2018

Does Mobile Phone Usage Boost Productivity in Developing Countries?

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SKIDMORE COLLEGE
DEPARTMENT OF ECONOMICS

Economics 375: Senior Seminar in Economics

Classroom: Lib 213

Term: Spring 2018

This thesis is submitted in partial fulfillment of the requirements for the course Senior Seminar (EC 375), during the Spring semester of 2018.

I have not witnessed any wrongdoing, nor have I personally violated any conditions of the Skidmore College Honor Code, while doing this project.

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Abstract
The aim of this study is to assess the impact of mobile phone proliferation on productivity, using data from 73 low-income countries, from the period 2000-2016. The sample includes countries from Sub-Saharan Africa, Latin America and Caribbean. The author's findings show that holding all else constant, a 1 percent increase in mobile penetration rate boosts output per capita by 2.6 percent. These findings confirm there are increasing returns (network effects) to productivity associated with an increase in penetration rate. Results also show that the ease of doing business matters in low-income countries in that it influences the speed at which higher productivity is achieved.

1. Introduction

This paper assesses the relationship between mobile phone penetration and economic development in low-income countries, particularly Sub-Saharan Africa, Latin America and Caribbean (all excluding high-income countries). The central question to this study is: does mobile phone proliferation have an impact on productivity in developing countries?

Developing countries typically lag in technology adoption and yet both popular news sources and academic literature support the hypothesis that technology has some substantial benefits to the broader economy. This paper focusses on information and communication technology, especially mobile phones. Information and communication technologies, including mobile phones raise productivity among economic agents in developing countries (Wamboye et. al., 2016a, 2015b). Equally important is that mobile phone proliferation provides access to micro financial services to underserved communities, who are then economically empowered when they use cell phones to get access to basic financial services (Suri and Jack, 2016). In this light, mobile phones can add to broader financial inclusion and lift people out of poverty as well as raise incomes. Other than financial inclusion, mobile phone technology can have an impact on the economy by boosting agricultural outcomes in developing countries (Zanello, 2012; Jensen 2007). Mobile phones can be used to access essential market information such as prices and improve efficiency. This boots agricultural outcomes, which then add to aggregate output in the economy. Information and communication technologies also have the capacity to empower women at the micro level (Suri and Jack, 2016; Addai, 2017). Women can become more get more autonomy in the household by using mobile phones, which make them more economically productive. On top of that, information and communication technology development is inherently capital intensive, meaning that mobile phone proliferation can boost physical capital accumulation in developing

countries (Andrianaivo and Kpodar, 2012). Development of mobile technology infrastructure require large investments in information technology hardware, which can be diffused and used to raise productivity in other sectors as well. Perhaps most important of all, with respect to low-income countries, is that mobile phone proliferation has "dramatic" effects on the real economy. These dramatic effects can be explained by the concept of increasing returns to scale or network effects (Aker and Mbiti, 2010; Gruber and Pantelis, 2011; Wamboye et. al., 2016a, 2015b). For instance, in rural Africa, mobile phones reduce information search costs, risk; encourage generation of employment; and improve coordination among firms. However, there are also some opportunity costs involved with mobile phone proliferation in low-income countries Heeks (1999). These are discussed in detail in the literature review section of this paper.

The purpose of this paper is to assess the impact of mobile phone proliferation on productivity in low-income countries. I answer the question of whether mobile phones do increase productivity in developing countries using OLS panel regression analysis. I assess the impact of mobile phone technology on productivity (output per capita) in a sample of 73 Sub-Saharan African, Latin American and Carribean countries over the period 2000–2016. Doing this adds to the existing body of literature that supports the idea of adopting the relatively cheaper and more accessible mobile phone technology while also critiquing previous studies on the topic. As already stated, technology adoption boosts economic outcomes in low-income countries. But this low-income status may mean countries may not able to adopt high value-added technologies typically found in industrialized or developed countries. As such, this paper provides basis for encouraging more adoption of the cheaper and more accessible mobile phone technologies, which provide also raise productivity. This implies that low-income countries can leapfrog the relatively costlier technologies of the industrialized world.

The contributions of this work are that while I largely replicate Wamboye et. al. (2016a, 2015b) panel regression model for the control indicators, I also add another control variable to indicate the ease of conducting business in low-income countries. This is important in that without a conducive business environment, mobile phone technology adoption may be futile in low-income countries. For instance, if one gets access to market information via a mobile phone device, it may not help if there are regulatory constraints that hinder use of this information. Unlike Wamboye et. al. (2016a, 2015b); who combine and use the sum of several information and communication technologies indicators as the main independent variable, I treat my independent variables separately. I then also add quadratic terms to these variables to reflect increasing returns or network effects. Wamboye et. al. (2016a, 2015b) measure productivity as real output per worker growth whereas I assess the impact of mobile phone proliferation on real output per person. The work of Wamboye et. al. (2016) has been identified as the basis for building the preliminary regression model for this project. Wamboye et. al. (2016) study is based on data from 43 Sub-Saharan African countries. The authors find that doubling the penetration rate of fixed and mobile-cellular telephones boost labor productivity growth by about 0. 12–0.15 per cent, and 0.05 per cent, respectively. The results prove financial inclusion as one of the possible channels through which mobile phone proliferation enhances labor productivity growth in sub-Saharan Africa (Wamboye et. al., 2016). From these findings, questions arise pertaining to what rates of proliferation are necessary for significant additions to economic growth for the countries in question. Also following up on these findings, there needs to be more clarity with respect to other channels through which mobile phones spur economic growth. These issues are discussed further in the subsections below.

My results are robust and consistent with previous studies. I find that an increase in mobile phone penetration in low income countries by 1 percent adds to per capita output by 2.6 percent, proving that networks effects are indeed present. Also, my contribution to existing literature also seems robust and valid based on these results. The ease of doing business matters in that I find an inverse relationship between number of days required to legally start operating a business and output per person.

The rest of this paper is structured into the following sections: Section 2 and its subsections review literature and emphasize the various channels in which mobile phone proliferations adds to productivity in low-income countries. Section 3 and 4 discuss capital accumulation potential as well as opportunity costs associated with mobile phone proliferation in developing countries respectively. Section 5 discusses the data, choice of variables and the econometric model. Section 6 discusses the results of this study. Section 7 concludes with potential implications of these findings and a discussion on future research opportunities.

