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Mobile goes global: The effect of cell phones on economic growth and development

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Mobile goes global: The effect of cell phones on economic growth and development

An econometric analysis

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Abstract

This study investigates the effect of cell phones on economic development and growth by performing an econometric analysis using data from the International Telecommunications Union and the Penn World Table. It discusses the various ways cell phones can make markets more efficient and how the diffusion of information and knowledge plays into development. Several approaches (OLS, Fixed Effects, 2SLS) were used to test over 20 econometric models. Overall, the mobile cellular subscriptions rate was found to have a positive and significant impact on countries' level of real per capita GDP and GDP growth rate. Furthermore, the study provides policy implications for the use of technology to promote global growth.

I. Introduction

Mobile devices have infiltrated and revolutionized the modern world. Although the effects of mobile devices on society are vast and can be examined through a variety of disciplines, this study will focus on measuring the impact of mobile devices on economic development and growth. Through econometric analysis, the study seeks to parse out the direct contribution of the proliferation of mobile devices on development. I expect to find a positive correlation between a country's cellular mobile subscriptions rate and several metrics of growth, including gross domestic product (GDP), GDP growth rate, and HDI (Human Development Index). Furthermore, this investigation will seek to explain the various factors contributing to economic development in order to isolate the true effect of mobile devices.

Significance of the Project

Mobile phones can impact economic development in a number of ways. They have the potential to reduce the costs of communication by lowering search costs and making information more accessible to the general population of developing countries. This, in turn, will lead to more efficient market operation by reducing the amount of waste caused by spoilage, and by facilitating communication between producers, sellers, and buyers. In addition, mobile phones can increase the economic welfare of both consumers and producers. Finally, cell phone use can stimulate the economy by creating more demand for mobile-based services, which in turn increases employment.

Mobile phones also offer the potential for mobile phone-based services and products. One example is m-banking, or mobile banking. In this application, users are able to transfer money between bank accounts and pay bills via phone (Aker & Mbiti, 2010). In addition, mobile phones have been used to monitor elections and provide voter education. Mobile phones, with their text messaging capabilities, may increase literacy as well. In Niger, users are able to take classes and practice sending messages in their local languages. As Aker and Mbiti write, “Text messaging makes literacy functional.”

By investigating the role that mobile phones play in economic development and growth, this study will provide further insight into an existing field of research on telecommunications and development. It will review the global effects of technological growth and consider more deeply the uses of what people in the developed world consider everyday technology. The study will also evaluate how to use existing technologies properly and creatively in order to promote economic development.

Section II provides background information on theories of economic development and growth, including the neoclassical and endogenous models of growth. It discusses the specific role of information in terms of growth and how cell phones aid the spread of information and knowledge. Section III provides an overview of the existing literature in the area of information technology and economic development, citing both empirical studies and case studies. Section IV includes a description of the data and the variables used in the study, as well as the sources from which these data derive. Section V explains the modeling approaches used, while Section VI describes the results of each model. Section VII is a discussion of the overall findings and policy implications, and Section VIII concludes.

II. Background

Economic Growth and Development Theory

Neoclassical Model

According to neoclassical theory, economic growth, as measured by the average annual growth rate of real GDP per person, results from savings and investment (Gordon, 2009). Growth in output stems from growth in factor inputs such as land, labor, and capital or from growth in output relative to growth in factor inputs. In Solow's model of economic growth, national savings and investment are related to the per person production function:

$$\frac{Y}{N} = Af(\frac{K}{N})$$

,where Y is real GDP per person, N is labor input, and K is capital input. What Solow posited in his neoclassical theory was that an increase in the ratio of national savings to output was not enough to sustain economic growth, and that growth in the autonomous growth factor (A) is needed for steady increases in per capita GDP.

An equilibrium level of growth is reached where the saving line (the national savings rate multiplied by output per person) and the steady-state investment line (the sum of the growth rate of labor input and the depreciation rate multiplied by the capital-labor ratio) intersect. The equation is as follows:

$$s\frac{Y}{N} = (n + d)\frac{K}{N}$$

, where s is the savings rate, n is the growth rate of labor input and d is the depreciation rate. Again, Y/N is per capita output and K/N is the capital to labor ratio. At the point of intersection, as shown in Figure 1, the capital-to-labor ratio is maintained at a fixed level; new members of the population are provided with what materials they need and worn out capital is replaced. Population growth affects the Solow model in three ways: it increases total output, lowers the level of output per worker, and alters the optimal steady-state level of capital in a country (Mankiw, 2005). When considered in the context of Solow's model, technology can either make each worker more efficient or it can shift the production function. The neoclassical model, however, ignores numerous other factors that may influence development. Moreover, it leaves unexplained the drivers of growth in the autonomous growth factor. Many economists have termed *a*, the growth in the

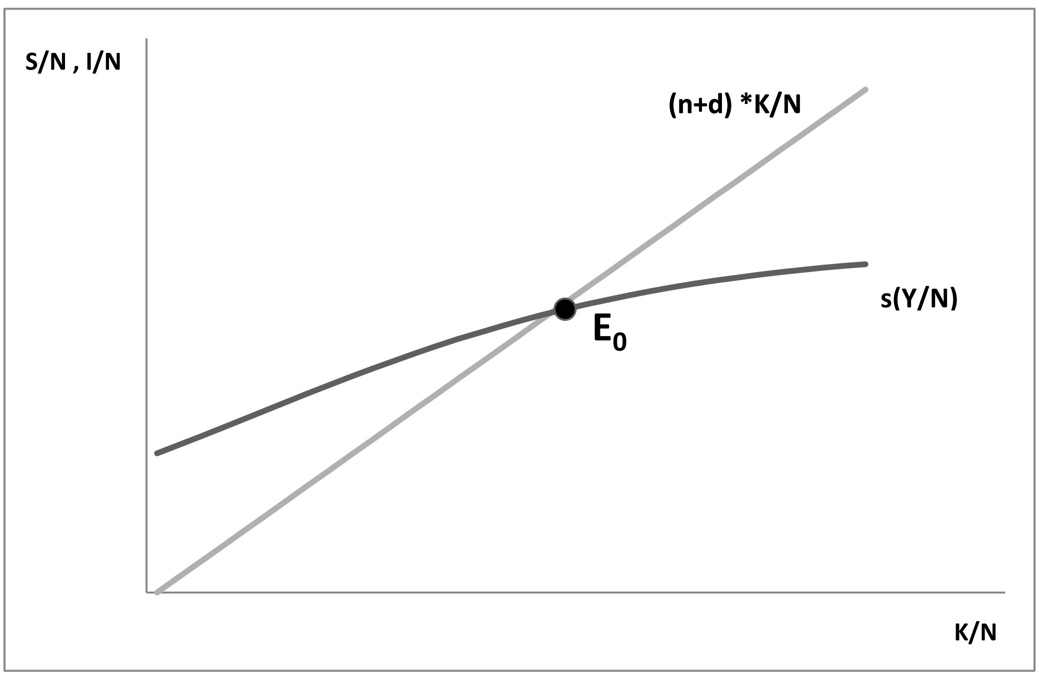

Figure 1. Equilibrium growth rate according to Solow's model of economic growth

autonomous growth factor, Solow's residual (Gordon, 2009). Others, such as the U.S. Bureau of Statistics, call *a* the growth in multifactor productivity, or total factor productivity. Critics of the neoclassical theory have pointed out that the model suggests that population growth is equal to output growth, and that the standard of living (Y/N) is fixed–none of which has been observed in the developed world, as the standard of living has risen substantially over the past 100 years.

Endogenous growth theory

During the 1980s an alternative to the neoclassical model of economic growth was developed by Paul Romer and Robert E. Lucas, Jr. (Gordon, 2009). Endogenous growth theory takes into consideration a myriad of variables that help explain the disparities in the standards of living between developed and underdeveloped nations. It also seeks to determine what factors influence *a*, the autonomous growth factor, and focuses on technical change as a result of market activity. For example, it emphasizes the importance of ideas more than objects, for it is ideas that drive growth and productivity (Romer, Economic Growth, 2007). How natural resources and goods are used is essential to improving the standard of living in a given country. Romer offers the example of Taiwan, which lacked many capital goods and natural resources yet still grew quickly. He also suggests that increasing information flows between the developed and developing worlds will propel growth; ideas about production and industry from foreign and leading nations will spread, resulting in greater output and efficiency. Many of Romer's models of endogenous growth mention the importance of technical change, and argue that technological change “arises in large part because of intentional actions taken by people who respond to market incentives” (Romer, Endogenous Technological Change, 1990). Also essential to growth is the establishment of an incentive system in which ideas are protected from the free rider effect, and the spread of ideas, which will increase knowledge, and ultimately increase human capital. Moreover, this theory gives greater credence to indicators of development besides economic growth. Such development indicators include life expectancy, level of democracy, healthcare, poverty rate, and literacy rate. Unlike the Solow growth model, the endogenous growth model does not exhibit diminishing returns; thus, savings and investment lead to sustained growth, rather than leveling off at a steady-state as in the Solow model (Mankiw 2005).

The Role of Information in Economic Development

Much in line with endogeneous growth theory, cell phones impact economic development and growth primarily through their function as a medium of communication. They improve information sharing, which is crucial to the diffusion of ideas that endogenous growth theory emphasizes. Information and communication technologies decouple information from a “physical repository,” enabling the spread of information, ideas, and knowledge that is so critical during the development process (Bedia, 1999). The easier exchange of ideas can reduce the knowledge gap among developed and developing nations, enabling developing countries to increase their standards of living.

Information technologies, such as cell phones, can increase efficiencies within a country by enabling the exchange of information among its inhabitants and lowering the cost of acquiring information. Mobile phones are especially important in developing nations where the needs of separate groups within the population may differ substantially (Unwin, 2009). For example, the poorest individuals in marginalized communities more immediately need information about sources of food and shelter. Producers and consumers, the majority of the population, would instead need information about employment opportunities, prices of goods, education, health, acceptable norms of behavior, and elections. With cell phones, distinct groups can receive the specialized information they need. The use of mobile phones also implies a two-way communication. After individuals receive the information they need, they can communicate their other needs to governing bodies. In this manner, cell phones increase the flow of information, as well as its overall availability.

