An Empirical Study of the Main Determinants of Mobile Proliferation in Developing and Affluent Countries

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Abstract-Mobile phone proliferation has been a fact of life in many parts of the world. It is seen as an empowering technology by many developing countries. In the literature there are many studies that relate this mobile proliferation to desirable results like economic growth and social development. The purpose of this paper is to analyze the factors that contribute to or inhibit mobile growth, furthermore to determine whether it is feasible for a developing country in (say) Africa to attain these benefits and if so, what the pre-requisites may be.

A data set containing a spectrum of developed and developing countries is considered and relationships are tested empirically. The data used are from sources like the World Bank reports, ITU reports and others. Methodologies employed are Multiple Linear Regression Analysis and the Linear Response Surface Analysis (LRSA) technique.

This paper is an extension of previous work done in [32]. It illustrates the use of the results obtained in that analysis to identify strategies for countries wanting to compare their position regarding an important response e.g. mobile proliferation .The idea is also to identify reasons why some – countries are more successful than others.

Index Terms—Mobile Phone Proliferation, Economic growth, Social Development, LRSA

I. INTRODUCTION

Many researchers investigating the relationship between telecommunication technology proliferation and other factors such as demographic and economic factors, have tried to determine whether adequate telecommunications technology infrastructure has a positive impact on economic growth potential of a country .This relationship is poorly understood and remains a challenge, especially the extent to which it exists in the developing world.

The lack of adequate telecommunication infrastructure and social and economic development in the developing world has led policy makers and researchers to investigate the role of telecommunication services, radio spectrum management and other factors such as freedom from corruption on economic growth and development. The unique institutional environment in these countries makes it very difficult to adopt economic strategies employed in the "first world countries". For instance some researchers such as those in [4] and [5] believe that there is a substitution effect between fixed lines and mobile phones, which will make it possible for developing countries to leap-frog their poor telecommunication infrastructure in order to realize the benefits of economic development. As pointed out later in this paper, the mechanism is not simplistic at all.

Determining the relationship between fixed lines and mobile services helps wireless LAN operators make better decisions such as adjusting prices for maximal returns and also to see how price changes in the fixed line sector can affect the demand for mobile services (See [13]).

Although some believe that the proliferation of telecommunication technology leads to economic growth, there are many (issues) factors involved in this relationship ([1], [2]).

The management of the radio spectrum has also been seen as a (bottleneck)key for economic development and researchers reporting in [15] and [16] have carried out empirical investigations to show that better management of the spectrum has some social and economic benefits.

Some of the above work has been done using econometric models such as stochastic production functions and other techniques, based on estimating models using economic theories (See [1],[3],[18], and [27]).

Many studies have been done to investigate factors that affect the proliferation of mobile telephone services and most of them have focused on the diffusion rate. In these studies, the main models used to explain the proliferation of mobile telephony have been the Gompertz, Logistic and the Bass models. Among these models, the Logistic model seems to be the most widely used.

It is our view that these studies have methodological and data shortcomings in their efforts to investigate how technology proliferation affects economic growth since most of them do not take a more holistic view.

This paper is an extension of previous work reported in [32]. In this report we illustrate the use of the results obtained from our analysis to identify strategies for countries wanting to compare their position regarding an important response e.g. mobile proliferation .The idea is also to identify reasons why some countries are more successful than others.

This paper begins with a brief review of literature (background), followed by a description of the research methodology employed, an overview of the linear response surface analysis technique, empirical experiments (illustrative examples and interpretation of findings), conclusions and future work.

II. BACKGROUND

Most researchers agree that a strong positive correlation exists between telecommunications infrastructure and economic growth and improved social welfare in a country. They agree that telecommunications infrastructure improvements and investments alone cannot drive economic growth but that a lack of adequate telecommunications infrastructure and poor investment and maintenance of this and other factors can inhibit the economic growth potential of a country. One of the main hypotheses is that investment in, and improvement of the telecommunications infrastructure will considerably increase the efficiency of businesses and bring about social welfare benefits.