2. Literature Review

Channels for Economic Impact

2.1 Financial Inclusion

Perhaps the most acknowledged channel for realizing the benefits of mobile phone usage in developing countries is financial inclusion. Financial inclusion is defined by the World Bank as access to useful and affordable financial products that satisfy daily needs such as processing payments, transactions, savings, credit, insurances, and so on. These must of course be delivered in a secure and sustainable way. The World Bank reports that around two billion people worldwide do not use formal financial services and more than half of adults in the poorest households are

unbanked (World Bank, 2018). And yet, financial inclusion has the potential to significantly reduce poverty and improve prosperity. For this reason, the Bank would like to see universal financial access (UFA) by 2020. Mobile phones, with their capacity to house mobile financial service applications, are one affordable way of bringing into the financial market households that were previously financially excluded.

One article from *The Economist* mentions discusses how mobile phones spur innovation and boost incomes (Economist, 2016). Farmers can use them to obtain essential market information such as prices before selling to the middlemen. Mobile phones also reduce transaction costs in that they can facility payments in mobile money, which is more secure and reliable that traditional systems. For instance, after gaining access to M-Pesa, ("M" for mobile and "Pesa" for money) Kenya's mobile-money service, approximately 2 percent of Kenyan households were lifted out of poverty between 2008 and 2014. M-Pesa has been widely acknowledged as a successful tool in achieving greater financial inclusion, one of the numerous channels through which mobile phones spur growth in underserved communities. Financial inclusion has very high potential to raise incomes and improve living standards. This article mentioned above provides a basis for expecting a positive relationship between the dependent and main independent variables used in my panel regression analysis. Here, the academic dilemma is as follows: is mobile phone usage correlated with productivity growth or financial inclusion correlated with growth? According to the work of Wamboye et. al. (2016), mobile phone penetration has a positive effect on economic growth, controlling for financial inclusion.

Although many people in the developing world, particularly Africa, do not have access to formal bank accounts that are known for security and reliability, a growing number are now using mobile phones as alternatives to traditional systems (Kunt and Klepper, 2012). There is a

significant rise in the use mobile money services, also known as "branchless banking," which has allowed millions to perform various economic transactions affordably and reliably as well. In sub-Saharan Africa, mobile money has made the most progress. It is reported that just under 20 percent of adults use a mobile phone to pay bills or send or receive money, thereby enhancing economic activity (Kunt and Klepper, 2012). Mobile phones allow transactions to happen faster and more efficiently in these underserved parts of the world compared to when they are not adopted. In Kenya specifically, where the M-PESA service was commercially launched in 2007, 68% of adults report using such mobile money platforms and when looking at Africa at large, more than 20% of adults report using mobile money (Kunt and Klepper, 2012). If such huge parts of the population are using mobile phones for financial services at such rates, then they are indeed adding to economic growth by harnessing the efficiencies associated with using mobile technology.

To confirm that mobile-cellular subscriptions indeed influence economic growth through financial inclusion, Andrianaivo and Kpodar (2012) do a panel study of 44 African countries from 1988 to 2007. This study analyzes the impact of mobile phone penetration on economic growth rates in Africa by adding to the regression model an indicator for financial inclusion. The authors find that mobile phone penetration indeed contributes to economic growth in Africa. Specifically, an additional 10 percent increase in penetration rate results in 0.6 percent increase in real GDP growth. Here, the dependent variable is real GDP growth unlike Wamboye et. al. (2016) who measure labor productivity growth. Nonetheless, the results are consistent with expected findings. Bringing to light the role of financial inclusion to this growth, they find that the coefficients of its indicators; measured as the number of deposits per head and the number of loans per head, are positive and significant. This means that greater financial inclusion, made possible by improved mobile penetration, results in economic growth in African economies.

While Andrianaivo and Kpodar (2012) make a major addition to their regression model to test whether financial inclusion is one of the channels in which mobile phone development stimulates economic growth, their approach is not perfect. They add to their economic growth model a variable of financial inclusion measured by either number of loans or deposits per head. However, this might give a limited view of the extent of which financial inclusion is impactful. A measure based on these two metrics alone, as Sarma (2015) argues, "effectively quantifies only one [or two] aspects of financial inclusion...and ignores other aspects, such as availability, affordability, quality and usage." This necessitates an alternative, more comprehensive approach. That is why Sarma (2015) propose an index of financial inclusion (IFI) - a comprehensive, meaningful, and mathematically robust measure comprising of quantifiable dimensions of an inclusive financial system. This suggestion can result in more improved findings than in earlier studies, which either used limited measures of financial inclusion like Andrianaivo and Kpodar (2012) or did not include it at all in the economic growth model with respect to mobile phone Despite these concerns, there is enough evidence to suggest that financial inclusion is one important avenue in which mobile phones can spur growth in developing countries. While literature currently does not yet give an assertive voice when it comes the necessary penetration rates such that increasing returns occur, mobile phones can ensure financial inclusion for those that would have otherwise not had access to basic transaction account services. This is especially important at a time when The World Bank strongly emphasizes broader financial inclusion because of its capacity to raise incomes and end poverty. Mobile phones are relatively affordable and accessible to more and more users in developing countries. They are a proven platform to ensure this desired broader financial inclusion.

2.2 Agriculture

Many developing countries rely on the agricultural sector for economic growth objectives. The developmental state model adopted by the "miracle economies" of East Asia in the latter half of the 20th Century shows this phenomenon. The trend was typically as follows: gain independence from colonizer, redistribute land to economically empower the masses, then use surpluses from agriculture to invest in the industrial sector – thereby achieving a "miraculous" path towards economic growth and development. This trend was also observed in some African countries who attained independence a while later, suggesting that the agricultural sector, when productive enough, can be the basis on which an economy thrives. At the same time, it is conventional wisdom that technology has the power to boost agricultural outcomes. Mobile phone technology, in particular, has been proven to enhance agricultural activities and yields in developing countries (Zanello, 2012). Therefore, by improving agricultural outcomes, holding all else constant, mobile phones can add to the economic growth of developing countries.