Bedia (1999) suggests that in developing countries, reliable information communication technologies lower the costs of transmitting information, which shifts the information supply curve to the right. The technologies can improve the quality of information by providing up-to-date and complete data. With more abundant and accurate information, people in developing countries will be able to make better and quicker decisions in order to facilitate economic growth and development and reduce poverty.

Moreover, as Unwin writes, “Information and knowledge have always been central to the effective functioning of human societies. They are the means through which societies reproduce themselves, through which understanding is passed on to future generations” (2009). Mobile devices proliferate knowledge, helping individuals in society communicate and establish an intricate network of information. Mobile devices decrease transaction costs and broaden product markets (Waverman, Meschi, & Fuss, 2005). They also lower search costs, reduce the degree of asymmetric information in markets, and reduce price dispersion (Abraham, 2007). Telecommunications further enhance the spread of information through network effects. As more and more users are linked into an information network, network externalities are generated, providing a benefit to citizens of developing countries.

III. Literature Review

Mobile devices, particularly cell phones, are now at a crossroads. The first official mobile phone debuted in 1946 (Kumar & Thomas, 2006), and three generations of mobile phones later, they have become a staple of modern society in the developed world. The story of the cell phone in the developing world, however, is more complicated.

A number of studies have examined the role that mobile phones play in the developing world. Waverman, Meschi and Fuss (2005) note that “mobile phones substitute for fixed lines in poor countries,” and that “mobile telephony has a positive and significant impact on economic growth.” The researchers found that a ten percent increase in the mobile penetration levels of developing countries increased the growth rate by 0.6 percent. In an earlier study by Roeller and Waverman (2001), fixed line telecommunications raised growth in output among OECD nations by one-third. A ten percent increase in the telecommunications penetration rate (both mobile and fixed-line telecommunications) was associated with a 1.5 percent increase in the growth rate. The adoption of mobile phones enabled the spread of information without the costly installation of physical phone lines.

Abraham (2007) studied the effect that mobile phones had on the fishing industry in India. Although telecommunications were considered a luxury in India, there were about 156 million mobile phone subscribers by 2007. Abraham notes that the teledensity of phones was about eleven telephone lines per 100 people, and that this low ratio suggests ample room for growth in telecommunications in the nation. After conducting a survey of Indian fisherman, he found that 80 percent of the respondents thought mobile phones useful. He concluded that because fisherman could take mobile phones with them to sea, they could more easily access market information, including selling prices and demand. Fishermen could then decide how much fish to catch, which reduced the amount of the catch that was dumped or used as fertilizer. Additionally, the fisherman could better communicate at sea, enabling them to catch more fish if a large shoal appeared in neighboring waters. The increased availability of information reduced the risks and uncertainty of the volatile fish market. Mobile phones thus reduced search costs, reduced waste and improved quality of life, as they allowed fishermen to communicate with their families and those on shore about bad weather forecasts like storms and other problems like engine failure.

Studies have also been done on the mobile revolution in China (Kumar & Thomas, 2006). In 2005, the number of mobile phone subscribers increased by 1.3 million each week, and the total number of subscribers had surpassed 350 million. Kumar and Thomas acknowledge the growth of mass media, including radio and television, but note that this vehicle of communication fell short of its development aspirations. While mass media certainly increases the capacity of information dispersion, it also lacks the "social and economic power structures at the grassroots level, or local cultures, local resources and indigenous knowledge" inherent to mobile phones. The grassroots power afforded by cell phones places the ability to take control of markets, improve efficiency, and effect change in the hands of farmers, fishermen, and other laborers.

Another study of the impact of cell phones in Uganda suggests that the mere expansion of mobile phone coverage, as opposed to the possession of mobile phones at the household level, allows an increase in information flow, inducing the market participation of farmers who produce perishable crops like bananas in areas far away from a district center (Muto & Yamano, 2009). Using panel data from household and community surveys in Uganda, Muto and Yamano estimate the determinants of mobile phone network coverage, household possession of mobile phones, and banana and maize market participation. According to the study, the increase in information flow reduces the marketing costs of crops, including transportation costs, and reduces the amount of wasted produce caused by spoilage. The study, however, is limited in its consideration of producers, rather than traders and consumers.

In addition, a study by Aker and Mbiti (2010) details the channels through which the adoption and use of mobile phones in sub-Saharan Africa has affected economic growth and development. For instance, in Ghana, cell phones are used to keep in touch with relatives, as well as learn about corn and tomato prices (Aker & Mbiti, 2010). In Niger, cell phones are used to learn about job opportunities. Cell phones and text messages also remind users to take prescribed medications on time, and even report violent conflicts. Aker and Mbiti suggest that the mobile device is more than just a simple communication tool; it is an agent of change that can transform lives. The mobile phone, because of its low cost relative to landline telecommunications and infrastructure, is more easily adopted by the sub-Saharan population. In fact, the number of mobile phone subscriptions in Africa jumped from 16 million in 2000 to 376 million in 2008 (International Telecommunications Union, 2009). The adoption of the cell phone has been important in improving agricultural labor market efficiency and increasing producer and consumer welfare. Moreover, mobile phones reduce information asymmetry by allowing better access to and use of information, by reducing search costs, and by improving coordination among agents (Aker & Mbiti, 2010). Cell phones aided firms in managing their supply chains and streamlining production processes by improving communication between firm and supplier.

Mobile phones can create more jobs by increasing the demand for mobile-related services. Klonner and Nolen (2008), for example, found that the introduction of mobile coverage in South Africa was correlated with a 15 percent increase in employment. Using panel data from annual labor force surveys in South Africa and data from a mobile network provider, Klonner and Nolen construct a fixed effects model to measure the effect of mobile network coverage on labor market outcomes. In addition to finding a positive and significant relationship between mobile coverage and employment, the study also concluded that employment among young men shifts away from agriculture as a result of the introduction of mobile phones. Employment among women, especially those without children, increased as well.

Mobile phone technologies facilitate the development of many mobile services that may enhance market efficiency. One way in which mobile devices enhance development is through mobile banking, which, in turn, creates business and entrepreneurship opportunities (Aker & Mbiti, 2010). Ivatury and Pickens (2006) discusse the impact of mobile banking in South Africa, finding that m-banking increases the availability of money, credit, and other financial services to poor people. Because banking can be done electronically, people no longer need to devote time and money to traveling to distant bank branches. Mobile banking trims transaction fees that ATMs typically charge. With mobile banking, individuals can make payments, transfer money, and buy prepaid electricity and mobile airtime. They can also make balance inquiries and deposit and withdraw cash. So far, the mobile banking provider WIZZIT has launched m-banking in South Africa (Ivatury & Pickens, 2006), and Safaricom has implemented M-PESA in Kenya (Jack & Suri, 2009).

Other studies in information technology and telecommunications similarly suggest the importance of mobile phones and communication entities, such as landlines, information kiosks, the internet, and computers, in reducing asymmetric information in developing countries. In Madhya Pradesh, India, a system called e-coupal was implemented in October 2000 (Goyal, 2010). As part of this plan, internet kiosks were established in villages to enable farmers to access soybean prices. According to Goyal’s study, there was an immediate and significant increase in the average market price for soybeans due to the introduction of kiosks. In fact, the kiosks increased the monthly market price of soybeans by one to three percentage points. The dispersion of soybean prices across markets also decreased.

Non-statistical studies have reported the various in ways cell phones contribute to development. In Vietnam, cell phones are used to look for new business opportunities. They are used for a mobile banking system, and many users find the service convenient because they can keep a record of the transactions (Foster, 2007). In Sierra Leone, though rural areas still lack coverage, mobile phones have replaced the landlines destroyed during civil war (Sesay, 2004). They are now used to coordinate business transactions as well as communicate with relatives. Furthermore, cell phones have generated additional business on the micro level. Entrepreneurs in developing countries such as Africa purchase multiple mobile phones, purchase airtime in bulk, and then sell calls to anyone passing through a village center (Hesse, 2007). Still others establish kiosks to transmit money without mobile banking. For example, in Uganda, customers buy mobile minutes on a prepaid card to transfer to a distant recipient. Kiosk owners send the minutes to another kiosk owner by reading the activation code aloud over the mobile phone. The other kiosk owner will then convert the minutes into money after subtracting a commission, and deliver the funds to the distant recipient. In this manner, mobile phones enable those without bank accounts to receive money, and also stimulate other types of business activity.

However, it should be noted that telecommunications by themselves are not sufficient to achieve development. Other variables such as a measure of democracy, political freedom, civil liberties, and literacy should also essential to economic development and should be included in the analysis (Andonova, 2006).

The majority of the studies reviewed here focus on the effect of cell phones on economic growth solely in developing countries, but the impact of cell phones in richer or poorer countries may differ. As such, this difference will be further examined later in this paper by partitioning the data into two groups and performing regression analyses.

The Digital Divide

Many studies have discussed the potential of mobile phones to increase the welfare gap between the rich and poor in developing nations. The digital divide is the term used to refer to the disproportionate effect of information and communication technologies on different groups. It has also been defined as “the inequality in access, distribution, and use of information and communication technologies between two or more populations” (Wilson, 2004). The different groups may be found within a single country (the intranational digital divide) or they may refer to several countries (the international digital divide). For instance, communities with computers, internet access, or other telecommunications technologies grow and develop while those without stand stagnant. Alternatively, wealthy individuals may be able to purchase and maintain technologies, increasing their productivity, efficiency, and quality of life, while poorer individuals may be unable to afford the same technologies. Access to the technology may depend on physical, financial, cognitive, design, content, production, institutional, or political restraints. Since connectivity and access to the internet vary across and within countries, telecommunications technologies can put some areas without access to these tools at a greater disadvantage (Unwin, 2009). As a result, poorer countries or communities without access to information and communication technologies may be unable to recover, and the gap between the rich and poor will diverge rather than converge. Moreover, the digital divide may exacerbate social and cultural inequalities, as certain groups within communities have greater access to information and communication technology. Women in Germany, Italy, Malaysia, South Africa, and Senegal, for example, have recorded much lower internet use.

Studying the phenomenon of the digital divide, Wilson (2004) designed a model to determine the theory's validity. In the study, he designed an Index of Technological Progress that took into account internet hosts, computers, TVs, cell phones, and fax machines, as well as newspapers and radios for 110 countries. Though he encountered several instances of limited data sets, which could bias his data set toward more developed countries, he found that there was a "substantial and worrisome" gap "between the information haves and have-nots" (Wilson, 2004). Furthermore, his study confirmed that even within countries, gaps among different groups existed in personal computer use and internet use. Wilson also finds that the growth rates of developing countries are significantly lower than those of developed countries, and that the digital divide will likely increase. Still, he also notes that because of a limited data set it is difficult to make definitive conclusions.