Some researchers examining the relationship between telecommunications and economic growth have only concentrated on the one way relationship i.e. that telecommunications stimulate economic growth. Researchers such as [1],[2],[3],[18] and [19] have empirically examined this relationship. Their methodology was mainly to make use of the Stochastic Frontier Production functions and variants of these. Work reported by [11] using an improved Stochastic production function, showed that institutional reforms and expansion of information and communication networks, can affect economic growth.

Other researchers have discovered that telecommunications is both a cause and a consequence of economic growth (see e.g. [7],[8],[9],[22] and [23]).The methodology used by them was mainly the Granger causality and Modified Sims tests. A different approach to the bidirectional relationship was reported in reference [27], using a dynamic panel data model.

The view taken in this paper is that affluence obviously influences the proliferation of (amongst other things) telecommunication technology .The real question however is whether less affluent countries can improve their economic growth and social development by investment in telecommunication infrastructure.

The rapid expansion of mobile phone subscribers which has seen them surpass fixed line users in certain regions of the world has encouraged researchers to explore the relationship between fixed-line penetration and mobile telephone subscription. References [29] and [30] report the discovery of the positive impact of fixed lines on mobile subscription. Researchers such as [5], [6] and [12] empirically discovered that fixed lines and mobile services are substitutes while [31] showed that the adoption of mobile telephones slowed the growth of fixed lines but that the reverse was not true. Other investigators such as [5] have proved that fixed lines and mobile services are both substitutes and complements in certain situations. The study of [11] found that fixed lines are substitutes in the mobile market but mobile phones are not substitutes in the fixed line market.

There has also been some interesting findings reported by researchers exploring the relationship between economic growth and “good” management of the radio frequency spectrum and they have discovered that there is a positive correlation between these aspects. The effect of the scarcity of radio frequency spectrum on mobile telecoms and hence economic growth was investigated in [15] and [16]. Reference [15] evaluated spectrum allocation policies in Latin America and empirically found that more liberal use of the spectrum such as making more of the spectrum available to mobile telephone networks had positive societal and economic implications. Reference [16] found that allocating more bandwidth to mobile operators increased competition and resulted in reduction of costs and the accrual of social welfare benefits.

A framework for radio spectrum management reforms for developing countries whose institutional environment is different from that of the developed world was proposed in [14]. The authors believed that such a framework would suit these countries who have high levels of corruption, lawlessness (weak rule of law) and poor fiscal freedom. They suggested a phased approach to spectrum reform .The work of [38] also showed that competition and better regulation resulted in lower telecommunication costs and improved telecommunication services.

Most of the empirical studies to determine the factors affecting mobile proliferation have found deregulation, market competition, GDP and technological innovation as the most important factors. Bohlin et al. in [34] empirically discovered that per capita income, urbanization, Internet/Broadband penetration and regulation are the main drivers of the diffusion of mobile communications. Gamboa and Otero in [33] examined the diffusion of mobile telephony in Colombia based on the Gompertz and Logistic model and they concluded that the diffusion of mobile telephony is better characterized by the logistic models. A similar approach was adopted by [31]who investigated the impact of the diffusion of cellular technology on the fixed line network. They found that the mobile phone diffusion negatively influenced the fixed line penetration rate.

From the literature, we can conclude that many empirical studies have been done to find the main determinants of telecommunication technology proliferation. The aim was to determine how technology growth could best be achieved, and especially how mobile technology can be used to improve the social and economic welfare of people in a country.

In the next paragraph, a description of the research methodology is given.

III. RESEARCH METHODOLOGY

The methodology used in the research is an empirical investigation where data were collected for 160 countries, of which 48 were from Africa. The paper describes some empirical analyses based on information given in World

Bank reports, ITU reports and others. We explore some of the relationships of cellular phone rollout, measured in terms of mobile lines per hundred (TML100) and factors like total telephone subscribers (TTS) for a sample of 50 countries. The empirical analysis entails some regression studies and applications of linear response surface analysis techniques.