In Zanello's (2012) study, the authors focus on Northern Ghana's agricultural regions to examine the impact of information communication technologies (mobile phones and radios in this case) on economic transactions and participation in food crop markets. They do this using agricultural season 2008 to 2009 survey data from 393 households in the region. The authors use a multi-stage sampling procedure with various categories based on the respondent's primary role in the market: "buyes, net-buyers, sellers, net-sellers, autarchies (non-traders)" (Zanello, 2012). The collected data are used to build a probit model to indicate the impact on net-sellers and net-buyers. They find that households that receive price information via mobile phones are significantly more active in the market despite being smallholders with either deficit or surplus of

food. On top of that, farmers that rely on mobile phones for information are more likely to see reductions in search costs – thereby maximizing profits.

However, while Zanello (2012) gives evidence for the economic advantages of using mobile phone technology in the agricultural sector of one country, the scale of the study seems too small to support the thesis of this paper. Zanello (2012) focuses on micro-level analysis – only survey data for one agricultural season for one developing country, Ghana. A more comprehensive study could look at more than one geographical location and or for a longer period of time to see if there are robust trends or patterns. Other than that, a comment must be made about the author's choice to aggregate and treat different kinds of crop (grain and legumes) as single output. This is done to make it easier to separate overall selling costs from transaction costs, thereby identifying areas for value addition by mobile phones. But while treating different kinds of crop as single output is intended to make calculations easier, the results may not be reliable. It may make it hard to determine with precision the markets that are more responsive to mobile phone development than others. Perhaps maintaining the integrity of the crop in calculations may give a more nuanced view of the association between agricultural output and mobile technology proliferation.

Even in India, information and communication technology penetration has improved agricultural outcomes (Jensen, 2007). Using micro-level survey data between 1997 and 2001, the author finds that adoption of mobile phones by fishermen and wholesalers in India's fishing industry is associated with "dramatic" reductions in price dispersion in the market. Price dispersion is problematic because it can result in misallocation of resources due to information asymmetry. Besides the dramatic reduction in price dispersion, mobile phone adoption in the region of study is also associated with the complete elimination of waste and almost perfect adherence to the Law of One Price (Jensen, 2007). The Law of One Price states that the price of a commodity is the same

even when exchange rates are considered. When this happens, the market is efficient. This shows the potential impact of information and communication technology growth on agriculture in developing countries. Based on this study, there are observable and clear welfare gains experienced in the marketplace due to mobile phone adoption. This is because mobile phones reduce cost of accessing critical market information that allows users to make rational decisions, which will then ultimately translate into economic growth and development.

However, Jensen's (2007) study was based on mobile phone adoption that happened in a series of stages or phases in the region of study. This could be problematic in that in practice, mobile phone proliferation does not typically happen in stages. Proliferation is as continuous as it is random. Perhaps a more strategic method would involve a randomized assessment of the rate of mobile phone adoption. While the author seems to acknowledge this concern about the methodology, the response may still leave the reader doubting the robustness of the study. The author mentions that nonrandom nature of mobile phone adoption in this region is not much of a concern given how they "do not see any differential trends, or large changes in the price series at any points in time other than when phones were introduced..." (Jensen, 2007). The assumption behind this claim is that there were no other observable factors contributing to price changes with increase in mobile phone adoption. But what if there may have been other factors affecting price changes that they may have overlooked?

Nonetheless, there is enough evidence to give the author some benefit of the doubt for attempting to address this concern. There is even more than enough evidence to show the economic benefits of mobile phone adoption. These information access and cost reduction benefits observed in the agricultural sector in developing countries are largely due to network effects. The network effects or increasing returns phenomenon is discussed below.

2.3 Network effects

The answer to why mobile phone proliferation seems to have such a "dramatic" impact on economic growth and development in low-income countries lies in network effects Aker and Mbiti (2010). Aker and Mbiti (2010) find that the increase in mobile phone usage can have "dramatic" effects on the economy, especially in rural Africa in it that reduces information search costs, risk, generates of employment, and improves coordination among firms. These advantages of mobile phone usage can have a significant impact on the economy. For instance, in most of rural Africa in the case of emergency or any other shocks to the market, it is assumed that kinship plays a role in the manner in which responses to these events are carried out. This may, however, be time-consuming and costly. Mobile phones provide a quick and cheap way of dispersing critical information in this case. Therefore, increased mobile phone usage is associated with positive welfare gains for these communities.

At the same time, without an explicit OLS method used for this study, the reader might be confused by Aker and Mbiti's approach in terms of specific relationships among the measures they chose to focus on. However, their study still suffices to show the nature of the relationship between mobile phone proliferation and economic development in low-income countries. It also gives the reader an opportunity to understand further the channels through which mobile phones are practically beneficial to low-income countries. In this context, mobile phones are not simply a communication tool, but have the potential to add to the broader economy.

In order to quantify and track these network effects, the work of Wamboye et. al. (2015) uses a different method: OLS panel regression model. Before discussing their numerical findings, the author argues that the social benefits of information and communication technology infrastructure and services outweigh the private benefits. When this happens, there are positive

externalities. The larger the number of people subscribed to a mobile cellular service, there more the information is shared and spread through the productivity-boosting mobile platforms related to agriculture, healthcare, financial services, and so on. One could think of positive externalities associated with mobile phone proliferation in terms of immunization. When more people are immunized for a particular disease in society, the lower the rate of infections. There will be lower medical treatment costs as well as reduced costs due to loss of life.

The sentiments expressed in this by Wamboye et. al. (2015) echo Acker and Mbiti (2010) discussion of network effects. The observed increasing returns to real output per worker can be explained by these network effects. Wamboye et. al. (2015) conduct a panel study of 43 Sub-Saharan African countries between 1975 and 2010 to examine the impact of information and communication technologies on labor productivity and growth. Besides including a quadratic function, the authors also use a nonparametric model to show and determine the specific thresholds for these network effects. They find, consistent with other studies, that fixed-line and mobile telecommunications have a positive and significant impact on growth after penetration rates reach a certain critical mass. Specifically, penetrations rates of between 20% and 30% for telephones and 5% for internet usage result in increasing returns on real output per worker. The author writes that in particular, an increase by 10 percent in the penetration rate of fixed-line telephones lowers productivity growth by approximately 3.17%-3.42% annually over the subsequent 3 years. Doubling that rate to 20 percentage points increases growth by roughly 0.12%-0.15%. These increasing return effects on labor productivity growth are also observed when the measure of information and communication technologies is expressed as the sum of the mobile cellular and fixed-line telephone subscriptions. These numerical findings give more weight to the value of

Acker and Mbiti's (2010) study, which contains no OLS regression but some rather limited descriptive statistics.

