DOES THE SPREAD OF MOBILE PHONES PROMOTE ECONOMIC DEVELOPMENT? EMPIRICAL EVIDENCE FROM SOUTH ASIA AND SUB-SAHARAN AFRICA REGIONS

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ABSTRACT

Since 2000 there has been an unprecedented increase in access to mobile phones. We analyze the impact of mobile phone penetration on economic growth by estimating a fixed-effect dynamic panel model on 56 South Asian and sub-Saharan African countries from 1990 to 2008. This study contributes to the existing literature by modeling the interactive effects between fixed-line phones and mobile phones and by employing the Arellano-Bond difference GMM estimator. Our empirical results indicate that mobile phones are positively correlated with economic growth, and that the marginal contribution is even greater where the conventional fixed-line telecommunications infrastructure is poor. ***JEL classifications:*** E13, L96

INTRODUCTION

In the 2000s, extensive technological advances in wireless telecommunications and liberalization of telecommunications markets ushered in rapid mobile network expansions worldwide. Correspondingly, access to mobile phone services rose dramatically: in 2002 the number of mobile phones in the world surpassed the number of conventional fixed-line phones, and the total number of mobile phones was estimated to be 4 billion by the end of 2008 (World Bank, 2010). In less-developed and developing countries the spread of mobile phones has been particularly vast, often substituting for inadequate, unreliable, or non-exiting infrastructure such as public transportation, postal services, and/or conventional fixed-line communications. Countries in South Asia and sub-Saharan African regions epitomize such cases. For instance, the number of conventional main telephone lines per 100 persons in these regions was merely 1.15 in 1990, 2.71 in 2000, and 3.53 in 2008. In stark contrast to the level of fixed-line phone penetration, the number of mobile phone subscribers per 100 persons increased from 0.04 in 1990, to 2.40 in 2000, and to 38.17 in 2008, reflecting not only a wide disparity in growth between fixed-line phones and mobile phones but also unprecedented growth in mobile telephony over less than one decade from 2000 to 2008 (World Bank, 2010).

As mobile telephony grows on an unprecedented scale amongst many low income countries of the world, the impact of this growth on the countries' economic development has been the subject of growing interest among economists and policymakers alike. Overall access to mobile phones in South Asia and sub-Saharan

Africa is still far below that of high income countries such as the OECD economies, but there is a plethora of anecdotal evidence and a few recent empirical studies indicating that mobile phones have become "tools of economic empowerment for the world's poorest people" (The Economist, 2009) and as a result "economic and social activities are being transformed" (World Bank, 2009).[1] Recent empirical work has focused on two questions: What has led to mobile phone penetration and what has been its impact on economic development? Our study explores the second question, and adds to the literature by conducting a macroeconomic analysis of the dynamic changes and accounting for endogeneity.

This study is organized as follows. The next section describes how the growth of mobile telephony has impacted less-developed and developing countries, including results from empirical studies on this topic and specifics on how our study contributes to existing knowledge. In Section 3 we introduce a macroeconomic growth model and data and discuss the estimation procedure with an emphasis on potential endogeneity problems. We report and discuss the estimation results in Section 4 and conclude this study with policy implications and directions for future research in Section 5.

BACKGROUND AND LITERATURE

Mobile phones are now seen as a crucial tool for economic development in many of the world's less-developed and developing countries. One reason researchers and policymakers have such high expectations that mobile phones will empower low income countries is that mobile phones are accessible even to very poor persons living in remote rural areas. Due to technological advances and growing competition, the prices of handsets have been steadily falling and are expected to continue to decrease. Also, whereas mobile phone users in developed countries typically have a prepaid calling plan through an established network, people in less-developed and developing countries can purchase vouchers with phone credit in denominations as small as $0.50. The wide availability of phone credit has made mobile phone use affordable and efficient for persons of all classes. For individuals who do not own a handset, they can often purchase mobile services from a woman in their village who sells calls to villagers as an informal business, often having acquired a mobile handset and antennae using a micro-finance loan. Calls from 'village phones' are often less expensive than purchasing calls from a credit voucher and do not require the fixed cost of purchasing a handset.

