0.0053	−0.0340
	(0.4570)	(0.7973)	(0.4636)	(0.7595)
LANDPHONES100	0.0540***	0.0324		
	(0.0187)	(0.0557)		
CELLPHONES100	0.0064	0.0191***		
	(0.0113)	(0.0058)		
LANDPHONES100 × CELLPHONES100	−0.00004	−0.0001*		
	(0.00006)	(0.00005)		
LANDPHONES100 + CELLPHONES100			0.0054	0.0069
			(0.0041)	(0.0052)
Number of observations	1037	229	1037	229
Number of groups	44	43	44	43
Wald χ^2	45.38	178.59	34.39	145.06
Hansen test of overidentification	χ^2 (1010) = 39.94	χ^2 (220) = 32.84	χ^2 (1012) = 39.54	χ^2 (222) = 34.98
Arellano–Bond test for AR(1)	$Z = -2.80$	$Z = -1.38$	$Z = -3.07$	$Z = -1.48$
Arellano–Bond test for AR(2)	$Z = -1.43$	$Z = -0.80$	$Z = -1.77$	$Z = -0.71$

Notes: Windmeijer's finite sample corrected SEs are reported in parentheses.
*, ** and *** indicate significance at 10, 5 and 1% levels, respectively.

Furthermore, this study differs from the previous studies in literature that typically impose the assumption of strict exogeneity on other independent variables such as the POPGR, GDI and gross government consumption expenditure. Instead, this study assumes that those commonly-assumed-to-be-exogenous independent variables are correlated with past realizations of the error term. Let x_{it}^k be an independent variable that may not be strictly exogenous. Then, $E[x_{it}\upsilon_{is}] \neq 0$ for $s < t$ while $E[x_{it}\upsilon_{is}] = 0$ for $s \geq t$ (Stata, 2005). For instance, the error term υ_{it-1} might have some impact on the subsequent realization of x_{it}^k, but not *vice versa*. Thus, following the standard treatment in the Arellano and Bover (1995)/Blundell and Bond (1998) difference GMM estimator, we use $\Delta x_{it-1}^k = x_{it-1}^k - x_{it-2}^k$ as instruments since x_{it-1}^k in $\Delta x_{it-1}^k = x_{it-1}^k - x_{it-2}^k$ is potentially correlated only with errors υ_{it-s} for $s \geq 2$, but not with $\Delta\upsilon_{it} = \upsilon_{it} - \upsilon_{it-1}$.

IV. Estimation Results

Table 3 reports four sets of the Arellano and Bover (1995)/Blundell and Bond (1998) two-step difference GMM dynamic panel data estimation results along with SDs in parentheses. Although the panel data in use was constructed for the period 1975 to 2006, as an asymmetric pattern in growth between the conventional land-line penetration and mobile phone service expansion has become most conspicuous in the 2000s, we estimated the cross-country economic growth model for the entire observation period 1975 to 2006 and for the cropped data from 2000 to 2006 in Regressions (1) and (2), respectively. Also, in Regressions (3) and (4), we explore another empirical specification where the two telecommunications variables – LANDPHONES100 and CELLPHONES100 – are combined rather than controlled for separately. Estimation results when this specification is used are contrasted with the results from Regressions (1) and (2).[4]

[4] As is standard in GMM estimation, the joint validity of the instruments is tested. The Hansen test of overindentifying restrictions is satisfactory for all regressions. Also, in all regressions, the Arellano–Bond test suggests that we do not reject the null hypothesis of no second-order autocorrelation in the first-differenced residuals at the 5% level.

As a principal issue of this study, we first focus on the estimation results of the telecommunications variables in Regressions (1) and (2). In Regression (1) for the observations from 1975 to 2006, the Arellano–Bond autocorrelation test statistic indicates that there is a first-order autocorrelation in the idiosyncratic error term (ν_{it}). Thus, following the standard treatment in the Arellano and Bover (1995)/Blundell and Bond (1998) difference GMM estimator, we instrumented the third lagged values of all potentially endogenous telecommunications variables. Among the telecommunications variables in Regression (1), LANDPHONES100 (the number of main telephone lines per 100 persons) is positively correlated with the growth rate of GDPPC and the estimated coefficient is statistically significant. The estimated coefficient of CELLPHONES100 (the number of mobile phone subscribers per 100 persons) is positive as expected but statistically insignificant. This finding could be attributable to the fact that the spread of cellular phones in less developed or developing countries in the sub-Saharan Africa was sparse until before the turn of the millennium. For instance, the mean value of CELLPHONES100 in the sub-Saharan Africa was less than 1.3 until 2000 and rapidly increased from 2.63 to 20.12 over a relatively short time span from 2000 to 2006. A small estimated impact on the economic growth of cellular phones and its statistical insignificance are very likely to result from the fact that we fit the regression over the entire sample period while a substantial increase in the penetration of cellular phones in the region only occurred towards the end of the observation period.