IV. Data

The panel data used in this study draw from a number of sources. Building upon an existing data set on worldwide civil war data compiled by Professor Chris Magee, I have updated and added new information pertaining to telecommunications technology use.

The data set consists of statistics on 182 countries over the period 1980 to 2007. The study focuses on this interval because during this time cell phones first began to come into use. Data from the most recent Penn World Table released in 2009 were only available up to 2007, which is why the analysis ends with this year.[1] A few data points were available for the year 2008 and were used where possible.

The primary variable of interest in this study is the mobile cellular subscriptions rate denoted by *cell_sub*. *Cell_sub* represents the number of mobile cellular subscriptions per 100 people; it includes both post-paid and prepaid subscriptions. The data were reported by the International Telecommunications Union. According to the data, the first country to record a non-zero mobile cellular subscriptions rate was Finland in 1980 (0.491). It was followed closely by Japan, Norway, and Sweden. Since the 1980s, mobile cellular subscriptions have increased substantially, as seen in Figure 2. From 1980 to 2007, the mean of *cell_sub* was 11.36 with a standard deviation of 25.61. From 1980 to 2007, Finland's mobile subscriptions rate increased from 0.491 to 114.96, which marks a 23,313.4 percent increase. Other countries have experienced similar growth in the mobile subscriptions rate. The United States' subscriptions rate, for example, increased from

[1] A more recent edition of the Penn World Table was released in March 2011, but the majority of the study had been completed by this time.

0.038 in 1984 to 88.21 in 2007. Cell phones have also proven vital in developing nations, where mobile phone use often exceeds landline use (Roller & Waverman, 2001; Waverman, Meschi, & Fuss, 2005). In China, the mobile subscriptions rate changed from 0.0000646 in 1987 to 48.41 in 2008. Equally striking is the growth in India's mobile subscriptions rate. Over 18 years, India's mobile subscriptions rate increased from 0.633 to 30.43. In the study, the variable c*ell_sub* ranges in value from 0 to 177.17. Mobile cellular subscriptions rate data were also available for the year 2008. Including data from an additional year in the analysis yields a mean of 13.58 cell phones per hundred people for the data set.

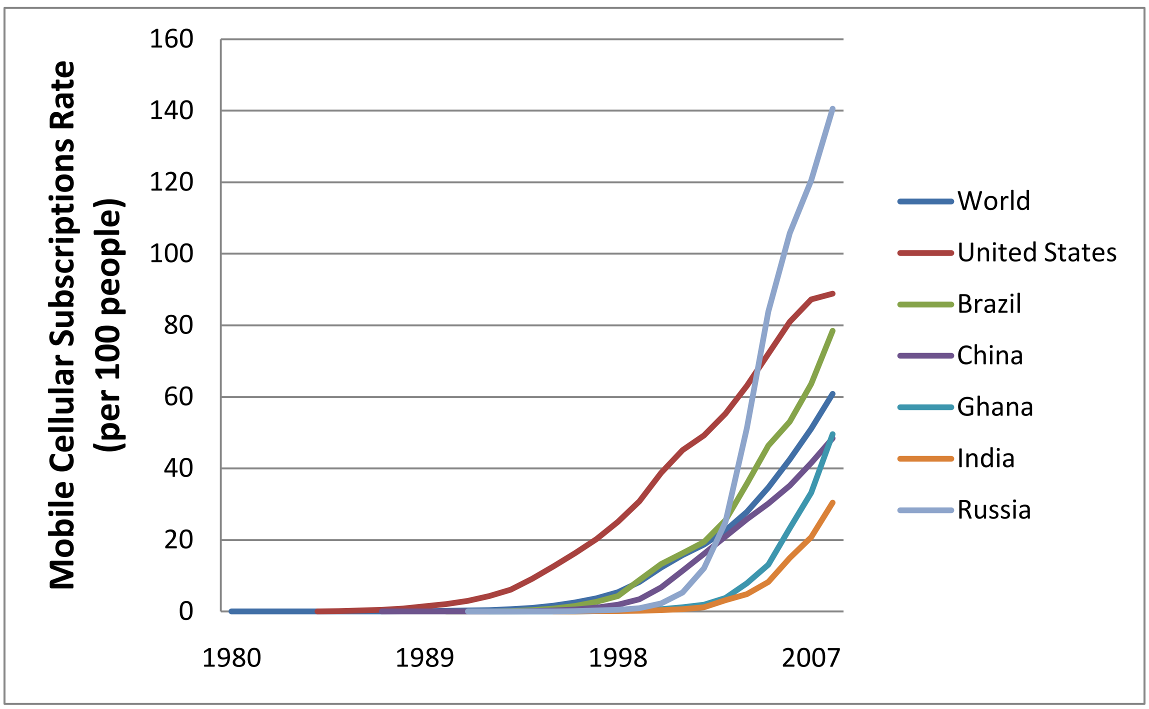

Figure 2. Growth in mobile cellular subscriptions rate

Much of the data were taken from the latest version of the Penn World Table (PWT) released in August 2009. Among the data taken from the PWT are population, level of trade openness, and several measures of per capita income. *Rgdpch* represents real GDP per capita in 2005 constant U.S. dollars calculated by a Chain Series. The mean GDP per capita of the 182 countries included in the study over the period 1980 to 2007 is $9964.04. The country with the lowest value for *rgdpch* in 2007 was Liberia with $385.67 as its GDP per capita. The country with the highest GDP per capita in 2007 was Qatar with $88,292.58. For the sake of comparison, the United States recorded a per capita GDP of $42,886.92 for 2007. In the study, *cell_sub* and several control variable will be regressed on *rgdpch*.

Country	rgdpch in 1980	rgdpch in 2007	Average annual growth rate, 1980-2007
United States	24537.41	42886.92	2.09%
Brazil	8457.82	9645.53	0.49%
China	917.77	8511.34	8.60%
Ghana	1229.85	1652.20	1.10%
India	1428.89	3826.32	3.72%
Russia	n/a	13406.34	--
Uganda	776.27	1170.95	1.53%
World	9347.78	13127.47	1.27%

Table 1. Comparisons of real per capita GDP in 2005 US$ and growth rates

Obtained from the Penn World Table, *grgdpch* is the average annual growth rate (%) of *rgdpch* calculated using 2005 constant prices. *Grgdpch* over the period 1980 to 2007 has a mean of 1.754 and standard deviation of 7.472. The variable ranges from

-64.360 (Iraq, 1991) to 118.24 (Equatorial Guinea, 1997). The country exhibiting the lowest rate of growth in 2007 was Guyana (-11.32), and the one displaying the highest rate of growth was Azerbaijan (26.19). Growth rates of per capita GDP will also be used as a dependent variable in the study.

The Human Development Index (*HDI*) was included in the data set as an alternative to real GDP per capita since other factors besides GDP are critical in measuring a country's level of development. The Human Development Report began in 1990, and the HDI provides a simple, convenient, and more holistic way to compare countries' development. As a composite index, the HDI combines indicators for the categories of health, income, and knowledge. In other words, it takes into account life expectancy at birth, mean years of schooling, expected years of schooling, and gross national income per capita when calculating an index for each of the three categories. The HDI is the geometric mean of the normalized indices for health, income, and knowledge.[2] While the HDI is not a complete measure of any country's level of social and economic development, it does take into consideration other factors crucial to development besides GDP per capita. Still, the indicator is lacking in the areas of political participation and gender inequality. The index ranges from 0 to 1, with 1 indicating that a country is more developed. For the study, the index was rescaled to range from 0 to 100. The HDI data for the countries included in this study's data set were available only for the years 1990,

[2] The dimension index = $\frac{actual\ value - minimum\ value}{maximum\ value - minimum\ value}$, (Human Development Report, 2010). The highest score in each category is thus 1. The HDI is the geometric mean of the three indexes, which equals $\sqrt[3]{(healthindex * edcuationindex * income\ index)}$.

2000, and 2005-2008. The mean of *HDI* for the years 2005-2008 was 0.6047 with a standard deviation of 0.189. *HDI* ranges from 0.158 to 0.987 in the study.

Because many factors besides the number of cell phones in use in a country affect growth, included in the data set are variables related to country characteristics, trade, and level of political freedom. These additional variables may be related to the proliferation of cell phone use, so by including them in the model I will obtain the effect of cell phones on growth after controlling for the impact these variables have on growth.

Openc is a measure of a country's level of trade openness and is used as a control variable in all of the study's models. It is calculated by summing a country's exports and imports for a given year and dividing it by GDP. In this data set, the values range from 1.98 to 456.94, and are calculated as a percentage of GDP. According to the data, the country with the lowest level of trade openness in 2007 was Somalia with 2.00. It was followed by Brazil (25.74), the United States (29.07), and Cuba (33.46). The country with the highest level of trade openness in 2007 was Singapore, with a value of 426.68. Seychelles (321.54) and Luxembourg (312.52) also recorded high values of trade openness. On average, the level of trade openness for the 182 countries for the period 1980 to 2007 is 81.76. *Openc* has been included as a control variable because a country's level of trade openness will impact availability of cell phones and related mobile technologies within a country.

Country	1990	2000	2005	2007
United States	20.54	26.34	26.93	29.07
Brazil	13.11	21.72	26.65	25.74
China	33.15	44.45	67.25	70.98
Ghana	39.40	116.70	97.74	95.89
India	15.03	27.51	44.31	48.27
Russia	36.35	68.09	56.60	52.84
Uganda	25.79	34.18	42.76	46.09
World	75.55	88.15	95.57	97.40

Table 2. Comparisons of levels of trade openness

The variables related to level of democracy draw from a dataset produced by the Integrated Network for Societal Conflict Research (INSCR). The policy score as given by the INSCR Polity IV 2009 data set was then used to determine if a country was a democracy (*democracy)*, semidemocracy (*semidem)*, or autocracy (*autocracy*), according to the definitions for each category established by Magee and Massoud (2011). If the polity score fell between 6 and 10, then the dummy variable *democracy* was given a value of 1. If the score fell between -5 and 5, the country was marked as a semidemocracy, and if the polity score fell between -6 and -10, it was marked as an autocracy. These dummy variables were included in the data set since studies such as Andonova (2005) and Howard and Mazaheri (2009) have found that political rights and liberalization have a positive and significant impact on cell phone use and economic growth, respectively. Table 3 provides the definitions of the variables included in the study, and Table 4 presents their means and standard deviations.