Recently several microeconomic studies have documented some of the ways mobile phones are transforming local markets. Jensen (2007) examined how mobile phones helped fishermen to engage in optimal arbitrage in Kerala, India, by calling several markets to find the best selling price. As mobile phone use grew over the time period of his study, 1997 – 2001, fishermen reported being able to find more buyers for their fish and significant reductions in the dispersion of fish prices across local markets. Aker (2010) analyzed the grain markets in Niger from 2001 to 2006 and found that extension of mobile phone coverage reduced the dispersion of grain prices across markets by as much as 10 percent. For both the fish market in India and the grain market in Niger, consumers saw prices fall and producers experienced higher profits.

These microeconomic studies support anecdotal evidence on the effects of mobile phones and help fuel the belief that mobile phones will promote economic growth in less-developed and developing countries. The view that mobile phones will have a much larger impact on economic growth in less-developed and developing countries is largely due to the theory that mobile phones are a substitute for fixed-line phones in less-developed and developing countries, rather than a complement as in higher income countries. This theory is strengthened by the incredible explosion in mobile phone use reported in less-developed and developing countries. In 2000 about thirty percent of total world subscriptions were in developing countries, but by 2009 their share had increased to seventy-five percent of a worldwide total over 4 billion. Mobile phones offer all the services available from fixed-line telephones, yet compared to using fixed-line telecommunications, users of mobile phones do not have to rely on the existing infrastructure and can use mobile services at very low costs.

The increases in consumer and producer surplus and reductions in price dispersion reported by Jensen (2007) and Aker (2010) are just some of the dramatic changes that have resulted from the extension of mobile phone coverage. Mobile telephony has impacted the economies of less-developed and developing countries by creating jobs, reducing travel and other transaction costs, promoting entrepreneurship, and making available information and communication that was previously difficult or impossible to obtain. In a study of rural labor market outcomes in South Africa, Klonner and Nolen (2008) found that in the formal labor sector employment increased by 15 percentage points when a locality received complete network coverage, with most of the increased employment going to women. Anecdotal evidence suggests that many employment opportunities have also been created in both the formal and informal job sector, as street vendors and shop owners have begun selling handsets, calling credit vouchers, and other mobile phone related services.

Many other benefits available through mobile phones are more difficult to quantify, but no less important to improving the productivity of people in less-developed areas of the world. For example, the use of mobile phones has allowed workers to reduce travel and other transaction costs by negotiating directly with suppliers, calling about pricing information in various local markets, finding information on possible job opportunities, and determining when deliveries are actually available rather than waiting for hours. Before the availability of mobile phones, attaining these types of information typically required long and costly travel, often on unreliable methods of transportation. Also, many examples of mobile phones promoting entrepreneurial activities have been reported in national media, such as the grain farmer who uses his phone to acquire information on when to plant and harvest and who will give the best prices for his products (Bellman, 2009); or the barber who could not afford to rent a shop but was able to use his phone to schedule appointments and go to his clients' homes (The Economist, 2009). Recently, mobile phones have also helped persons in less-developed countries to have access to credit and to transfer money through 'mobile money,' a simple process by which people can transfer cash via a phone call or text message. Basic macroeconomic theory suggests that mobile phones will continue to have a larger impact on increasing productivity and reducing transaction costs for less-developed and developing countries because they have more potential for improvement, or "catch-up," than developed countries.

Whether mobile telephony has led to significant economic growth at the country level in less-developed and developing countries has only recently been studied in a few macroeconomic analyses. Waverman et al. (2005) assessed how dramatic growth in access to mobile phones translated into tangible macroeconomic gains in 92 low and middle-income countries for 1996 – 2003. Using the endogenous technical change approach similar to Barro (1991), the study found that the impact of mobile phones on economic growth was twice as large in developing countries compared to developed countries. When a typical developing country added ten more mobile phones per 100 people for the sample time period, the country's annual growth rate of GDP per capita was estimated to be 0.59 percent higher than an otherwise identical country. However, these results are based on a purely cross-sectional model where the dependent variable is simply the average growth rate of per capita GDP over this time period. They also did not analyze the differential impacts of mobile phones versus fixed-line infrastructure.

In a study examining the effect of mobile phones on GDP per person for 120 developed and developing countries, Qiang et al. (2009) found that that for every 10 percentage point increase in the penetration of mobile phones, there is an increase in economic growth of 0.81 percentage points in developing countries, versus 0.60 percentage points in developed countries. Her analysis also found that mobile phones were more effective at promoting growth than fixed line phones, but less effective than internet access or broadband. However, she argues that since mobile phones have much greater penetration than broadband, the "aggregate impact is highest for mobile."