These network effects are observed on a larger scale by the work of Gruber and Pantelis (2011). In this study, the authors use annual data from a sample of 192 countries over the period 1990 to 2007 to assess the impact of mobile telecommunications on economic growth. Gruber and Pantelis (2011) use simultaneous equations to formulate a model, which links national aggregate economic output to a set of production factors in each country - in particular the stock of capital, labor, and the stock of mobile and fixed telecommunications infrastructure. This is done to account for reverse causality concerns. Just like Wamboye et. al. (2015), Gruber and Pantelis (2011) also find that once the level around 30% penetration has been achieved, economies earn a lot more from the same infrastructure compared to their previous returns, providing evidence from increasing returns from mobile phone adoption.

As shown, these two studies provide an explanation for the existence of network effects, despite their differences in methodology. From the onset, Wamboye et. al. (2015) use real output per worker on the LHS of their model while Gruber and Pantelis (2011) use real output of the country as a function of capital, labor, and telecommunications infrastructure to deal with causality concerns. Gruber and Pantelis (2011) assess a larger sample of countries and assess the economic impact of mobile technologies based on countries' income level. But even with a larger sample size, Gruber and Pantelis's (2011) methodology to analyze network effects seems misplaced. They create three dummy variables to indicate low, medium, and high mobile penetration levels. The rational here is that throughout their period of study (1990 – 2007), most countries started either at zero or slightly above mobile penetration. Countries then moved to high penetration rates at different speeds. The authors, then, divide their sample into three equal groups of 320 mobile

penetrations observations each: 0 to 5 percent, 5 to 30 percent, and lastly 30 percent and more. This raises a few concerns. First, the range of these dummy variables is different across the three groups. The reader can get easily confused about the choice of these ranges since the authors offer no explanation about how they came to be. Also, in response to Gruber and Pantelis's (2011) paper, one economist (Mayer, 2011) writes, "it does not seem totally implausible that the within variance [of the dummy variables] is much smaller in and medium categories, potentially explaining the difference in coefficients, which should be standardized in one way or the other." These concerns give good reason why we should not accept these critical mass (network effects) results at face value. The percent penetration rates are easy to understand as a measure of proliferation – simply usage expressed in association with population size of the country. But having equal observations in three clusters of different ranges of penetration is difficult to grapple with at this point.

Even when a distinction is made in terms of where a country falls on the low-to-high-income spectrum, different results should be expected with respect to increase in information and communications technology development. Particularly: “impact is smaller for countries with a low mobile penetration, usually low-income countries. While in low-income countries the mobile telecommunications contribution to annual GDP growth is 0.11%, for high-income countries this is 0.20%” (Gruber and Pantelis, 2011). Another study also shows similar results. Meijers (2013) assesses the relationship between internet use and economic growth between high and low-income countries. Given that recent cross-country panel data studies find a positive impact of internet use on economic growth and a positive impact of internet use on trade, the author challenges current models that prove that internet use is associated with economic growth in a fully specified model. Instead, internet use impacts trade, and then trade impacts economic growth. Therefore, the author presents a simultaneous equations model to show this phenomenon. The model shows that internet

use is more impactful on trade in lower-income countries compared to high income countries. At the same time, impact of internet use on economic growth is the same for both kinds of countries.

Results based on country's income level can be linked to the network effects (increasing returns) concept. Low-income countries show "dramatic" returns on productivity from smaller proportionate increases in mobile proliferation. High-income countries show relatively higher returns on real output growth (and not productivity) over time. The implications are that low-income countries should aim for specific (critical) levels of proliferation in order to experience higher levels of real output growth over time.

2.4 Women empowerment

The observed effective critical mass results confirm that the size of the network matters. However, it is not only the size of the network that matters. It is also important to consider who participates within the network. It is important to note that there are 300 million fewer women globally than men who own mobile devices (West, 2012). Globally, there is a 21 percent gender gap in owning a phone. When looking at specific parts of the world, there are some disparities: 23 percent in Africa, 24 percent in the Middle East, and 37 percent in Asia. Women where such disparities exist do not have the same opportunities as their male counterparts in different aspects of life. They quite often do not enjoy the same legal and economic advantages that help men thrive in their business endeavors. Information and communications technology development and adoption helps solve this problem as found by West (2012). Information and communication technologies help train female students to become entrepreneurs. On top of that, the survey done by the Development Fund found out that 55 percent of women around the world earned extra income because of owning a mobile cellular device. More than 40 percent increased their income

and got the opportunity to engage in other professional opportunities. This shows that mobile phone technologies enable women and other disadvantaged groups access to markets; suppliers, customers, and other critical resources which could otherwise require physical transport. They therefore provide access to resources and markets free of discriminatory gender biases. Women can become more autonomous entities in the household by making use of these opportunities availed to them by the relatively more accessible and cheaper mobile phones compared to traditional financial institutions for instance.

Suri and Jack (2016) explore the economic benefits of using M-PESA, a mobile phone financial services platform in Kenya. They find that mobile phone usage provides access to basic financial services to households that would otherwise be financially excluded. The survey they carried out over several years shows that usage lifted about two percent of the population out of poverty together with improving women empowerment. The expansion of M-PESA (M is for mobile and *pesa* is the Swahili word for money) was particularly beneficial to women, who through the new system gained access to a new way of sending and receiving money. They observed that when M-PESA came to an area, women shifted their occupations and their savings increased as well. About 185,000 women shifted occupations from subsistence farming to business or retail sales, shifting to more sustainable sources of living. Mobile money has therefore increased the efficiency of the spending and consumption patterns and, at the same time, facilitating more improved labor markets, resulting in a significant reduction of poverty in Kenya. This evidence shows that mobile phones give women more autonomy in the household. Mobile phone usage adds to economic growth because it empowers women who would otherwise not participate in economic activity as suggested by the findings in Kenya by Jack and Suri (2016).

A separate study in Ghana found almost similar results: there is a significant positive relationship between the microfinance provided through mobile phones and women empowerment, suggesting that financial inclusion has both economic and social benefits for women (Addai, 2017). Addai (2017) uses purposive non-probability sampling technique with a sample size of 500 microfinance customers from Ashanti, Greater Accra, Central, Eastern and Western Regions of Ghana (100 from each region). In this study, structured questionnaires are used to understand better the livelihood of these women with respect to financial services. They find that both age and level of education influence whether more micro-financial services lead to improved economic empowerment of women. On the other hand, the dummy variable; marital status also matters in that married women are less likely to be economically empowered from microfinance. However, such a small sample size in the work of Addai (2017) may be inadequate to see the fundamental associations between mobile phone adoption and empowerment of women.