In contrast to Regression (1), the Arellano–Bond test for AR(1) in Regression (2) suggests that we do not reject the null hypothesis of no first-order autocorrelation in the first-differenced residuals, validating the second lagged values of all telecommunications variables as the instruments. The estimated coefficients and statistical significance of LANDPHONES100 and CELLPHONES100 in Regression (2) are quite different from those in Regression (1). When the same empirical specification as in Regression (1) is estimated using a cropped panel data from 2000 to 2006, the estimated coefficient of LANDPHONES100 is smaller than in Regression (1) and is no longer statistically significant.[5] On the other hand, cellular phone penetration appears to have more evident impact on economic growth, both economically and statistically. Also, the estimated coefficient of CELLPHONES100 in Regression (2) is much larger than in Regression (1). This finding is consistent with a trend that has reshaped telecommunications in the sub-Saharan Africa. In the region where the infrastructure for the conventional landline-based telecommunications has long been inadequate due to its capital-intensive nature, cellular phone technology has emerged as a new instrument for economic empowerment, and its direct impact on economic growth has become more significant in the 2000s as the deployment of the mobile telecommunications infrastructure is relatively easy to fund. Such significant growth in mobile telephony in the sub-Saharan Africa over a relatively short time span is also partly due to affordable handsets and competitive cellular telecommunications markets by the emergence of home-grown mobile operators in the region (ITU, 2007). Furthermore, the indirect benefits of cellular phone penetration to economic growth could be quite substantial as it has recently become a practical means of communication in the region where postal services are unreliable and the public transportation system is poor. Mobile phones have not only substituted for travel and allowed better access to information on prices, but also enabled traders to reach wider markets and helped promote entrepreneurship in the region (The Economist, 2009).

Another interesting finding is that the estimated coefficient of the interaction term, LANDPHONES100 × CELLPHONES100, is negative. In Regression (2), holding all other variables fixed, the partial (marginal) effect of CELLPHONES100 on GDP *Per Capita* Growth Rate (GDPPCGR) is given as follows:

$$\frac{\partial \text{GDPPCGR}}{\partial \text{CELLPHONES100}} = 0.0191 - 0.0001 \cdot \text{LANDPHONES100}$$

A negative coefficient of the interaction term suggests that the marginal impact of CELLPHONES100 on GDPPCGR is relatively large when the level of land-line phone penetration is relatively low. For instance, as of 2005, the number of main telephone lines per 100 persons across the countries in the sub-Saharan Africa varied widely from 0.018 to 28.87. Thus, it can be inferred that an

[5] Note that, in Regression (2), the estimated coefficient of LANDPHONES100 is statistically insignificant but larger than that of CELLPHONES100. However, its statistical insignificance should not lead to a conclusion that conventional land-line telephony is no longer relevant to the region's economic growth, especially from a theoretical point of view. A relatively large SD of the variable only suggests that the regression provides weak empirical evidence against the null hypothesis that the coefficient is not significantly different from zero. From 2000 to 2006, the mean value of LANDPHONES100 in the region varied little, from 2.62 to 3.5.

increase in the spread of cellular phones yields a higher growth rate for countries where land-line phones are rare.

Among other determinants of economic growth, the coefficient of lagged GDPPC is negative and significant at the 1% significance level in both regressions, supporting the convergence hypothesis that GDPPC tends to grow at a slow rate in countries with higher level of GDPPC. The share of trade in GDP (TRADE/GDP) as a proxy for the level of openness of a country's economy is positively correlated with the GDPPCGR and its coefficient is significant at the 10% level in both regressions. The results indicate that countries with greater global interaction achieve higher GDPPCGR. The coefficient of GDI as a share of GDP (GDI/GDP) is positive and significant at the 5% level in Regression (1), but insignificant in Regression (2). The impact on economic growth of the share of GDI in GDP appears to be insignificant as the sample data is cropped to the time period 2000 to 2006. Compared to other regions in the world, the countries in the sub-Sahara region have long experienced the lack of capital for domestic investment. The estimated coefficient of the share of GC expenditure in GDP (GC/GDP) is negative and significant at the 10% level in Regression (1), but insignificant in Regression (2), suggesting that the GC expenditure has become a less significant factor in a country's economic growth for the cropped data. The POPGR does not appear to have a significant association with the GDPPCGR in either regression.