Variable	Definition	Source
country	country name	
year	= year-1980	
cell_sub	Mobile cellular subscriptions rate per 100 people	ITU 2010
cell_sub_lag	A lagged version of cell_sub	
cell_sub_sq	$(\text{cell\_sub})^2$	
openc	Openness, exports and imports as share of current GDP	Penn World Table
rgdpch	Real gross domestic product per capita, Chain Series	Penn World Table
grgdpch	The growth rate of real gross domestic product per capita, Chain Series	Penn World Table
polity	Polity score from polity IV 2009 data set	INCSR
polity2	Polity score with missing values replaced	
democracy	=1 if polity score is 6 to 10	
semidem	=1 if polity score is -5 to 5	
autocracy	=1 if polity score is -6 to -10	
HDI	Value of the HDI index	Human Development Report
develop	=1if country is currently developing	IMF
pplocal	Pre-paid minimum per minute local call during peak hours in US$	ITU 2010
pplocal3	Price of 3 minute local call (off-peak) in US$	ITU 2010
cellsubcharge	Mobile cellular monthly subscription charge (US$)	ITU 2010
mobilenetrev	Revenue from mobile networks (US$)	ITU 2010
ythblgap	Percentage of the population ages 15-24	Urdal (2006)

Table 3. Variable Definitions

Variable	Observations	Mean	Std. Dev.	Min	Max
year	5169	1993.493	8.075	1980	2007
cell_sub	4968	11.359	25.614	0	177.169
openc	4812	81.765	48.267	1.983	456.936
rgdpch	4773	9964.04	11444.54	153.1648	97721.26
grdpch	4741	1.754	7.472	-64.360	118.244
democracy	4171	0.434	0.496	0	1
semidem	4171	0.254	0.436	0	1
autocracy	4168	0.311	0.463	0	1
develop	5093	0.808	0.394	0	1
HDI	662	0.584	0.191	0.158	0.934
pplocal	793	0.271	0.276	0	3.46
pplocal3	2660	0.321	0.412	0	3.6
mobilenetrev	3948	$1.31X10^{12}$	$4.76X10^{13}$	0	$1.85X10^{15}$
cellsubcharge	4255	9.97	20.79	0	99.9
ythblgap	3640	29.1163	7.35	12.24	45

Table 4. Summary Statistics

Potential Data Problems

A number of data problems could be cited in this study. For instance, for the *cell_sub* variable it is uncertain why the mobile subscriptions rate was unreported for many countries. Some countries may not have acquired mobile technology at an early date, or they may not have had the means to measure the rate. This could potentially create a biased sample if more developed countries were more likely to report their mobile subscriptions rate than less developed nations. No changes were made to the data obtained from the International Telecommunications Union, but dashes were interpreted as missing values, while a value of “0” was interpreted as a country reporting a mobile cellular subscriptions rate of 0.

Related to this issue is the possibility that *cell_sub* is not the best measure of cell phone use. *Cell_sub* accounts only for the number of mobile subscriptions in a given year. In reality, as Donner (2008) points out, several people, or even an entire community may share a single cell phone, which would make the mobile subscriptions rate underestimate the true impact of mobile phones on economic growth and development. In other regions of the world, however, some people own more than one cell phone; in that case, the mobile cellular subscriptions rate would overestimate cell phone use in a given country during a year.

Another potential problem is the limited availability of data for the Human Development Index. Without additional observations, it is difficult to draw accurate conclusions using the fixed-effects model this paper has formulated. Moreover, the lack of available data may bias the estimates of mobile telephony over a crucial time period.

V. Models

Ordinary Least Squares (OLS)

To gauge the effect of mobile devices on economic development and growth, multivariable regressions were performed in the study using STATA. The following is the ordinary least squares (OLS) model estimated based on economic development theory and the existing literature:

$$rgdpch_{it} = \beta_0 + \beta_1 cell\_sub_{it} + \beta_2 cell\_sub\_lag_{it} + \beta_3 democracy_{it} + \beta_4 semidem_{it} + \beta_5 openc_{it} + a_i + \mu_{it} \quad (1)$$

,where *i* represents a country and *t* represents a given year, *rgdpch* represents real per capita GDP, and *cell_sub* is the mobile cellular subscriptions rate. Regarding measures of democracy, political freedom, and civil liberties, *dem* is a dummy variable representing whether a given country is a democracy while *semidem* is a dummy variable that equals one if a given country is a semidemocracy. *Autocracy* is similarly determined, but was omitted in the regression due to perfect collinearity. *Openc* denotes the level of international trade openness.

In creating this model, I sought to include variables that might affect both real per capita GDP and cell phone use in a country. In addition to regressing real per capita GDP on the cellular subscriptions rate, I also included the lagged term because it is likely that part of the effect of an increase in cellular phone usage would not be realized in *rgdpch* until the following year. In addition, I included measures of democracy (*democracy*, *semidem*, and *autocracy*) in the model because the political structure may determine how and to what extent cell phones are allowed and used. *Openc* similarly may be related to cell phone usage and real per capita GDP. The level of trade openness determines not only the extent to which mobile technologies may proliferate the globe, but also the degree of trade participation, which often leads to growth in GDP. Harrison (1996) finds a positive correlation between a country's openness and its growth rate.

Variations of the OLS model include a squared term of *cell_sub* to investigate the possibility of diminishing returns. Another variation includes *year*, a time variable, in order to account for changes in real per capita GDP over time.

Using OLS treats *cell_sub* as an exogenous variable; that is, *cell_sub* has an effect on per capita GDP (*rgdpch)*, but per capita GDP does not impact cell phone use. Because this assumption is probably not true, other methods of estimation will also be used.

The growth rate of real per capita GDP will be used as a dependent variable in a variation of Model 1. Though increases in GDP will likely affect the rate of cell phone use since cell phones are a normal good, the growth rate of real per capita GDP may not have the same relationship. The level of GDP per capita will be included as an explanatory variable in the estimation because of diminishing returns to capital. In other words, poorer countries (as indicated by lower levels of per capita GDP) may be able to grow faster than richer ones. Increasing the capital stock in a poorer country will have a greater effect than it will in a country that already has a substantial level of capital.

Fixed Effects Approach

Since panel data were available for this study, a fixed effects approach was also tested in order to account for other variables over time and by country that may affect real per capita GDP. The fixed effects approach, however, controls only for factors that are constant in a given country over a given time period. For each *i*, the equation was averaged over time to obtain:

$$\overline{rgdpch_{\iota t}} = \beta_0 + \beta_1\overline{cell\_sub_{\iota t}} + \beta_2\overline{cell\_sub\_lag_{\iota t}} + \beta_3\overline{democracy_{\iota t}} + \beta_4\overline{semidem_{\iota t}} + \beta_5\overline{openc_{\iota t}} + \alpha_i + \overline{\mu_{\iota t}} \ . \qquad (2)$$

Next, the data were time-demeaned by subtracting equation (2) from equation (1), resulting in

$$rgd\ddot{p}ch_{\iota t} = \beta_1 cell\_\ddot{s}ub_{\iota t} + \beta_2 cell\_s\ddot{u}b\_lag_{\iota t} + \beta_3 de\ddot{m}_{\iota t} + \beta_4 semi\ddot{d}em_{\iota t} + \beta_5 op\ddot{e}nc_{\iota t} + \ddot{\mu}_{\iota t} \qquad (3)$$

, which is the general time-demeaned equation for each country.

Fixed effects estimation is useful in this case because there might be an unobserved effect, a_i, that affects a country's economic growth. The willingness of a country to adopt new technology, for example, may impact growth; I argue that it is reasonable to assume that this effect would be fixed over the time period of interest, 1980 to 2007. In using a fixed effects approach, the unobserved, constant effect a_i included in equation 2 drops out, and we are left with equation 3. The dependent variable in equation 3 is the change in real per capita GDP rather than the level of *rgdpch*. Equation 3 is similar to the OLS model estimated with per capita GDP growth rates in that there is less concern about the change in cell phone use being endogenous with the change in real per capita GDP.

Endogeneity, Instrumental Variable Estimation, and Two-Stage Least Squares

Bedia (1999) notes that much work in the area of telecommunications research is plagued by issue of endogeneity. He writes that "a myriad of factors…may influence growth, and ignoring them may lead to an overestimate of the effect of ICTs [information and communication technologies]." Indeed, the use of telecommunications is by no means the sole driver of economic growth. Moreover, Bedia (1999) writes that a single-equation approach does not capture the "possibly endogenous nature of ICTs and growth, i.e. the greater availability of ICTs may lead to higher GDP, but at the same time, higher GDP may lead to greater demand for ICTs" (18). Mobile use is thus an endogenous variable. Although Norton (1992) attempts to reduce the possibility of overestimating the effect of ICTs on annual growth by including more regressors in his study on transaction costs and telecommunications, Bedia argues that the study still suffers from endogeneity bias.

Drawing from Roller and Waverman (2001), Waverman, Meschi and Fuss (2005) attempt to examine the impact of telecommunications on economic growth in developing countries by estimating a four-equation model. The first equation is the macroeconomic production function; the second estimates the demand for telecommunications; the third is the investment in telecommunications infrastructure, and the fourth estimates the effect of investment on increased proliferation of telecommunications. Using this model, the researchers tested the possible endogeneity of the mobile penetration rate as a regressor by performing a Hausman test. They concluded that endogeneity "was not likely to be an issue." This method took into account the endogenous nature of mobile phone use with its estimation of additional and related equations.

Sridhar and Sridhar (2007) similarly note the problem of endogeneity and attempt to resolve it in their study. Following Waverman, Meschi, and Fuss (2005), they estimate systems of equations, including the demand for and supply of telecommunications infrastructure and service, the production of telecommunication service and the change in telecommunication penetration. They find that reverse causation between telecommunication and economic growth exists, and that "any increases in GDP translate to increase in personal disposable income, and hence increase demand for telephone services." The endogenous nature of cell phone use is thus a valid criticism of any study on the effect of telecommunications on economic growth.