While previous studies suggest that telecommunications investment is positively correlated with economic development, they have seldom focused on markedly different growth patterns between fixed-line penetration and mobile phone expansion in less-developed and developing countries, nor have their estimation models allowed for varying degrees of substitutability between mobile phones and fixed-line phones. Moreover, an issue of endogeneity of key regressors such as telecommunications variables has not always been properly addressed. In this article we attempt to extend the existing research on the relationship between mobile phone technology and economic growth along two different dimensions. First, with a particular focus on a wide disparity between fixed-line penetration and mobile phone expansion in South Asia and sub-Saharan Africa, we recognize that fixed-line phones and mobile phones are imperfect substitutes, and thus hypothesize that marginal effects of mobile phones on economic growth would be pronounced differently when countries have different levels of fixed-line phone penetration. For this purpose, we depart from the existing research and control for not only fixed-line phones and mobile phones separately, but also an interaction term between the two imperfectly substitutable technologies.

Second, we allow for the potential endogeneity that runs from telecommunications expansion to economic growth, and vice versa. As discussed in Aker and Mbiti (2010), it has long been an issue of great econometric concern to find valid exogenous instruments for telecommunications variables and other economic indicators in the context of cross-country growth models. For such methodological improvement, this study employs a recent development in dynamic panel data estimators, a linear Generalized Method of Moments (GMM) estimator. Using a difference GMM estimator that is specifically designed for a panel data with short time series and a large number of countries, we estimate a fixed-effect dynamic panel model with endogenous regressors while correcting standard errors for panel-specific autocorrelation and heteroskedasticity.[2]

AN ECONOMETRIC MODEL, DATA, AND THE ESTIMATION PROCEDURE

Since our goal is to examine the major sources of economic growth and to confirm the convergence hypothesis from neoclassical growth theory, our estimation model closely follows that of Barro (1991), Levine and Renelt (1992), and Datta and Agarwal (2004). Our estimating equation is:

$$GRTH_{it} = \alpha GRTH_{it-1} + \mathbf{X}_{it}^{\prime}\boldsymbol{\beta} + u_i + v_{it} \tag{1}$$

where $\mathbf{X}$ = [$GDPPC_{it-1}$, $TRADE/GDP_{it}$, $GDFI/GDP_{it}$, $GCON/GDP_{it}$, $POPGR_{it}$, $TPEN_{it}$, $MPEN_{it}$, $(TPEN\times MPEN)_{it}$] and $GRTH_{it}$ is the annual growth rate of real GDP per capita (GDPPC) in country *i* at time *t*. Unobservable country-fixed effects and idiosyncratic shocks are represented by u_i and v_{it}, respectively. We assume these two components are orthogonal such that $E[u_i]=E[v_{it}]=E[u_i v_{it}]=0$.

Based on the convergence hypothesis of neoclassical growth theory, we expect the estimated coefficient of $GDPPC_{it-1}$ to be negative. A negative estimated coefficient of $GDPPC_{it-1}$ would confirm general findings in the literature that a country's subsequent growth rate tends to be relatively low when the level of its real GDP per capita in the previous period is relatively high. We also expect the sign of the estimated coefficient of the lagged growth rate ($GRTH_{it-1}$) to be negative. The economic reasoning behind this presumption is that a country's real GDP per capita may increase, but not necessarily at an increasing rate.

Among other regressors, TRADE/GDP is a country's trade as a share of GDP and is a proxy for the degree of overall globalization of a country's economy. GDFI/GDP measures the share of gross domestic fixed investment in GDP. Both TRADE/GDP and GDFI/GDP are expected to be positively associated with economic growth. GCON/GDP is government consumption as a share of GDP and POPGR is the annual population growth rate. We expect a country's annual growth rate of GDP per capita to be lower when its population growth rate is higher and/or its government share of GDP is higher. Among the telecommunications measures, TPEN is the number of main telephone lines per 100 people and it measures the level of conventional fixed-line telephone penetration. MPEN is the number of mobile phone subscribers per 100 people and is used as a measure of mobile phone expansion.[3] Both TPEN and MPEN are expected to have a positive impact on economic growth.