These findings suggest that although financial inclusion has the potential to make women more economically active, and thereby contribute to the economic growth of their communities, it cannot be impactful due to some cultural values or beliefs which limit women's participation in the economy. In some societies today, women are still not considered as equal to men in the household. As a result, some women get left behind when it comes to service provision. Ultimately, these communities lose out by excluding women in accessing financial services that promote economic growth. As a solution, in order to fully harness the productive potential of financial inclusion in developing communities, there needs to be a paradigm shift such that women have access to the same services as men. Particularly, service providers could hold workshops in communities where women are underrepresented so as to educate all members on the benefits of having everyone have equal access to financial products and services. If the excuse is that some

women do not have access because they cannot afford mobile connection devices, then service provides can subsidize them to encourage usage.

3. Capital Accumulation

Mobile phone and internet proliferation is associated with increase in capital accumulation in that the information and communication technology sector is inherently capital intensive (Andrianaivo and Kpodar, 2012). At the same time, there are opportunities for "diffusion" of technologies needed in the provision of mobile phone services. For instance, establishing a mobile phone network requires large investments in computer and other information technology hardware, communications software and equipment. Therefore, investment in mobile phone technology could be one way in which developing countries may speed up their rate of overall technology adoption. Nonetheless, mobile phone proliferation can also add to physical capital accumulation in that a strong information and technology infrastructure may encourage foreign direct investment (Andrianaivo and Kpodar, 2012). More foreign direct investments in turn result higher in physical capital accumulation, which is necessary for economic growth in developing countries.

However, not all capital accumulation leads to growth. Andrianaivo and Kpodar (2012) acknowledge that mobile phone proliferation can also lead to faster depreciation of capital. This is because investments are directed more towards information technology equipment, which inherently depreciates at fast rates. In such a case, capital accumulation may negatively impact economic growth and productivity. Even beyond this argument, King and Levine (1993) present a different way of measuring economic growth to emphasize that not all capital accumulation is good for growth. King and Levine (1993) use a production function with predetermined parameters; decomposing the measure for economic growth to show a separation between rate of

physical capital accumulation, and rate of growth of "everything else." This separation ensures that analysts get a better understanding of the effect of capital accumulation on productivity and growth.

4. Opportunity Costs

There are also opportunity costs associated with mobile phone proliferation in developing countries (Heeks, 1999). Developing countries lag when it comes to provision of other services such as electricity and education. When such services are lacking, internet and mobile technology may reach only a few people. If the population is largely illiterate, and there is inadequate power supply needed to support information and communication technologies, then only a few can benefit from these mobile phone service investments. This is because users need to be literate and have some level of intellectual capacity to such that usage of mobile technologies is economically productive. This is consistent with the findings of Addai (2017) regarding women empowerment. At the same time, one could also view the opportunity cost of investment in mobile phone proliferation as investments in electricity supply and education provision. While this is an interesting perspective, one should keep in mind the respective weights or share of gross domestic product of what these investments in these sectors are. This will give more clarity in assessing whether investments in mobile phone proliferation come in the way developments of other sectors.

Heeks (1999) also suggests that even if sectors like education and electricity provision are improved in developing countries, the poor still face challenges in harnessing the potential of information and communication technology proliferation. This is because these technologies require money to buy, access, use, and maintain them. For instance, one needs money to buy a mobile phone and then money to pay for cellular services as well. This again will make only a few

be able to benefit from mobile phone proliferation. Taken from the opportunity cost stand point, large investments in information and technology infrastructure may result in small investments in poverty alleviation programs. Also, money used to buy mobile phones and to pay for cellular services may be otherwise used to purchase food. At the time when Heeks published his study, there probably was good reason to believe that there was this opportunity cost indeed. This is because the more recent works of Suri and Jack (2016) do not reflect these opportunity costs. Suri and Jack (2016) provide evidence that mobile phone proliferation can lift the poor out of poverty. This of course happens through mobile financial service platforms such as M-PESA, as already highlighted above. The poverty alleviation effects of mobile phone proliferation are also guaranteed by women empowerment. Women who would be economically unproductive in the absence of mobile phone technology become empowered in the entrepreneurial sense and ultimately add to increase in household income. This implies that there is no opportunity cost of mobile phone proliferation in terms of poverty alleviation efforts. The other possibility is that there is no need of lifting people out of poverty first to benefit from information and communication technology growth.

5. Data, Variables, and Model

For my panel regression analysis, I formulate two panel equations below such that I experiment and analyze results in these different situations or combination of variables. The precise distinction between the two models is that one is linear while the other is quadratic. The choice of the variables is largely based on the work of Wamboye (2016) as well as from other studies discussed above. All data come from the World Bank Development Indicators and Doing

Business databases. Using data from 73 countries over the period 2000-2016, the goal is to see whether mobile phone proliferation leads to higher productivity in developing countries.

Definition and Discussion of Variables:

Y_{it} is the natural log of GDP per capita in country *i* over time *t,* which is gross domestic product divided by midyear population of the country. This is the dependent variable of the model on the left-hand side of the panel regression model (equation). This economic indicator is not largely different from Wamboye et. al. (2016), who use the natural log of real output per worker growth (three-year averaged) in country *i* over time *t.* Wamboye et. al. (2016) focus on labor productivity outcomes while I use real output per person. Essentially, these two seemingly different variables indicate the same thing: productivity.

On the right-hand side, the main independent variable is *Penrate. Penrate* is the rate of mobile phone penetration in a country. This is expressed as the number of active mobile subscriptions to a public cellular service provider divided by the midyear population of the country. After *Penrate*, *Broadband* represents the fixed broadband subscriptions (per 100 people) in the country. Higher access to broadband or wired internet in general means that communication necessary for flow of information among economic agents is increasing and this in turn should boost economic activity and growth. *Penrate* and *Broadband* are good indicators of the extent of general technological adoption and development in these developing countries. Wamboye et. al. (2016) have their main independent variable as a measure that includes three "technology adoption variables": fixed telephone subscriptions, mobile-cellular subscriptions, and internet users. For this study, I treat *Penrate* and *Broadband* separately due to data constraints. However, just like

Wamboye et. al. (2016), and consistent with other previous literature, I also add a quadratic term for *Penrate,* taking network effects into account.