In this study, I attempt a variation of the model that both Sridhar and Sridhar (2007) and Waverman, Meschi, and Fuss (2005) construct. In order to account for possible endogeneity, this study also uses instrumental variables and Two-Stage Least Squares. With an endogenous variable, the dependent variable is correlated with the error, which violates one of the assumptions of the multiple regression model. An instrumental variable is related to the endogenous variable but is uncorrelated with the error. In Two-Stage Least Squares (2SLS), the estimator is obtained by running two regressions. The first regresses the endogenous variable, which, in this case, is cellular mobile subscriptions (*cell_sub*) on instrumental variables. The instruments used in this study include youth bulge and mobile phone prices. Youth bulge, the percentage of a country's population between the ages 15 and 24, may be a viable instrument for mobile cellular subscriptions as it is usually the younger generations that are more likely to adopt new technologies, such as cell phones. Mobile phone prices have been used in previous studies as an instrument for cell phone use (Sridhar & Sridhar, 2007). Both are good instruments for mobile phone subscriptions since they should affect cell phone use, but not growth rates. The first regression is as follows:

$$\widehat{cell\_sub} = \hat{\pi}_0 + \hat{\pi}_1 ythblgap + \hat{\pi}_2 pplocal + \hat{\pi}_3 democracy_{it} + \hat{\pi}_4 semidem_{it} + \hat{\pi}_5 openc_{it} \ . \tag{4}$$

The second regression replaces the value of *cell_sub* with the fitted values of *cell_sub*. The fitted values become the instrumental variable for *cell_sub*, that is:

$$rgdpch_{it} = \beta_0 + \beta_1 \widehat{cell\_sub}_{it} + \beta_2 democracy_{it} + \beta_3 semidem_{it} + \beta_4 openc_{it} + \alpha_i + \mu_{it}. \tag{5}$$

2SLS essentially eliminates the correlation between the endogenous variable ($cell\_sub$) and the error μ_{it} before it performs the desired OLS regression. Equation (5) thus takes into account the endogenous nature of cell phone use in order to obtain a more accurate measure of the effect of cell phone use on economic growth. The 2SLS method will also be combined with the fixed-effects approach. Additional instruments are tested and described in the results section.

VI. Results

Ordinary Least Squares

The results of the initial OLS regressions are reported in Table 5. This first set of regressions reports the effects of the mobile cellular subscriptions rate, a lagged version of the mobile cellular subscriptions rate, level of trade openness, and level of democracy on real per capita GDP (calculated by Chain Series). In the first model, all terms included in the regression were significant at the one percent level except *cell_sub*. The lagged version of the mobile cellular subscriptions rate, *cell_sub_lag*, however, did prove significant at the one percent level. The coefficient on this variable was 222.19 with a standard error of 41.21; this means that a one unit increase in the mobile subscriptions rate during a given year would increase real per capita GDP by 222.19 US$ the following year. The coefficient on *cell_sub* is negative and insignificant because the large positive effect of cell phones on the level of GDP per capita is evidenced in *cell_sub_lag*. The levels of trade openness and democracy were also significant in this first equation, with a one unit increase in *openc* increasing real per capita GDP by 28.75. Having a democratic form of government increased *rgdpch* by 2798.67 relative to a country with an autocracy, while having a semidemocracy decreased *rgdpch* by 3748.92. The *autocracy* variable was omitted in the estimation of the model due to perfect collinearity with *democracy* and *semidem.* Overall, this model yielded an R^2 of 0.30 and the variables were found to be jointly statistically significant at the one percent level by an F-test.

Model 2 added *cell_sub_sq*, which is the cellular mobile subscriptions rate squared, as an explanatory variable. The coefficient on *cell_sub_sq* was small, yet significant (-0.959). Interestingly the sign on this coefficient was negative, which suggests that cell phone penetration exhibits diminishing returns. The coefficient on *cell_sub* was negative and insignificant at the ten percent level, which is consistent with the previous model. To measure the permanent effect of cell phone coverage on the level of per capita GDP, I added the coefficients to obtain 294.25. Over a two-year period, a unit increase in the mobile cellular subscriptions rate would thus increase *rgdpch* by 294.25. In order to determine the level at which the effect of cell phones on *rgdpch* is maximized, the derivative of *rgdpch* was found with respect to *cell_sub*:

$$\widehat{rgdpch} = \widehat{B_0} + \widehat{B_1} cell\_sub + \widehat{B_2} cell\_sub\_lag + \widehat{B_3}(cell\_sub)^2 + \widehat{B_4} openc + \widehat{B_5} democracy + \widehat{B_6} semidem + \widehat{B_7} year\,. \quad (6)$$

Combining the coefficients on *cell_sub* and *cell_sub_lag* to obtain the permanent increase in cell phone use over a two-year period, I obtain:

$$\widehat{rgdpch} = \widehat{B_0} + (\widehat{B_1} + \widehat{B_2}) cell\_sub_{2years} + \widehat{B_3}(cell\_sub)^2 + \widehat{B_4} openc + \widehat{B_5} democracy + \widehat{B_6} semidem + \widehat{B_7} year. \quad (7)$$

Taking the derivative of the previous equation yields:

$$\frac{\partial rgdpch}{\partial cell\_sub} = \widehat{B_1} + \widehat{B_2} + 2\widehat{B_3}(cell\_sub)\,. \quad (8)$$

I then set the derivative equal to 0 to find the maximum point, substituted in the estimated coefficients from Model 2, and solved for the value of *cell_sub*.

$$\frac{\partial rgdpch}{\partial cell\_sub} = 0 = 323.11 - 28.87 + 2(-.959)(cell\_sub). \quad (9)$$

Solving this equation for *cell_sub,* I found that the effect of cell phone use on the level of per capita GDP over a two-year period was optimal at a level of 153.42 cell phones per 100 people. At this point, the impact of cell phones on the level of *rgdpch* is maximized. Of the countries in the data set, only the United Arab Emirates had a cell phone usage rates as high as 153 cell phones per 100 people.[3] Thus, over the relevant range of data per

[3] In 2007, the United Arab Emirates recorded a cellular mobile subscriptions rate of 177.17 per 100 people.

capita GDP always increases when cell phone coverage increases, but it increases at a diminishing rate. The other results in this model were consistent with those of the previous model. All of the terms included were significant at the one percent level. In addition, the results were fairly robust, as the estimated coefficients remained similar in both magnitude and sign. This regression also yielded an R^2 of 0.30 and the parameters were found to be jointly statistically significant by the F-statistic that STATA reported.

Variable	**Model 1** **OLS**	**Model 2** **OLS**	**Model 3** **OLS w/ Time trend**
Dependent variable: Real GDP per capita (*rgdpch*)			
constant	5077.77*** (334.30)	5032.07*** (335.47)	7869.90*** (382.05)
cell_sub	-31.067 (35.82)	-28.87 (35.72)	142.90*** (36.91)
cell_sub_lag	222.19*** (41.21)	323.12*** (45.91)	276.89*** (44.93)
cell_sub_sq		-0.959*** (0.194)	-1.79*** (0.20)
openc	28.75*** (3.06)	28.44*** (3.06)	30.55*** (3.00)
democracy	2798.67*** (341.67)	2541.50*** (344.66)	3112.71*** (338.79)
semidem	-3748.92*** (334.30)	-3833.59*** (373.89)	-2226.39*** (382.10)
year			-325.17*** (22.93)
Number of Observations	4024	4024	4024
R^2	0.30	0.30	0.33
Adjusted R^2	0.30	0.30	0.33
Standard Errors in parentheses *significant at the 10% level **significant at the 5% level ***significant at the 1% level			

Table 5. OLS Regressions

The third OLS model estimated included a year time trend to account for changes in real per capita GDP that are not explained by the variables included in the regression. In this model, all of the estimated coefficients were found to be significant at the one percent level, though they differ substantially in magnitude from the previous two models. For instance, the coefficient on *cell_sub* was positive and about five times the magnitude of the estimated *cell_sub* coefficients from the previous two models. The results for *cell_sub_lag*, *cell_sub_sq*, *openc*, *democracy*, and *semidem*, however, remained consistent. The *year* time trend was found to have a negative, yet statistically significant coefficient, which is perplexing since real per capita GDP tends to increase over time. Still, since the parameter for *cell_sub_sq* was again negative, this model also suggested that the cellular mobile subscriptions rate displayed diminishing returns. The value of *cell_sub* at the maximum point was found to be 116.67, which could be interpreted as the optimal number of mobile cell phone subscriptions per 100 people. At this cellular mobile subscriptions rate, the effect of cell phones on real per capita GDP is maximized. Model 3 reported a higher value for the adjusted R^2 than Models 1 or 2, which suggests that Model 3 explains more of the variation in *rgdpch*. In addition, the parameters in Model 3 were also found to be jointly statistically significant at the one percent level.

The results also suggest that cell phones may be more valuable in developing countries than developed countries. Due to diminishing returns to the increased use of cell phones, the effect of increasing mobile cellular subscriptions in Bangladesh, for example, differs from the effect in Finland. The following table uses the results from

Model 3 to illustrate the impact of a one unit increase in the mobile cellular subscriptions rate on the level of real per capita GDP for several countries in a given year, holding all other factors constant.

Country	Year	Cell_sub	Predicted change in rgdpch[4]
Afghanistan	2007	16.51	360.68
Bangladesh	2007	21.79	341.78
Finland	2007	114.96	8.23
United States	2007	87.21	107.58
World	2007	65.39	185.69

Table 6. Impact of increasing *cell_sub* in developing vs. developed nations

As seen in Table 6, the effect of a one-unit increase in the cellular mobile subscriptions rate over a period of two years increases the predicted *rgdpch* by differing amounts. For Finland and the United States, two countries with high rates of cell phone use, the impact of increasing the mobile cellular subscriptions rate is smaller than it is in countries with lower rates of cell phone usage. This finding regarding the differing impacts of an increase in cell phone proliferation suggests that technology should be used differently in developing and developed nations. While handing out cell phones in developed nations may not drastically alter the standard of living, in developing countries, the potential for the cell phone to be used as a development tool is great.