We hypothesize that the impact of mobile phone growth on the annual growth rate may be related to the existing availability of fixed telephone lines. Our estimation model controls for a possible relationship between these two forms of communication by including the interaction term TPEN×MPEN. We expect the estimated coefficient of the interaction term to be negative for two reasons. First, fixed-line phones and mobile phones may be considered close substitutes, especially in less-developed or developing countries where fixed-line phones are still rare and costly. Second, unlike developed countries where fixed-line phone penetration is near its saturation point, economic development in many low-income countries has long been hindered by deficient social overhead capital such as expenditures on telecommunications and other public infrastructure. Particularly in South Asia and sub-Saharan Africa, the rollout of mobile phones has been considered not merely as a communication tool but as a developmental springboard, not only compensating for poor public infrastructure but also boosting entrepreneurship in local economies (The Economist, 2009). Since the telecommunications infrastructure is a crucial component of public infrastructure, we test a hypothesis that the marginal impact of mobile phones on economic growth is pronounced more when a country has a relatively low level of fixed-line phone penetration.

All data are from the *World Development Indicators* 2010 of the World Bank. We include 8 countries in South Asia and 48 countries in sub-Saharan Africa that we expect to have markedly asymmetric growth patterns between fixed-line phones and mobile phones. Annual observations are collected for the sample period 1990 – 2008. Tables 1 and 2 report the sample countries included in this study and a summary of the descriptive statistics, respectively.

TABLE 1
LIST OF THE SAMPLE COUNTRIES

South Asia	Burundi	Ghana	Rwanda
Afghanistan	Cameroon	Guinea	Senegal
Bangladesh	Cape Verde	Guinea-Bissau	Seychelles
Bhutan	Central African Rep.	Kenya	Sierra Leone
India	Chad	Lesotho	South Africa
Maldives	Comoros	Madagascar	Sudan
Nepal	Congo (Dem. Rep.)	Malawi	Swaziland
Pakistan	Congo (Rep.)	Mali	Tanzania
Sri Lanka	Cote d'Ivoire	Mauritania	Togo
Sub-Saharan Africa	Equatorial Guinea	Mauritius	Uganda
Angola	Eritrea	Mozambique	Zambia
Benin	Ethiopia	Namibia	Zimbabwe
Botswana	Gabon	Niger	
Burkina Faso	Gambia	Nigeria	

An issue of great econometric concern when using panel data of countries over time to study economic growth is the possible endogeneity of regressors. To effectively estimate regression equation (1), several possible empirical problems need to be addressed. One immediate issue is the presence of the lagged dependent variable ($GRTH_{it-1}$) on the right hand side. In the cross-country fixed-effect estimation, the lagged dependent variable is correlated with the fixed effects (u_i), and thus causes dynamic panel bias (Roodman, 2009). A second empirical concern is a possible correlation between the lagged dependent variable ($GRTH_{it-1}$) and the idiosyncratic error term (v_{it}) when the error process is autocorrelated. For instance, if v_{it} is serially correlated of order 1, then $GRTH_{it-1}$ would be endogenous to v_{it} because v_{it} is mathematically related to v_{it-1}. A third econometric concern is the endogeneity of some regressors other than the lagged dependent variable. Suppose that some regressors on the right hand side are potentially endogenous. Then those regressors are to be correlated with the error term and the estimated coefficients will be biased. In a typical macro production function or cross-country growth model, it is highly plausible that causality runs in both ways between the dependent variable (GRTH) and some (or even all) of the explanatory variables.

TABLE 2
DESCRIPTIVE STATISTICS (1980 – 2008)

Variable		Mean	Standard deviation	Observations
GRTH	overall	1.7449	7.2638	988
	between		3.0770	55
	within		6.6352	
GDPPC	overall	2517.681	3799.834	992
	between		3475.875	54
	within		1496.64	
TRADE/GDP	overall	73.8163	41.1249	969
	between		36.8106	54
	within		17.9867	
GDFI/GDP	overall	20.8386	11.0365	928
	between		8.5186	53
	within		7.0621	
GCON/GDP	overall	14.8414	7.5679	920
	between		7.2777	52
	within		3.8588	
POPGR	overall	2.3372	1.2273	1051
	between		0.6373	56
	within		1.0520	
TPEN	overall	2.4404	4.6303	1025
	between		4.2894	55
	within		1.7784	
MPEN	overall	6.8977	15.6409	1024
	between		7.3099	55
	within		13.9233	

Among the empirical issues discussed above, the issue of the endogeneity between the lagged dependent variable ($GRTH_{it-1}$) and the fixed-effect (u_i) can be easily accommodated by taking first differences of equation (1) as follows:

$$\Delta GRTH_{it} = \alpha \Delta GRTH_{it-1} + \mathbf{\Delta X}_{it}^{\prime}\boldsymbol{\beta} + \Delta v_{it} \qquad (2)$$

where $\Delta v_{it} = v_{it} - v_{it-1}$.