The other non-technological control variables are *G*, *FDI*, *I*, *DTSB*, *Edu*, and *Open*. *G* represents the government final consumption expenditure expressed as percentage of the country's gross domestic product. According to Wamboye et. al. (2016), high budget deficits are problematic because they negatively impact capital accumulation and productivity. At the same time, government spending can be used to stimulate output and growth during economic downturns. As long as intervention is not politically motivated or leads to corruption or other non-economic activities, government spending can have a positive impact on long-run productivity growth. This makes the case for why *G* is also included in my model. While Wamboye et. al. (2016) expect *G* to either add or diminish labor productivity growth, I assess *G*'s impact on per capita income over time.

Next to *G* is the variable *I* which is a measure of gross capital formation (formally known as domestic investment according to the World Bank), expressed as a percentage of gross domestic product. The longer definition for *I* includes "Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchase; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings..."(World Bank, 2018). *I* therefore is a comprehensive measure of physical capital accumulation, which also adds to economic growth. Literature and economic theory supports the thesis that high savings and investment rates are a prerequisite for rapid economic growth (Meijers, 2014). Developing (low-income) countries that can save and invest more should see relatively more economic growth those that do otherwise, holding all else constant.

FDI is net inflows of foreign direct investment in the country, also expressed as a percentage of gross domestic product like *G* and *FDI*. Long-term private international capital flows (*FDI*) can strengthen domestic productivity (Wamboye et. al., 2016). This is because *FDI* allows or contributes to skills and knowledge transfer, employment creation, and export led growth, among other benefits. There are efficiency gains associated with the rapid adoption of technology that happens when foreign direct investments flow into the country. I assume that all these advantages ultimately lead to per capita income increase.

My contribution to literature, *DTSB* (days to start a business) is the time required to legally start operating a business in a country. The variable is expressed as the actual number of business days needed to begin operations, which is just one of the many other measures that indicate the ease of doing business in a country. The ease of conducting business or productive economic activity in an economy also affects the rate at which economies grow and develop. For this analysis, the indicator used to reflect this easiness is *DTSB*. A high number of DTSB may also discourage foreign direct investments, which are crucial for the rapid growth and development of low-income countries. According to Djankov et al. (2006), business regulations have a significant impact on annual economic growth. Djankov et al. (2006) assess business regulations in 135 countries and find that improving from the worst quartile to the best quartile can translate into 2.3 percent increase in annual growth. Typically, developing (low-income) countries score lower in terms of measures that indicate the ease of "doing business" compared to their developed counterparts. Given that the results of Djankov et al.'s (2016) study are significant even when controlling for other factors such as trade and investments, developing countries could experience higher rates of growth and productivity by establishing business friendly regulations and or

environments. I use the same World Bank Doing Business database as Djankov et al. (2006) to obtain data on *DTSB*.

Edu is the *g*ross enrollment ratio in tertiary education regardless of age, to the population of the age group that corresponds to the level of education shown. Educational attainment influences how attractive the human capital base is in a country (Wamboye et. al., 2016). Countries with high levels of education and or human capital can attract more foreign investment, holding all else constant. High human capital levels imply that the economically active can learn foreign concepts, skills, and technologies, which they can translate into domestic innovations. Assuming that the higher the level of education attained, the more attractive is the country to foreign direct investment, I use tertiary education whereas Wamboye et. al. (2016) use primary education. Meijers (2014) uses secondary school enrollment (% gross) while focusing on internet use (proliferation) and not mobile phone penetration.

Open is a measure of the openness to trade of the country. Openness to trade is also generally accepted as a way in which developing countries can achieve faster growth. Trade with other countries encourages competition and innovation necessary for development. Developing countries also benefit from international trade in that they can access and adopt certain successful technologies and processes used abroad. But just as with government spending, not all international trade is beneficial due to the infant industry/protectionist argument. Meijers (2014) have their openness to trade variable as openness ratio trade as a percentage of GDP defined as: imports plus exports of goods and services (% gdp). In my model, the variable is expressed as only as taxes on imports as a percentage of gross domestic product due to data limitations. The assumption here is that the higher the tax on imports revenue is as a percentage of gross domestic

product, the more open to trade the country is. And based on Wamboye et. al. (2016a; 2016b), this is good for economic growth purposes, especially when using East Asia as a case study.

With these variables, I construct two panel regression models as shown below: Equation (1) is a linear model testing whether mobile phone proliferation has any impact on economic growth in low-income countries. Equation (2) is a non-linear expression with similar variables as the first model.

Linear model:

$$Y_{it} = \beta_0 + \beta_1 Penrate_{it} + \beta_2 Broadband_{it} + \beta_3 G_{it} + \beta_4 I_{it} + \beta_5 FDI_{it} + \beta_6 Edu_{it} + \beta_7 Open_{it} + \beta_8 DTSB_{it} + \varepsilon_{it}$$

Non-linear model:

$$Y_{it} = \beta_0 + \beta_1 Penrate_{it} + \beta_2 Penrate_{it}^2 + \beta_3 Broadband_{it} + \beta_4 Broadband_{it}^2 + \beta_5 G_{it} + \beta_6 I_{it} + \beta_7 FDI_{it} + \beta_8 Edu_{it} + \beta_9 Open_{it} + \beta_{10} DTSB_{it} + \varepsilon_{it}$$

Expected Signs of Regression Coefficients

Based on the work of Wamboye et.al. (2016), holding all else constant, I expect to find a positive sign between the dependent variable *Y* and independent variable *Penrate* both the linear and the non-linear models. As discussed above, an increase in mobile phone proliferation should add to per capita gross domestic product. In the non-linear model however, where *Penrate* is raised to the second power, I expect to see a negative sign behind $Penrate^2$ to reflect increasing returns (network effects) to the economic growth variable of the model. Graphically, the non-linear model would be n-shaped and shows these network effects.

As for the independent variables, in both the linear and quadratic models, I expect to see a positive relationship between *Y* and *Broadband* as more access to fixed or wired internet should have a similar effect on growth as *Penrate*, in both models. The main assumption here is: generally, developing countries benefit from an increase in having access to more information and telecommunications services, which include mobile cellular and fixed or wired internet technologies.