The Linear Response Surface Analysis (LRSA) described by Bruwer and Hattingh in [10] will be explained in the next section. The LRSA method interprets regression findings by looking at the space or region of experience defined as the convex hull of the data points (taking the independent variables).Thereafter the regression function (linear in this case) is evaluated over this convex hull by linear programming applications. The objective is to find points in the convex hull where the regression function attains a minimum/maximum. These results are then displayed graphically.

OVERVIEW OF THE LRSA METHOD

Linear response surface analysis (LRSA) is a subset of the statistical field Response Surface Methodology (RSM). RSM is a research field dedicated to the optimization and forecasting of linear and non-linear models [25]. These models are presented in terms of various "independent" variables that influence a dependent (or response) variable. The feature that normally distinguishes LRSA from RSM is that LRSA can be applied to both planned and raw data compared to RSM which applies mainly to planned data. The terms "planned" and "raw" are used to differentiate between data collected from a planned experiment and data collected randomly. (e.g. observational studies) [25].

LRSA makes use of mathematical programming techniques to generate graphic representations of linear models and data (see [10] and [25]).

The LRSA technique can be summarized as consisting of the following steps:

- Obtain a regression model that is "satisfactory".
- Determine the area of experience of the regression model by identifying the convex hull of the available points.
- Identify the variable (often a state variable) for which the influence on the dependent variable have to be investigated.
- Select a specific level for this variable.
- Optimize the regression function over the convex hull where this variable is at a specific level. Obtain maximum and minimum values. Select another level and repeat the procedure.
- Graph the optimum values (maximum and minimum) of the regression function against different levels of the chosen variable.

The vertical distances between the maximum and the minimum piecewise linear graphs are an indication of the relative importance of other independent variables not fixed in the linear program. The reader is referred to [10], [25], and [32] for a detailed analysis, including the mathematical formulation of the LRSA method.

Results of the empirical analysis as well as illustrative examples and the interpretation of some of our findings is the focus of the next section. A few selected countries and their relative positions are indicated on the graphs.

IV. Empirical Experiments

Exploratory models that relate TML100 (mobile proliferation) as a response variable to factors like trade freedom, institutional reforms, gross domestic product per capita and others were investigated .

A hypothetical linear function of the form:

TML100 = f (TFL100, TelCost, GDPT, GDPC, FDI, INSTREFS, TF, KEI) was fitted to the data where the acronyms have the following meaning"

TML100: Mobile subscribers per hundred inhabitants
TFL100: Fixed telephone lines per hundred inhabitants
TelCost: Telecommunications Cost
GDPT: Gross Domestic Product Total
GDPC: Gross Domestic Product per Capita
FDI: Foreign direct investment
INSTREFS: Institutional reforms
TF: Trade Freedom
KEI: Knowledge Economy Index

INSTREFS = f(Regulatory quality, Rule of law, Government effectiveness, Voice and Accountability, Political stability, Corruption).

A good fit characterized by an R-squared of 88.6% and an adjusted R-squared of 86.4% was obtained.

Applying the LRSA technique, the following graphs were obtained with both maximum and minimum values (maxTML100 and minTML100) given in the tables. Please note that some columns have been removed from the tables in order to fit the tables in this report without compromising the quality of the results. Please note that the values of TelCost, GDPT, GDPC and KEI are omitted but are available upon request. The graphs also show current positions of a few selected countries relative to the set of indicators considered, before performance improvement proposals have been suggested .

Table 1:maxTML100

TFL100	FDI	INSTREF	TF	TML100
0.39	26.00	5.93	62.00	-2.88
10.60	1771.57	3.74	66.95	24.40
20.82	3524.85	5.17	71.12	37.20
31.03	5278.13	6.61	75.29	50.00
41.24	7031.40	8.04	79.45	62.80
51.45	7933.63	9.26	82.64	73.46
61.67	3984.82	9.29	80.22	71.91
71.88	36.00	9.31	77.80	70.36