Finally, to discuss the possible issues associated with the adequacy of the specification used in Regressions (1) and (2), we explore another empirical specification where the two telecommunications variables – LANDPHONES100 and CELLPHONES100 – are combined rather than controlled for separately. Estimation results are reported in Regression (3) for the entire sample period and in Regression (4) for the cropped data. Although the estimated coefficients of the nontelecommunications variables do not vary significantly, the estimated coefficients for the combined telecommunications variable, LANDPHONES100 + CELLPHONES100, are much smaller and statistically insignificant in both regressions. The results are not quite obvious, yet suggest a couple of points. First, from a viewpoint of empirical analysis, combining the two distinct telecommunications variables may cause a loss in adequate information to explain the variation in the dependent variable, especially when the two variables exhibit measurably asymmetric variations over the sample observation period. Second, from an economic viewpoint, cellular phones may not just be a substitute for land-line phones. In the sub-Saharan Africa where land-line phones are still scarce, the growth of cellular-phone based data services such as agricultural advice, health care and money transfer could provide much more economic benefits beyond basic voice calls and text messages (The Economist, 2009). Thus, controlling separately for the two distinct telecommunications technologies may help assess their economic impacts more accurately than combining the two variables as one, and also may guide policy makers to a more efficient resource allocation for the cellular phone industry and ultimately for economic growth.

V. Conclusions and Policy Implications

Traditionally, development economists paid much attention to the usefulness of infrastructure as proper roads and electrical grids are considered a prerequisite to strong economic growth. After all, one must be able to produce the goods and bring them to the market. Since Hardy's seminal paper (1980), development economists have broadened their view to include telecommunications infrastructure among the variables conducive to growth. The efficiency of a market, and thus its rate of growth, depends upon the minimization of trading costs, including those associated with the use of, and knowledge of, the relevant market prices. Where should an African fisherman sell his fish today, up-coast or in-land? Growth rates of average incomes in Africa, and everywhere, depend crucially upon whether people have access to such information.

The most recent development studies have treated all phones – cellular and landline – as equal, as they both serve to connect people to market information. But cellular phones are different in several important aspects. First, the up-front infrastructure costs are substantially different. Cellular phones are significantly less costly to install, as opposed to stringing together physical telephone wires. So, a dollar invested in cellular phone infrastructure yields many more phones, and much more information, than a dollar invested in landlines. Second, cellular phones are portable, so remote villagers can use them, and just as importantly, they can use them while *en route* to markets.

Our article differs from others in that we treat cellular and land-line phones as separate, though not completely dissimilar technologies. More importantly, we explicitly model the degree of substitutability between cellular and land-line phones by including an interaction term. This allows the marginal contributions of cellular phones on growth to vary with the level of land-line phones already in place.

Our final improvement is methodological. Previous studies have focused on the potential endogeneity of telecommunications and GDP growth along Granger-causal lines. However, this is done at the cost of having to treat all other variables as strictly exogenous. We, on the other hand, allow for our variables not to be strictly exogenous, by employing the Arellano and Bover (1995) and Blundell and Bond (1998) GMM estimator.

We find the current importance of traditional land-line phones for economic growth to be negligible in the sub-Saharan region. On the other hand, the contribution of cellular phones to economic growth has been growing in importance. While it is obvious that cellular phone use has been growing, we document that the impact itself of a single cellular phone has also been growing. Moreover, we find that the marginal impact of cellular phones is greater wherever land-line phones are rare. Combining these two results with the fact that cellular phone infrastructure is comparatively cheap, and the policy implication is clear, more cellular phone infrastructure should be encouraged in the sub-Saharan region, as its technology is more cost-effective and beneficial.

References

Antonelli, C. (1991) *The Diffusion of Advanced Technologies in Developing Countries*, Organization for Economic Cooperation and Development, Paris.