For reasons already discussed above, the expected sign for government spending on final consumption as percentage of gross domestic product (*G*) is hard to predict without running the regression first. The aggregate macro-economic output equation contains government spending in the economy, suggesting that more government spending in developing countries should boost economic growth. However, not all government spending adds to growth. For this reason, I use the results of the regression to formulate informed policy implications with respect to government spending.

The expected sign for *I* (the indicator for overall domestic investment) is positive. The expected sign for *FDI* is positive. As already discussed, foreign and domestic investments add to the economic growth and development of low-income countries.

It is also not unreasonable to expect a positive sign for the variable *Edu.* Just as they rely on physical capital to meet growth objectives, developing countries need a strong human capital base for the same reason. However, Wamboye et. al. (2016) argue that it is hard to also predict the sign for *Edu.* Therefore, results from the regression are also used to formulate recommendations with respect to educational attainment.

For my model, the expected sign for the variable that indicates openness to trade is not predicted. This is because "while the success stories from the export-led growth of East Asian

economies lend some support to the beneficial effects of trade openness...most sub-Saharan African countries are net importers...their export sectors are characterized by primary commodity production and agriculture-based manufacturing, with potentially neutral or detrimental effects on productivity growth" (Wamboye et. al., 2016). This means that if the same assumption is extended to Latin America and the Carribean (low-income countries), I have good reason to expect either a negative or positive sign for *Open* regression coefficient. Also, when it comes to trade openness, if *Open* does not add to per capita output increase, that is if the coefficient happens to be negative based on results, then one possible explanation why this may be the case is the infant industry (protectionist) argument. It could be that these developing countries mostly engage in trade that hurts emerging domestic industries, which are not yet mature enough to compete on the global scale. Another reason why engaging in foreign trade may not be necessarily adding to growth is that these developing countries may be producing low-value added goods and services, which do not bring back significant domestic economic gains.

Lastly, the expected sign for *DTSB* is negative because based on the definition of this variable, a higher number of days needed to legally start conducting business should slow down economic activity and growth.

Robustness Checks

For this analysis I check for multicollinearity for the linear model and all variables have a variance inflation factor (VIF) of less than 5. With a mean VIF of less 1.8 (see Table 1 below), the degree of multicollinearity among variables is minimal, giving no reason to drop any variables. Given that I conduct a panel regression analysis, I also run the Hausman Test to see whether I should pick the random effects or fixed effects model. Based on the Hausman Test, the p-value (0.0001) implies that the random effects and fixed effects coefficients of my analysis are not

necessarily similar. Therefore, the null hypothesis is rejected such that I pick the fixed effects model for analysis and discussion. This is of course the non-liner (quadratic) model that shows the network effects as already discussed above.

Also, to correct for autocorrelation, STATA drops the variable *I* in both OLS regressions used in my study.

Overall, the model does seem robust. The R-squared value of 57 percent in the quadratic model shows slightly above half of the observed variance in the dependent variable can be explained by the independent variables in the quadratic model. At this level, there is further proof that there is minimal autocorrelation in the model. See Table 1 in the Appendix section for multicollinearity test results.

Summary Statistics: See Table 2 in Appendix

6. Regression results

Refer to Table 3 in Appendix: Assessing the impact of mobile phone proliferation on gdp per capita in Sub-Saharan Africa, Latin America and Caribbean (excluding high-income countries).

Discussion of Results

As shown, the results in Table 3 (refer to Appendix) seem to help in answering the research question. Based on these results, increase in mobile phone penetration leads to an increase in economic growth, which is consistent with literature. This is confirmed by the positive sign for the coefficient for *Penrate.* And based on my regression analysis, this variable is also statistically significant at the one percent level of confidence. Also consistent with previous studies is the finding that the nature of the increase in economic growth, when expressed as per capita income

growth, is such that it is somewhat exponential. Therefore, the coefficient for $Penrate^2$ is negative, reflecting the n-shaped nature of the model typical in relationships where increasing returns (network effects) are present. Holding all else constant, gross domestic product per capita will increase with increase in mobile penetration rate, but only to a certain point. Afterwards, further increases in penetration rate results in a decrease in gross domestic product per capita. The quadratic term for *Penrate* confirms network effects. Wamboye et. al. (2016) results show expected signs for the coefficient of fixed telephone plus mobile-cellular subscriptions. Their coefficients in the linear and quadratic terms confirm increasing returns to mobile-cellular telephones. Increasing the combined fixed-telephone and mobile-cellular penetration rate by 10 percent reduces productivity growth by 1.72–1.97 percent annually. When the rate is doubled, it adds to growth by 0.02 per cent. Andrianaivo and Kpodar (2011) did not find these increasing returns, citing that network effects are most likely present, but they could not be observed by the end of their sampling period. I also find presence of network effects in that, as shown in Table 1, an increase in *Penrate* by one percentage point results in gross domestic product per capita increase by 1.16 percentage points. Adding the quadratic terms shows that an increase in *Penrate* by one percent results in increase in output per capita by 2.6 percent. Both my and Wamboye et. al. (2016) results are statistically significant even at the one percent level of significance.

The coefficient for *Broadband* is also promising, despite being statistically insignificant in this analysis. *Broadband* coefficients confirm that more proliferation of information and communication technologies in developing countries is a key prerequisite for economic growth. *Broadband* coefficients in my study, however, are not statistically significant, not even at the 10 percent level of significance. Wamboye et. al. (2016) fixed broadband coefficients are statistically significant at the 5 percent level of significance.

While the variable *I* has been omitted to account for autocorrelation, the results also show expected signs for the other control variables *FDI*, *Edu*, *Open* and *DTSB*. Even though foreign direct investment is not statistically significant, how well educated a population is statistically robust, confirming the results of Addai (2017). These results are consistent with the Heeks (1999) argument that mobile technology adoption in developing countries requires an educated or literate user base, which can fully harness its growth-promoting potential. *Edu* also shows similar results as Wamboye et. al. (2016) who acknowledge that fruitful adoption of new technologies such as information and communication technologies, has in the past required a skilled workforce, or high levels of formal education. In my study, *Edu* measured as the gross enrollment ratio of tertiary education, shows significant results. Therefore, a well-educated population base will add to the human capital needed to meet economic objectives in developing countries.