Besides running regressions using the level of real per capita GDP as the dependent variable, I also estimated a few models regressing *cell_sub* and the same

[4] These figures were calculated using the derivative of Model 3.

control variables on the growth rate of *rgdpch.* While there may be an endogenous relationship between cell phone usage and per capita GDP, no evidence suggests that growth rates will necessarily have an impact on cell phone usage; therefore, using the growth rate of *rgdpch*, labeled *grgdpch* in the study, could avoid the problem of endogeneity while still measuring the impact of cell phone use on economic growth. Table 7 lists the results for the regressions performed using growth rate as the dependent variable.

Variable	**Model 4**	**Model 5**	**Model 6**
Dependent variable: GDP per capita growth rate (*grgdpch*)			
		If develop=1	If develop=0
constant	0.111 (0.294)	0.122 (0.364)	1.58** (0.609)
rgdpch	-0.0000207 (0.0000136)	-0.0000479 (0.000195)	-0.0000342* (0.0000187)
cell_sub	0.184*** (0.037)	0.193*** (0.0455)	0.0721*** (0.0238)
cell_sub_lag	-0.176*** (0.035)	-0.167*** (0.0445)	-0.0705*** (0.0257)
openc	0.0116*** (0.002)	0.0129*** (0.003)	0.0072** (0.0027)
democracy	0.589** (0.294)	0.169 (0.361)	0.815 (0.643)
semidem	0.491 (0.325)	0.377 (0.363)	2.44** (1.077)
Number of Observations	4003	3232	771
R^2	0.0274	0.0288	0.0655
Adjusted R^2	0.0260	0.0270	0.0581
Standard Errors in parentheses *significant at the 10% level **significant at the 5% level ***significant at the 1% level			

Table 7. Growth rate models

The results of the growth rates regressions suggest that *cell_sub* does have small, positive and significant on growth rates. Models 4, 5, and 6 all used the same regressors, but found slightly different outcomes. Model 4 performed the regression for all of the countries included in the data set, while Models 5 and 6 divided the data set into two groups – developing and developed countries, according to the definition provided by the International Monetary Fund. Model 5 included only the countries considered as currently in development (develop=1), while Model 6 limited the data used to countries considered as developed. The coefficients that were statistically significant throughout were *cell_sub, cell_sub_lag*, and *openc. Cell_sub* and *cell_sub_lag* were both of a similar magnitude and found to be statistically significant at the one percent level in all models; however, their signs differed. These results suggest that among developed countries an increase in the cellular subscriptions rate would increase the growth rate of GDP temporarily, since the effect would be negated the following year, as indicated by the negative coefficient on *cell_sub_lag*. Using the results from Model 4, I find that a more permanent (two-year) increase in cell phone use would increase the growth rate by 0.008.[5] Likewise, the results from Model 5 indicate that an increase in cell phone use would increase growth rates by 0.026 in developing countries. On the other hand, the effect shrinks in Model 6, in which the same increase in cell phone use increases the growth rate by only 0.0016 in developed countries. Still, a small, positive, permanent effect on the growth rate of GDP would be evidenced. Also of interest is the difference in magnitude of the coefficients on *cell_sub* and *cell_sub_lag* in Models 5 and 6. For

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[5] This value was obtained by adding together the coefficients on *cell_sub* and *cell_sub_lag*, as was done in the discussion of Models 2 and 3.

countries currently in development, it appears that an increase in the cellular mobile subscriptions rate would have a larger impact on growth rates than it would in already developed nations.

Another important factor to note is the very low R^2 reported for Models 4 and 5, which indicate that *grgdpch* may be very difficult to predict. The growth rate data could be very noisy, and many other factors besides those included in the model could affect the growth rates. Notably, the R^2 does increase in Model 6 – the regression performed using only data from developed countries. It might be the case that growth rates in developed countries are more stable and therefore easier to predict using regression analysis.

Since the level of civil liberties may impact the degree to which cell phone use increases GDP (Andonova, 2006), interaction effects were considered in conjunction with the OLS models using the growth rate of GDP as the dependent variable. When the interaction effects were included in the model, the effect of a country having a democracy versus a semidemocracy or autocracy did change the impact of cell phone use on the growth rate. The coefficients on the interaction terms differed slightly, and a country having an autocracy or semidemocracy increased the impact of cell phone use on growth rates relative to a country with a democracy. Including the same terms as Model 4 and dividing the sample into separate groups before running the regression led to similar results. One explanation for the difference in the effectiveness of cell phones due to different structures of government may be the ability of cell phones to communicate individuals' needs. In autocracies and semidemocracies, where freedom of expression may be limited, cell phones provide a way for individuals to communicate their needs. For example, in China, which is an autocracy according to the IMF, censorship, privacy, and the infringement of basic human rights are serious issues. Cell phones can make available information that is normally censored or obscured by the government. At the same time, however, the government may also decrease the effectiveness of cell phones by controlling the content that can be shared. For much of 2011, China has been censoring calls and messages sent over cell phones and the Internet (LaFraniere & Barboza, 2011).

Fixed Effects Models

While the coefficients estimated by OLS seem satisfactory at first glance, the method cannot take into account unobserved differences among countries and across time periods. Thus, I next used a fixed effects approach to account for variations among countries over time. The results of this set of regressions are reported in Table 8. The parameters in each model were all jointly statistically significant, according to the F-statistic reported by STATA. The table includes a fixed effect for each country.

In Model 7, the same terms as in Model 1 were included as explanatory variables. Of these terms, the constant, *cell_sub_lag*, and *openc* all recorded coefficients that were significant at the one percent level. A one unit increase in the cellular mobile subscriptions rate in one year contributed to a change in real per capita GDP of 60.99 US$ in the following year. When a fixed effects approach was used, the coefficient on *cell_sub* decreased substantially. Meanwhile, a one unit increase in the level of trade openness indicated a change in real per capita GDP of 14.43. Significant at the five percent level were the coefficients on *cell_sub* and *democracy*. According to the results, a one unit increase in the mobile subscriptions rate was associated with an increase in *rgdpch* of 24.09 US$ during the same year. The R^2 value for this regression was 0.38.

Model 8 adjusted Model 4-7 by including the squared mobile cellular subscriptions rate as an explanatory variable. The results of this regression yielded results consistent with those of Model 7. As in the previous regression, all of the estimated coefficients included were at least significant at the five percent level, though a few (*cell_sub_lag, cell_sub_sq, openc, democracy*) were also significant at the one percent level. The main differences are that the estimated coefficient on *cell_sub_lag* increased in magnitude by approximately 40 units when the *cell_sub_sq* term was included. The coefficient on *cell_sub_sq* is positive, which differs from the OLS models. The positive sign suggests that there are instead increasing returns to cell phone use.

Model 9 is also a variation of Model 7 in that it includes the same explanatory variables, as well as a yearly time trend. In general, the results were relatively consistent with those obtained in Model 7. In this model, all of the coefficients except the one on *cell_sub* were statistically significant at the one percent level. The coefficient on *cell_sub* was not found to be significant even at the ten percent level. The constant term in this case, however, differed greatly from the one estimated in Models 7 and 8. The coefficients on *cell_sub_lag, openc, democracy*, and *semidem* were on the same order of magnitude as the previous results and also maintained the same sign. The *year* term yielded a positive coefficient, which is more reasonable than the result obtained in Model 6 with OLS.

Model 10 builds upon Model 9 by adding a squared year term. Other than that, however, the results were again consistent. Interestingly enough, the coefficient on *year* now increased to 130.43 from 42.98 when the squared year term was included in the regression, which the addition of the squared time trend explains. The negative coefficient on the year squared variable indicates that GDP per capita is rising over time but at a decreasing rate.

Though fixed effects are one way to control for other factors that affect GDP growth and are related to cell phone use, other factors may change over time and thus have not been captured in the model. Omitted variables, such as internet use in a country or the amount of total mobile network coverage, may affect both GDP growth and cell phone use. These factors could cause the correlation seen between GDP growth and cell phone use, leading to biased coefficient estimates. In this case, the coefficients would likely have a positive bias, since cell phone use, internet use, and mobile network coverage are probably positively correlated. These variables were not included in the model for a number of reasons, one of which is the lack of available data on mobile network coverage. Moreover, the relationship between internet use and cell phone use is not clear. Internet use neither enables nor necessitates cellular mobile phone use, but it may have a role in making information and communication technologies more easily adopted. Similarly, infrastructure is often required for reliable and fast Internet access, which is why mobile phones are a simpler alternative to laptop computers.

Variable	Model 7 FE	Model 8 FE	Model 9 FE, time trend	Model 10 FE, time trend sq.
Dependent variable: Real GDP per capita (*rgdpch*)				
constant	7527.10*** (164.49)	7568.10*** (163.71)	7461.63*** (164.14)	7030.91*** (186.83)
cell_sub	24.09** (10.01)	24.14** (9.95)	6.096 (10.41)	18.42* (10.70)
cell_sub_lag	60.99*** (11.50)	100.37*** (12.89)	72.88*** (11.62)	65.95*** (11.68)
cell_sub_sq		0.365*** (0.055)		
openc	14.43*** (2.01)	13.79*** (2.00)	12.63*** (2.01)	13.53*** (2.03)
democracy	-381.85** (162.56)	-521.36*** (163.03)	-848.82*** (179.88)	-833.50*** (179.41)
semidem	-251.94* (132.63)	-287.25** (132.01)	-627.06*** (146.34)	-597.24*** (146.06)
year			42.98*** (7.22)	130.43*** (19.66)
year_sq				-3.67*** (.77)
Number of Observations	4024	4024	4024	4024
R^2 (within)	0.38	0.39	0.39	0.39
R^2 (overall)	0.23	0.23	0.21	0.23
Standard Errors in parentheses *significant at the 10% level **significant at the 5% level ***significant at the 1% level				

Table 8. Fixed Effects Regressions

Time Dummy Variables

Table 9 lists the results of two regressions performed with dummy time variables. In the first, Model 11, an OLS regression was performed, and in Model 12 the fixed effects approach was used to control for country by country variations. The dummy year variables included in this set of regressions allows us to account for unexplained variations in real per capita GDP during a given year. In Model 11, the coefficients on the years represent how much real per capita GDP changed in a given year, while in Model 12, the coefficients signify the change in real GDP for a given year relative to the omitted year (1980). In both models, the constant, *openc*, *democracy*, and *semidem* were significant at the one percent level. *Cell_sub* was significant at the one percent level in the OLS model while *cell_sub_lag* was significant at the one percent level in the fixed effects model. In Model 12 the sign on the year dummy variables change from negative to positive in 1991, which corresponds to the period when cell phones were beginning to grow in use. The positive trend, signifying an increase in the rate of growth of real per capita GDP, lasts until the year 2005.