Arellano, M. and Bond, S. (1991) Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations, *Review of Economic Studies*, **58**, 277–97.

Arellano, M. and Bover, O. (1995) Another look at the instrumental variables estimation of error-components models, *Journal of Econometrics*, **68**, 29–51.

Barro, R. (1991) Economic growth in a cross section of countries, *Quarterly Journal of Economics*, **106**, 407–43.

Beil, R., Ford, G. and Jackson, J. (2005) On the relationship between telecommunications investment and economic growth in the United States, *International Economic Journal*, **19**, 3–9.

Blundell, R. and Bond, S. (1998) Initial conditions and moment restrictions in dynamic panel data models, *Journal of Econometrics*, **87**, 115–43.

Cronin, F., Colleran, E., Herbert, P. and Lewitzky, S. (1993a) Telecommunications and economic growth: the contribution of telecommunications infrastructure investment to aggregate and sectoral productivity, *Telecommunications Policy*, **17**, 677–90.

Cronin, F., Parker, E., Colleran, E. and Gold, M. (1991) Telecommunications infrastructure and economic growth: an analysis of causality, *Telecommunications Policy*, **15**, 529–35.

Cronin, F., Parker, E., Colleran, E. and Gold, M. (1993b) Telecommunications infrastructure investment and economic development, *Telecommunications Policy*, **17**, 415–30.

Datta, A. and Agarwal, S. (2004) Telecommunications and economic growth: a panel data approach, *Applied Economics*, **36**, 1649–54.

Dutta, A. (2001) Telecommunications and economic activity: an analysis of Granger causality, *Journal of Management Information System*, **17**, 71–95.

Gray, V. (2006) *The Un-wired Continent: Africa's Mobile Success Story*, International Telecommunication Union, Geneva, Switzerland.

Greenstein, S. and Spiller, P. (1995) Modern telecommunications infrastructure and economic activity: an empirical investigation, *Industrial and Corporate Change*, **4**, 647–65.

Hardy, A. (1980) The role of the telephone in economic development, *Telecommunications Policy*, **4**, 278–86.

International Telecommunication Union (ITU) (2007) *Telecommunication/ICT Markets and Trends in Africa*, ITU, Geneva, Switzerland.

Islam, N. (1995) Growth empirics: a panel data approach, *Quarterly Journal of Economics*, **110**, 1127–70.

Leff, N. (1984) Externalities, information costs, and social benefit-cost analysis for economic development: an example from telecommunications, *Economic Development and Cultural Change*, **32**, 255–76.

Levine, R. and Renelt, D. (1992) A sensitivity analysis of cross-country growth regressions, *American Economic Review*, **82**, 942–63.

Madden, G. and Savage, S. (2000) Telecommunications and economic growth, *International Journal of Social Economics*, **27**, 893–906.

Mankiw, N., Romer, D. and Weil, D. (1992) A contribution to the empirics of economic growth, *Quarterly Journal of Economics*, **107**, 407–37.

Norton, S. (1992) Transaction costs, telecommunications, and the microeconomics of macroeconomic growth, *Economic Development and Cultural Change*, **41**, 175–96.

Perkins, P., Fedderke, J. and Luiz, J. (2005) An analysis of economic infrastructure investment in South Africa, *South African Journal of Economics*, **73**, 211–28.

Pesaran, M., Shin, Y. and Smith, R. (2001) Bounds testing approaches to the analysis of level relationships, *Journal of Applied Econometrics*, **16**, 289–326.

Röller, L. and Waverman, L. (2001) Telecommunications infrastructure and economic development: a simultaneous approach, *American Economic Review*, **91**, 909–23.

Roodman, D. (2006) How to do xtabond2: an introduction to difference and system GMM in Stata, Working Paper No. 103, Center for Global Development, Washington, DC.

Stata (2005) *Longitudinal/Panel Data: Reference Manual Release 9*, A Stata Press, College Station, Texas.

The Economist (2009) Mobile marvels: a special report on telecoms in emerging markets, *The Economist*, **392**, 3–19.

Tisdell, C. (1981) *Science and Technology Policy: Priorities of Governments*, Chapman & Hall, London.

Wolde-Rufael, Y. (2007) Another look at the relationship between telecommunications investment and economic activity in the United States, *International Economic Journal*, **21**, 199–205.