Although the first-difference transform of the regression equation removes the country-specific fixed effect (u_i), the endogeneity problems still exist. For example, $GRTH_{it-1}$ in $\Delta GRTH_{it-1} = GRTH_{it-1} - GRTH_{it-2}$ is still mathematically correlated with v_{it-1} in $\Delta v_{it} = v_{it} - v_{it-1}$. Moreover, if any regressors other than the lagged dependent variable are endogenous, those endogenous regressors will also be correlated with the error term (Δv_{it}) and will result in biased estimated coefficients.

In order to address this endogeneity problem, we apply to our fixed-effect dynamic panel estimation the one-step difference Generalized Method of Moments (GMM) estimator by Arellano-Bond (1991). An essential empirical feature of the Arellano-Bond difference GMM estimator is that the estimator instruments a first-differenced endogenous regressor in the transformed regression equation (2) with its lagged levels. To see the reasoning behind this, let x_{it} be an endogenous regressor in $\mathbf{X}$. At the center of the Arellano-Bond difference GMM estimator is the idea that past (lagged) levels are often predictive of current changes (Δx_{it}). Further, second or even deeper lagged levels of an endogenous regressor (x_{it-k} for $k \geq 2$) are available as instruments for its first-differenced endogenous regressor (Δx_{it}) because, unlike the mean-deviations transform in standard fixed-effect estimations, second or deeper lagged levels of the endogenous regressor (x_{it-k} for $k \geq 2$) remain orthogonal to the error term ($\Delta v_{it} = v_{it} - v_{it-1}$) (Roodman, 2009). However the validity of lagged levels as instruments heavily depends on the process of the error term (Δv_{it}) in the first-difference regression equation (2). For example, if v_{it} follows AR(1) process, then x_{it-2} is no longer a valid instrument for Δx_{it}, and so even deeper lags (x_{it-k} for $k \geq 3$) need to be used as instruments. In this study, we use the Arellano-Bond test for autocorrelation in the first-differenced residuals to determine the number of lags available for instruments. Also, it is not uncommon for a cross-country growth estimation to involve a large number of instruments relative to the number of sample countries, especially for panel data that covers a relatively short sample period. We use the Sargan test to determine if over-identifying restrictions are valid in our estimations.

ESTIMATION RESULTS

Considering that the roll out of mobile phones has occurred mostly in the 2000s, we expect that the impact on economic growth of the two different telecommunications technologies – fixed-line phones and mobile phones – would be pronounced differently over different sample periods. So the fixed-effect difference GMM estimation is fitted for the data sets cropped for two different sample periods: from 1990 to 2008 and from 2000 to 2008. Table 3 reports the results of the Arellano-Bond one-step difference GMM estimations with the standard errors that are consistent with the panel-specific autocorrelation and heteroskedasticity in one-step estimations.

In regressions (1) and (2), we fitted a dynamic panel-data estimation for 1990-2008 and for 2000-2008, respectively. As a primary objective of this study, we first discuss the estimation results of the telecommunications variables: TPEN and MPEN. In regression (1) for the observations from 1990 to 2008, the estimated coefficients of TPEN (the number of main telephone lines per 100 people) and MPEN (the number of mobile phone subscribers per 100 people) are both positive as we expected but only the estimated coefficient of TPEN is statistically significant. However, when the regression is fitted over the sample period from 2000 to 2008, both TPEN and MPEN have positive estimated coefficients, yet only the estimated coefficient of MPEN is statistically significant. These estimation results are consistent with the fact that the only practical telecommunications infrastructure in the 1990s in South Asia and sub-Saharan Africa was the fixed-line telephony and significant mobile phone expansions in the regions occur a few years after the turn of the millennium. In summary, our empirical findings suggest the following: first, for the extended sample period of 1990 – 2008, only the conventional fixed-line telephones are factors of statistical significance in economic growth; second, for the sample period of 2000 – 2008, mobile phones began to emerge as a statistically significant factor of economic growth because the number of mobile phone users per 100 people (MPEN) in the regions multiplied, especially in the mid 2000s, while the level of the fixed-line phone penetration had been stagnant.