When compared to Model 3, which was estimated using OLS and includes a *year* variable to capture the tendency of real per capita GDP to rise over time, Model 11 exhibits a slightly higher value for adjusted R^2. The adjusted R^2 value is a measure of the goodness of fit of a model and takes into account the number of variables included in the variable, enabling comparisons between models. This comparison suggests that the year dummy variables are a better way to control for changes over time than simply including a linear time trend.

Variable	**Model 11** **OLS, Dummy Year**	**Model 12** **FE, Dummy Year**
Dependent variable: Real GDP per capita (*rgdpch*)		
constant	6290.85*** (788.47)	7978.88*** (259.85)
cell_sub	206.96*** (37.72)	19.58* (10.82)
cell_sub_lag	60.04 (41.60)	69.65*** (11.79)
openc	28.55*** (2.96)	12.47*** (2.02)
democracy	2717.57*** (338.55)	-895.07*** (179.52)
semidem	-2458.17*** (379.31)	-676.76*** (146.35)
1981	-235.95 (1054.67)	-297.81 (290.94)
1982	-522.21 (1054.71)	-558.65 (291.00)
1983	-720.53 (1054.76)	-707.90 (291.09)
1984	-688.92 (1054.75)	-628.78 (291.04)
1985	-695.92 (1054.75)	-642.77 (291.07)
1986	-543.99 (1052.88)	-616.47 (290.77)
1987	-506.91 (1052.79)	-540.52 (290.6)
1988	-453.61 (1052.79)	-392.69 (290.59)
1989	-333.83 (1050.97)	-192.91 (289.75)
1990	-339.11 (1047.81)	-87.45 (289.75)
1991	-350.98 (1040.21)	17.48 (288.47)
1992	-645.03 (1037.40)	133.21 (288.22)
1993	-971.36 (1019.92)	173.54 (284.20)
1994	-1043.85 (1017.72)	231.92 (284.17)
1995	-1029.48 (1018.32)	338.12 (284.41)
1996	-911.84	737.75

	(1016.10)	(284.86)
1997	-994.66 (1018.71)	527.32 (283.71)
1998	-1253.12 (1020.98)	780.61* (286.04)
1999	-1931.86 (1025.07)	775.78* (287.99)
2000	-3038.75*** (1033.44)	708.61 (291.87)
2001	-4174.42*** (1032.96)	416.96 (293.02)
2002	-5179.43*** (1033.03)	161.16 (294.09)
2003	-6029.45*** (1039.25)	39.96 (297.11)
2004	-7347.43*** (1053.88)	98.38 (303.93)
2005	-9119.36*** (1075.04)	-81.41 (313.73)
2006	-11091.68*** (1105.27)	-359.95 (325.81)
2007	-13247.26*** (1137.99)	-664.36 (338.75)
Number of Observations	4024	4024
R^2	0.35	0.40
Adjusted R^2	0.34	
Standard Errors in parentheses *significant at the 10% level **significant at the 5% level ***significant at the 1% level		

Table 9. Time Dummy Variable Regressions

HDI

For the sake of gauging the effect of cell phone use on economic development as well as economic growth, I also performed a few regressions using the human development index as the dependent variable. The results obtained, however, are limited by the paucity of data available for HDI. Indeed, the Human Development Report only began reporting the index in 1990, and the data are only available for approximately every subsequent five year period. Still, according to the F-statistics reported for each regression, the parameters included were all found to be jointly statistically significant.

For the first set of HDI Regressions, reported in Table 10, for the first three models, I limited the time period to 2005-2007 and performed fixed effects regressions. Before 2005, the reporting of HDI was sporadic. After inspecting the data, I found that prior to 2005, more developed countries were more likely to report a value for HDI, which could bias the results. To avoid possible bias, only the HDI data from 2005-2007 were included as dependent variables in the regressions. The HDI data were also rescaled to range from 0 to 100 instead of 0 to 1 in order to present clearer results. Model 13, which does not include a lag term for *cell_sub*, yields statistically significant coefficients at the one percent level on the constant and *cell_sub*. *Openc*, *democracy,* and *semidem* were all insignificant even at the ten percent level. This regression reported an R^2 value of 0.62.

Variable	Model 13 FE	Model 14 FE	Model 15 FE, time trend	Model 16 OLS
Dependent variable: HDI				
constant	590.18*** (5.57)	586.05*** (5.31)	491.88*** (9.04)	510.18*** (16.85)
cell_sub	0.399*** (0.019)	0.501*** (0.050)	0.094** (0.0367)	3.38*** (0.714)
cell_sub_lag		0.152*** (0.04)	0.021 (0.0361)	0.164 (0.774)
cell_sub_sq		-0.0016*** (0.00026)		
openc	0.039 (0.033)	0.027 (0.031)	0.0082 (0.026)	0.291 (0.110)
democracy	-7.04 (5.03)	-5.20 (4.72)	-4.39 (3.99)	63.24 *** (14.00)
semidem	-8.34 (5.37)	-6.59 (5.05)	-4.58 (4.27)	-43.12*** (15.42)
year			4.43*** (.350)	
1995				-191.71 (122.69)
2000				-30.01* (17.12)
2005				-111.90*** (17.68)
2006				-139.72*** (18.46)
2007				-171.43*** (19.35)
Number of Observations	431	429	431	656
R^2	0.61	0.664	0.76	0.60
Standard Errors in parentheses *significant at the 10% level **significant at the 5% level ***significant at the 1% level				

Table 10. HDI Regressions

Model 14 builds upon Model 13 by including both *cell_sub_lag* and *cell_sub_sq*. The coefficients on both these terms were found to be statistically significant at the one percent level. Moreover, the coefficients on the constant and on *cell_sub* remained statistically significant at the one percent level, while the coefficients on *openc*, *democracy*, and *semidem* remained insignificant. Again, the coefficient on *cell_sub_sq* was negative, suggesting diminishing returns of the effect of cell phones on HDI. In addition, the magnitude and sign of the estimated coefficients stayed consistent with the results reported by Model 12. The R^2 value for this regression was found to be 0.665.

Model 15 adjusted Model 14 by eliminating the squared cellular mobile subscriptions term and instead adding a year term to capture the effect of a time trend. In this case, the coefficient on *cell_sub_lag* was no longer significant, but that could be due to high multicollinearity with *cell_sub*. Multicollinearity will create large standard errors, which leads to less precise estimates of coefficients.

Using the data collected for the years 1990-2007, Model 16 incorporated additional year dummy variables into the model and used OLS instead of fixed effects. The dummy year variables were included to account for changes specific to a certain year, since data were not available for a substantial and continuous time period. In this model, the constant, *cell_sub*, *democracy*, and *semidem* were all significant at the one percent level. Most of the dummy year variables (2000, 20005, 2006, 2007) were significant at least at the ten percent level. Again, *autocracy* was omitted because of perfect collinearity with *democracy* and *semidem*, while the year 1990 was omitted for the same reason. Interpreting the coefficients on the dummy variables is thus done in comparison with these omitted categories. For example, if a country was a democracy in the year 2000, real GDP per capita would increase by 33.2 (which is the sum of the coefficients on *democracy* and *2000)* relative to a country with an autocracy in 1990.

The regressions using HDI as a dependent variable presented results consistent with those of the *rgdpch* set. Overall, the mobile cellular subscriptions rate had a positive, significant effect on HDI, which suggests that cell phones can indeed facilitate development.

Two-Stage Least Squares (2SLS)

Table 11 lists the results for the two-stage least squares regressions performed to control for the possible endogeneity of the *cell_sub* variable. The first four models employ fixed effects in conjunction with two-stage least squares, and the fifth adopts OLS. All models use real GDP per capita as the dependent variable and only differ by the choice of instrument for *cell_sub*. Four variables were considered as possible instruments for *cell_sub* – the mobile cellular monthly subscription charge in US dollars, the pre-paid minimum per minute local call during peak hours, the total revenue from mobile networks in US dollars, and the youth bulge, which is the percentage of the population between ages 15 and 24.

Notably, the only model with a statistically significant *cell_sub* coefficient was Model 20, which used youth bulge as an instrument. In this model, a one unit increase in the mobile cellular subscriptions rate would explain an increase in the change of real per capita GDP of 158.68 US$. The only other significant variable in the model was *openc*, which was significant in both the OLS and FE regressions performed with real GDP per capita (*rgdpch*) as a dependent variable.

The remaining models reported all insignificant coefficients. After performing additional regressions of each instrument on *rgdpch*, I found that these instruments did not have a significant effect on *cell_sub*, which could make these results suffer from bias. In addition, the number of observations available for the 2SLS regressions was fewer than those available for regular fixed effects or OLS because data were missing for the following instrumental variables: the price of a local one-minute call (*pplocal*), the price of local three-minute call (*pplocal3*), and the total revenue from mobile networks (*mobilenetrev*). The coefficients in Models 17 through 19 are plagued by large standard errors, which may explain why they are not statistically significant. It is also important to note that Model 20, which used youth bulge as an instrument for *cell_sub* had the most observations available for regression.

Still, other interesting results have been garnered from these regressions. For instance, like in Models 7 through 9, which used fixed effects, the coefficient on *cell_sub* in Model 20 is both positive and large. In addition, the coefficients on *openc* are likewise positive, though again only significant in Model 20.