In my study, *FDI* and Open, also known as the "technology transfer" indicators according to Wamboye et. al. (2016a; 2015b), have coefficients that are not robust enough to confirm that developing countries, on top of information and communications technology proliferation, rely on foreign investments and opening trade to experience economic growth. This is unlike Wamboye et. al. (2016a; 2015b) who find robust growth enhancing effects of these two variables across various model specifications in their analysis. For instance, a ten percent rise in foreign direct investments as a share of total gross domestic product boosts labor productivity growth by about 5 percent per year for the next three years (Wamboye et. al. 2016). My results show that an increase in mobile penetration rate by one percent boosts output per person by a proportionately smaller margin compared to the results of Wamboye et. al. (2016). The answer to these subtle differences lies in methodology.

It is not surprising, however, that based on this analysis, holding all else constant, there is an inverse relationship between government spending and per capita gross domestic product in developing countries. There could be quite a few explanations for the unexpected coefficient for *G*. One possible explanation is that government spending in developing countries may not necessarily be directed towards economically productive activities. There are large losses to real gross domestic product due to corruption. Wamboye et. al. (2016) cite that huge budget deficits can have a negative impact on productivity and capital accumulation. During periods of recession, government spending can be used to stimulate economic growth by boosting demand. But corruption and politically driven expenditure may hinder growth. In my model, government spending is statistically robust and may confirm the argument of high budget deficits in low-income countries. The sign and coefficient robustness are similar to Wamboye et. al. (2016) results as well.

The value-addition variable, *DTSB*, also shows promising results in my model. I obtain the expected negative sign based on Djankov et al. (2016) findings. Djankov et al. (2016) use several indicators from the Word Bank Doing Business database including measures for starting a business, hiring and firing, registration processes, access to credit, legal framework, and closing a business. In my model I focus only on starting a business, specifically the number of calendar days need to complete all necessary procedures before beginning operations. The negative coefficient confirms that the higher number of days needed, that is, the longer it takes before being legally established, affects the ease of doing business in the country. It is therefore within the best interest of developing countries to improve their regulatory and business environments, which can quickly attract investments necessary for growth.

7. Conclusion

This work adds to the growing body of literature supporting mobile phone usage in developing countries. Mobile phones do raise output per capita or productivity in low-income countries. I confirm presence of network effects with respect to mobile technology adoption. On top of that, I also contribute that the business environment (and or legal framework) matters in developing countries if they are to experience higher productivity. This paper emphasizes that mobile phones add to broader financial inclusion, better agricultural outcomes, and improved women empowerment. Perhaps the underlying reason why we see improvements in all these areas is the network effects associated with mobile phone penetration or usage.

Implications

My results imply that policy-makers in developing countries must make it easy for entrepreneurs and other adopters of mobile phones to conduct economically productive activities. This could be done through minimizing or opportunities to by-pass some of the requirements needed before one can legally start operating their entrepreneurial venture. Registrations fees must be as small as possible. All these and other measures may lead to improvements in the ease of doing business in a country. Given that there is also a chance that mobile phone technology developments add to physical capital accumulation, which is also necessary for productivity and growth, precaution must be taken. Adopters should take precaution by ensuring that they understand the nature of information and communication technologies infrastructure or hardware equipment, which depreciates quickly. Planners and policy-makers should ensure that structures are in place to guarantee overall long-lasting and high value add physical capital accumulation takes place. On top of that, at the macro-level, investments towards mobile phone proliferation must be done in a way that does not take away developments in others key sectors such as education, which also boost productivity. At the micro-level, expenditures on mobile phone

adoption and services must be moderate such that they do not take away from money spent of food and other essential services, especially for the poor. Realizing the productive potential mobile phone technology has on the poor, policy makers could structure poverty alleviation programs centered around usage of these services. For instance, poor subsistence farmers could be provided with mobile technologies and services at subsidized rates such that they raise their productivity, output, and ultimately incomes. This will enable them to beat the poverty trap.

Opportunities for Future Research

One of the opportunities for future research involves reverse causality. Here, the dilemma is as follows: does mobile phone adoption lead to higher output per capita or higher output per capita leads to higher mobile adoption? To account for reverse causality, the dependent variable in this study could be expressed as a function of capital, labor, and telecommunications infrastructure, consistent with Gruber and Pantelis (2011). Another opportunity is to perform by-country or by-region analysis such that one can compare and evaluate the impact of mobile phone proliferation in Africa, Latin America and Carribean separately.

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Appendix

Table 1: Multicollinearity test results

Variable	VIF	1/VIF
Broadband	2.34	0.426988
G	2.24	0.447209
I	2.15	0.465841
Penrate	1.90	0.526844
Edu	1.65	0.607436
DTSB	1.23	0.810699
Open	1.20	0.832330
FDI	1.19	0.842525

Mean VIF = 1.8

Table 2: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Y	1,210	11.2598	2.43961	4.89406	17.45252
Penrate	1,236	.5718945	1.231504	0	18.79081
Broadband	889	2.13652	3.845686	0	21.21013
G	1,210	4.728723	20.9247	0	286.9915
I	1,097	2.33e-14	2.85e-13	0	7.69e-12
FDI	1,206	1.802891	8.910707	-12.56733	131.9414
Edu	624	16.38925	18.38706	.33312	119.7787
Open	607	1993.688	12122.91	0	118512
DTSB	923	50.53478	73.60712	3	697.5

Table 3: Results on assessing the impact of mobile phone proliferation on gdp per capita in Sub-Saharan Africa, Latin America and Caribbean (excluding high-income countries).

	Linear Model	Quadratic Model
Dep Var Y		
Penrate	1.16*** (.26)	2.6*** (.72)
Penrate^2		-1.1** (.5)
Broadband	-.03 (.04)	-.01 (.09)
Broadband^2		.0003 (.007)
G	-.4*** (.03)	-.39*** (.02)
I	0 (omitted)	0 (omitted)
FDI	.004 (.02)	.001 (.02)
Edu	.01*** (0.004)	.01*** (.004)
Open	.47 (.01)	.4 (.00001)
DTSB	-.27*** (7993.569)	-.25*** (.09)
Cons	12.4*** (.36)	12*** (.4)
N	325	325
R^2	56%	57%

Standard errors are in parentheses
*** significant at 1% level, ** significant at 5% level, * significant at 10% level