With special emphasis on markedly asymmetric growth patterns of the fixed-line phone penetration and mobile phone expansion in South Asia and sub-Saharan Africa, we added to the current regression equation an interaction term between the fixed-line phone penetration and mobile phone expansions (TPEN×MPEN). In South

TABLE 3
ARELLANO-BOND ONE-STEP DIFFERENCE GMM ESTIMATION RESULTS

Variable	Regression (1) (1990-2008)	Regression (2) (2000-2008)	Regression (3) (1990-2008)	Regression (4) (2000-2008)
$GRTH_{t-1}$	-0.0173	-0.1065	-0.0236	-0.1101
	(0.0616)	(0.1228)	(0.0601)	(0.1225)
$GDPPC_{t-1}$	-0.0011***	-0.0012***	-0.0011***	-0.0012***
	(0.0002)	(0.0001)	(0.0002)	(0.0001)
TRADE/GDP	0.0433**	0.0345**	0.0486**	0.0391***
	(0.0218)	(0.0152)	(0.0206)	(0.0152)
GDFI/GDP	0.0971***	0.1145**	0.0894**	0.1121**
	(0.0374)	(0.0527)	(0.0364)	(0.0512)
GCON/GDP	-0.2812***	-0.2050**	-0.2931***	-0.2138**
	(0.0788)	(0.0886)	(0.0763)	(0.0896)
POPGR	0.3056	0.0707	-0.3420	-0.0979
	(0.2274)	(0.6396)	(0.2236)	(0.6505)
TPEN	0.1309**	0.1264	0.2707***	0.2406
	(0.0651)	(0.1646)	(0.0633)	(0.1836)
MPEN	0.0143	0.0348**	0.0446**	0.0481***
	(0.0175)	(0.0161)	(0.0216)	(0.0184)
TPEN×MPEN			-0.0038**	-0.0019
			(0.0017)	(0.0012)
Number of observations	860	395	860	395
Number of groups	51	50	51	50
Wald Chi^2	355.96	724.20	309.34	767.44
Sargan test of overidentification	Chi^2 (852) = 847.19	Chi^2 (387) = 428.31	Chi^2 (851) = 845.53	Chi^2 (386) = 427.94
Arellano-Bond test for AR(1)	Z=-3.56	Z=-3.64	Z=-3.54	Z=-3.64
Arellano-Bond test for AR(2)	Z=-1.34	Z=-1.19	Z=-1.37	Z=-1.19

Standard errors are reported in parentheses, and corrected for panel-specific autocorrelation and heteroskedasticity.
*, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively.

Asia and sub-Saharan Africa, mobile phones are considered the first practical communications tool for the public just as the fixed-line phones were in developed economies in the 1970s and 1980s. We hypothesize that marginal effects of mobile phones on economic growth would be pronounced differently when countries have different levels of fixed-line phone penetration. We expect the estimated coefficient of the interaction term to be negative for the following reason: the two telecommunications technologies are (imperfect) substitutes and mobile phones are rapidly replacing the role of the fixed-line phones especially in South Asia and sub-Saharan Africa where the fixed-line telephone infrastructure has long been inadequate; so it is plausible that the marginal impact on economic growth of mobile phones may be larger in a country where the fixed-line phone penetration is lower. In regression (3), the regression equation with the interaction term is fitted over the sample period of 1990 – 2008 and the estimated coefficient of the interaction term

(TPEN×MPEN) is negative as expected and statistically significant. Holding all other factors constant, the marginal effect of mobile phone expansion on the growth rate of GDP per capita is given as follows:

$$\frac{\partial \text{GRTH}}{\partial \text{MPEN}} = 0.0446 - 0.0038 \cdot \text{TPEN}$$

For example, in 2000 in South Asia and sub-Saharan Africa, the standard deviation in the number of main telephone lines per 100 people (TPEN) was 5.09. If a country's TPEN is one standard-deviation lower than that of an otherwise identical country, the marginal impact of mobile phone expansion on GDP per capita growth rate will be greater approximately by 0.19 percentage point (= –0.0038×–5.09). However the interaction term becomes statistically insignificant when the regression is estimated from 2000 to 2008. This result was expected because the estimated coefficient of TPEN is no longer statistically significant in regression (4) as the penetration level of the fixed-line phones (TPEN) had been stagnant for the sample period.