Variable	Model 17 IV, FE	Model 18 IV, FE	Model 19 IV, FE	Model 20 IV, FE	Model 21 IV, OLS
Dependent variable: Real GDP per capita (*rgdpch*)					
Instrument for cell_sub	cellsubcharge	pplocal	mobilenetrev	ythblgap	ythblgap
constant	4476.08 (6575.79)	6956.08*** (2300.83)	-19175.17 (73970.3)	8130.22*** (221.10)	17460.75*** (1022.17)
cell_sub	-83.06 (397.20)	36.32 (113.30)	-1654.43 (4878.41)	158.68*** (17.15)	1273.43*** (62.76)
openc	47.26 (63.09)	8.33 (9.83)	261.11 (674.87)	7.82*** (2.52)	-3.11 (6.76)
democracy	-3830.70 (6626.41)	487.29 (456.98)	-28525.4 (77342.5)	177.78 (261.50)	-1174.41 (788.71)
semidem	-3520.71 (7295.47)	817.30 (670.88)	-28128.28 (77674.72)	217.04 (23.36)	2557.77*** (868.57)
year	339.91 (801.01)	71.77 (208.58)	3358.65 (9408.36)	-50.60* (23.85)	-1351.47*** (84.66)
Number of Observations	2309	446	2160	3217	3217
R^2 (overall)	0.0041	0.204	0.135	0.225	n/a
Standard Errors in parentheses *significant at the 10% level **significant at the 5% level ***significant at the 1% level					

Table 11. Two-Stage Least Squares Regressions

Test for Endogeneity

Because of the large standard errors reported in the 2SLS regressions, I performed a test for endogeneity to determine whether or not 2SLS was necessary (Wooldridge, 2009). First I regressed *cell_sub*, the suspected endogenous variable on all other exogenous variables: *openc*, *democracy*, *semidem*, *year*, and *ythblgap*, and saved the residuals. I omitted *cellsubcharge*, *pplocal*, and *mobilenetrev* in the test since I already found these variables to be only weakly correlated with *cell_sub*. Then I included the residuals in the structural (GDP per capita) equation and estimated the coefficients on each variable using OLS. Inspecting the coefficient on the residuals, I found that it was indeed significantly different from 0. Thus, *cell_sub* is endogenous, and 2SLS was necessary.

VII. Discussion & Implications

Overall, the results of the study suggest that the growth in cell phone use over the past two decades has had a significant effect on real per capita GDP. In the majority of the regressions performed, the cellular mobile subscriptions rate or the lagged version of this variable has had a large, positive, and significant impact on the real per capita GDP for a given country, even after factors like level of trade openness and level of democracy were taken into account. Cell phone use also exhibited a small, yet significant impact on the change in the level of real per capita GDP, as well as the growth rates of real per capita GDP. Similar results were discovered in terms of level of economic development, which takes factors such as education and life expectancy into account. The results proved fairly robust, and the impacts of the additional explanatory variables were similar across the models. In fact, in Model 20, which takes into account fixed effects and the endogeneity of *cell_sub*, a one unit increase in the cellular mobile subscriptions rate would increase real GDP per capita by 158.68 US$. In that model, a country like the United Arab Emirates with a cell phone usage rate of 177.17 per 100 people has a predicted GDP per capita $25984.27 higher than Liberia, which has a cell phone subscriptions rate of 15.52.

In the study, several statistical models were tested and refined. Ordinary Least Squares and fixed effects models were tested, and instrumental variables were used to control for the possible endogeneity of cell phone use. While the mobile cellular subscriptions rate was found to be endogenous, I argue that this fact does not discount the finding that cell phones have had a profound impact on global economic development and growth.

As such, the results of this study suggest that cell phones can in fact be used to facilitate and promote economic development and growth. Again, the ways that cell phones can impact economic development and growth are numerous. Cell phone use can reduce search costs and increase information availability, which makes markets function more efficiently. In terms of the diffusion of ideas and knowledge, mobile phones make available information about market prices and employment opportunities. Cell phones can also be used to deliver important information about health and to increase literacy. Mobile phones have lately found exceptional use in mobile banking, enabling greater access to capital, which facilitates investment and productivity. Likewise, mobile banking eliminates the need for clients to spend time traveling to the physical banks. The growth of the cell phone industry itself, adding more jobs and creating more demand for products and services is another way in which mobile phones have contributed to economic growth.

Already the use of cell phones has grown. For many developing countries, mobile lines outnumber landlines. But this technology can be used to encourage further growth and development. How to approach the issue of development using mobile technologies, however, remains contentious. According to Unwin (2009), top-down approaches often impose Western ideals and culture upon other nations, resulting in a “practical elitism.” Often, governments and other organizations believe they know what the poor need for development, but in reality may harbor personal interests and biases. Historically, messages of development transmitted via mass media also have not necessarily been effective, since development requires not only the delivery of information, but the processing and dynamic sharing of information. Unwin encourages a more participatory, bottom-up approach that will allow a more personal approach to development. Access to information should be universal – it should not be limited to the privileged groups in a society, but available to women, youth, and the impoverished. It should be focused on meeting the needs of the community at hand and centered on building and strengthening relationships and communication. Mobile phones, if used effectively, can empower individuals to take actions to improve their standards of living.

In terms of policy guidelines, governments can and should promote the use of cell phones to improve market functionality and the quality of life in developing nations. They could accomplish this in a number of ways, such as keeping open channels of trade in order to increase the diffusion of new technology among nations. Governments could also provide subsidies for constructing additional cell towers or try to attract foreign investors. The present scarcity of cell towers has impeded greater cell phone coverage and thus cell phone use. Currently, one issue in using mobile technologies for development is the difference in access. Wealthier communities, often found in urban areas of developing nations, experience better access to technology. This gap between the wealthy and poor increases the digital divide and diminishes the opportunities for the poorer communities to catch up to wealthier communities. Moreover, two additional areas of interest for the use of the cell phone include e-commerce and m-banking. To ensure that a mobile transition is successful, it may also be useful to establish financial frameworks and policies for mobile transactions as well as provisions for privacy and security (Roy, 2005). Technology support networks may also need to be developed in order to make cell phone technologies more functional.

Though the study has found that cell phones can and do promote economic development and growth, the flaws of the study must still be noted. One main issue is the endogeneity of the cell phone subscriptions rate. While I have used instrumental variables to purge the cell phone subscriptions data of its correlation with the error in the real per capita GDP equation, there may exist a better instrument for *cell_sub*. Indeed, the youth bulge may also be correlated with the error in the per capita GDP equation, which could make my findings spurious.

Another potential issue is the infrastructure. The study has not taken into account the availability of cell phone towers or the coverage provided by the cell towers. Especially in developing countries, the availability of coverage will be a limiting factor in terms of the growth of cell phones and in terms of the potential for economic development. According to Aker and Mbiti (2010), though mobile coverage has grown over the past decade, coverage is still not equally distributed within countries. In example, of the 65 percent of the African population with access to mobile phone coverage, 93 percent of this group was found in North Africa, consisting of Algeria, Egypt, Libya, Morocco, and Tunisia. Currently, coverage in Africa is provided by a “network of specialized base stations” that provide service to a five to ten kilometer radius. The availability and reliability of electricity and/or diesel generators may also provide a barrier to growth.

Data reliability and data availability continue to be issues of interest in any telecommunications study. The study neglects to estimate the full macro and micro demand models that other studies have established, instead opting for a simpler and more direct way of estimating the effect of cell phones on economic development and growth. The study also has not been able to incorporate estimations of literacy, urbanization, and life expectancy into the models. In terms of data, the mobile cellular subscriptions rate may be inaccurate, which could lead to measurement error and bias the results of the study. Some members of population may own more than one cell phone, which could make the mobile cellular subscriptions rate (the number of mobile phone subscriptions per 100 people) overestimate cell phone use. On the other hand, other users may use a communal phone, which would make the mobile cellular subscriptions rate underestimate the true number of cell phone users.

Still, even in light of possible data and estimation problems, the potential for cell phones as a tool for development cannot be ignored. Roy writes that although the relationship between information and telecommunications technology and productivity may not be clear or direct, such technology can make small process improvements that will impact development:

> There is controversy on the scope of such innovations in the growth process. It is, however, important to recognize the ways in which ICT can ease the process of production in specific services and industries and its capacity to stimulate the process of acquisition of knowledge, literacy and health. (Roy, 2005)

Real per capita GDP may not be the only way to view growth and development; other small, yet substantial changes can impact the standard of living and the functioning of everyday life. Such changes can be effected by the adoption of the cell phone.

VIII. Conclusion

The mobile revolution has already begun, and as cell phones continue to be adopted globally, the telecommunications landscape will undoubtedly continue to grow and change. This study has reviewed several theories of economic development and growth, finding that information is vital to any country's development. In addition, several empirical and case studies were enumerated to establish the landscape of studies in the field of telecommunications and development. After collecting and analyzing data on 182 countries from the years 1980 to 2007, I find that cell phones do indeed have a significant impact on economic growth and development. Increases in the cellular mobile subscriptions rate contribute to increases in real per capita GDP, as calculated by Chain Series. In addition, cell phone use has a small, but significant impact on GDP growth rates.

Over the next ten years, the mobile phone industry will continue to grow. As such, the issue of the digital divide may become of more consequence. If poorer countries do not have equitable access to mobile technologies, it is quite possible that they will not experience as high a level of growth as would be expected from the results of this study. Of course, this does not mean that more advanced countries should impose technology on underdeveloped countries, but that they should make cell phones more accessible to the developing world.

Cell phones are merely a development tool. They are not enough in and of themselves to revolutionize any country's main productive industries. In agrarian nations such as Uganda, cell phones can make agricultural production more efficient. They can increase communication about market prices and demand, as well as help coordinate production and labor schedules. In countries where fishing is a major source of revenue, cell phones can improve the standard and quality of life by lowering search costs and lowering the risks of fishing. Mobile technologies create small, gradual changes to existing industries so that each country can grow and develop at its own, stable rate.

Plans for how mobile technology can continue to be used to facilitate growth and development are still being outlined, but most studies agree that a grassroots, bottom-up approach to development is advisable and that mobile phones can aid in sharing and communicating information for such an approach to be successful. Finding evidence supporting that view, this study affirms that cell phones can and should be used as a tool for economic development.

As mobile technologies continue to evolve, the increased functionality of cell phones will likely drastically improve their effects on development. The advent of the iPhone, with its variety of applications, augments the potential for cell phones to continue aiding growth and hints at the technological innovations still to come. 3G and 4G Internet access on phones similarly enhance the ability of mobile phones to act as a medium of communication. Mobile phones used in conjunction with the Internet will most likely be invaluable for communication at the local and global levels–an idea that is heavily emphasized in endogenous growth theory. In the future, I expect that cell phones will facilitate growth until the level of mobile saturation is reached. At this point, new technologies will likely replace the cell phone as a development tool.

Until then, the mobile phone is critically important to growth and development. Unlike other studies, this study has conducted a comprehensive evaluation of the effect of cell phones on growth and development on the global level. It has employed a number of estimation techniques to construct econometric models, finding that, across the results, cell phones have a positive and significant impact on economic growth.

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