Except for the lagged dependent variable ($GRTH_{it-1}$) and the growth rate of population (POPGR), the estimated coefficients of all other explanatory variables are statistically significant at least at a 5% significance level with expected signs across the four regressions in Table 3. First, the estimated coefficient of the lagged GDP per capita ($GDPPC_{it-1}$) is negative and confirms the convergence hypothesis in the neoclassical growth theory. Both TRADE/GDP and GDFI/GDP are positively correlated with economic growth: the more open an economy and the larger the share of infrastructure investment in GDP, the higher the growth rate of GDP per capita. The estimated coefficient of the government consumption as a share of GDP (GCON/GDP) is negative and the finding is common in the economic development literature, suggesting that annual economic growth rate tends to be lower when the government share of GDP is relatively large.

Table 3 also reports the Arellano-Bond tests for autocorrelation in the first-differenced residuals. The null hypothesis of no AR(1) process is usually rejected because $\Delta v_{it} = v_{it} - v_{it-1}$ and $\Delta v_{it-1} = v_{it-1} - v_{it-2}$ are related to each other through v_{it-1}. The test for AR(2) is what detects the level of autocorrelation and thus determines the number of lags for instruments. As shown in the table, the null hypothesis of no serial autocorrelation of order 1 (in levels) could not be rejected at all standard significance levels across the four estimations. Therefore we instrumented first differences of all regressors with second and deeper lags for all regressors were assumed to be potentially endogenous in our estimations. Finally, the Sargan test statistics supports that the instruments used in the regressions are exogenous as group.

CONCLUSIONS

Worldwide access to mobile phones has exploded during and since the 2000s, creating unprecedented opportunities for economic growth in less-developed and developing countries. As mobile phone penetration continues to increase at a rapid pace in sub-Saharan Africa and South Asia, the economic and social benefits of its use are expected to reveal economies of scale as more persons become part of the telecommunications network. A small but growing number of studies have produced empirical evidence of a positive relationship between economic growth and mobile phone expansions over the past couple of decades. This study contributes to the existing literature by incorporating the theory that fixed-line phones and mobile phones are imperfect substitutes in the empirical model so that we can empirically examine how the marginal impact of mobile phone coverage on economic growth varies depending on the level of fixed-phone penetration. Another contribution of this study is that we employ the Arellano-Bond difference GMM estimator, allowing all regressors to be potentially endogenous.

Our empirical results indicate that mobile phones are positively correlated with economic growth, and that its marginal contribution to economic growth is even greater where the conventional fixed-line telecommunications infrastructure is poor. For policymakers in developing countries, designing and implementing an appropriate plan for economic development could be challenging, especially when a country's potential for economic growth is largely limited by deficiency in investments in the public infrastructure. The main findings in this study suggest that increasing access to mobile phones is one way to compensate for poor public infrastructure as well as to boost entrepreneurship and market efficiency.

Since mobile phones have been replacing the role of the fixed-line phones largely in the 2000s, most cross-country studies of economic growth have relied upon data sets of "small T and large N," and thus it has yet to be seen whether the current findings would hold even in the long run. Also due to the endogenous nature of telecommunications variables, a simultaneous panel approach is increasingly desired in future research. Yet the application of rigorous methods to measuring the effect of mobile telephony on economic development amongst the poorest nations is crucial in helping policymakers in making regulatory and investment decisions in these countries. Mobile phones could serve as a springboard for major advances in economic development as they create a network not only for mobile telephony, but also for the spread of internet access and mobile money transfers.

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ENDNOTES

1. As of 2008 in the OECD member countries, the number of main telephone lines per 100 persons and the number of mobile phone subscribers per 100 persons were 45.05 and 115.23, respectively.

2. Our discussion of a linear Generalized Method of Moments (GMM) estimator and its application to our cross-country growth model draws heavily on Roodman (2009).

3. The number of mobile phone subscribers may not be a completely accurate measure of the number of phone users, since many owners of phones share their phones with friends and family on a regular basis. Also, in some countries people living in rural areas may purchase phone services from a woman in the village who sells calls from her phone, as in the "village model."