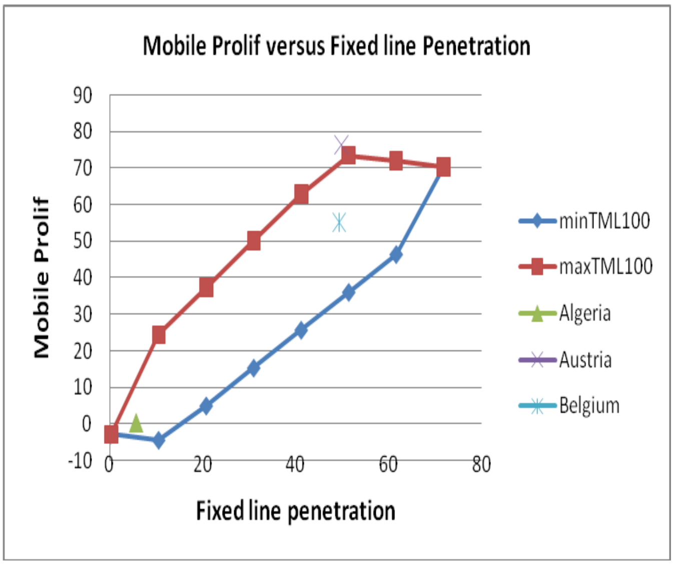

Figure 1

TFL100	FDI	INSTREF	TF	TML100
0.39	26.00	5.93	62.00	-2.88
10.60	37.10	4.46	44.05	-4.37
20.82	42.65	5.15	48.38	5.01
31.03	47.72	6.02	54.68	15.35
41.24	52.78	6.90	60.97	25.70
51.45	57.84	7.78	67.26	36.04
61.67	62.91	8.65	73.55	46.38
71.88	36.00	9.31	77.80	70.36

Table 2: minTML100

The graph shows the range of expected values of TML100, which is a measure of mobile proliferation, over the range indicated for TFL100. Both the maximum expected values and the minimum expected values are indicated. The difference (distance) between the two graphs can be attributed to the other factors in the model.

There is a strong positive correlation between fixed lines and mobile phones. The diagram does not show evidence of the leap-frog effect. (There is low mobile proliferation for countries with low fixed line penetration).

Tables 1 and 2 illustrate that the model of high mobile proliferation is characterized by high fixed line penetration, high GDPC, high FDI, high INSTREFS, high TF and high KEI.(Recall there are omitted values from tables)

Table 3: maxTML100

TFL100	FDI	INSTREF	TF	TML100
0.39	26.00	5.93	62.00	-2.88
51.19	6999.22	7.42	73.26	49.74
54.05	9065.85	7.73	73.14	60.35
52.11	8810.25	8.45	77.78	66.63
50.17	8554.65	9.17	82.43	72.91
52.07	5962.60	9.39	81.78	73.10
54.52	3040.30	9.55	80.39	72.44
56.96	118.00	9.70	79.00	71.77

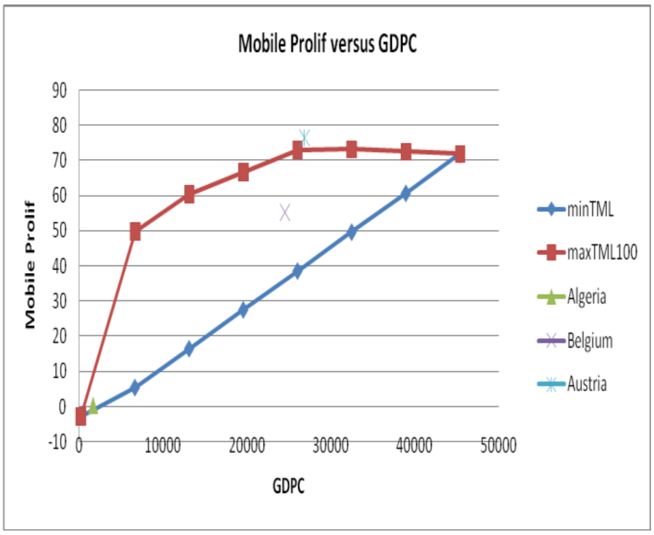

Figure 2

Table 4: minTML100

TFL100	FDI	INSTREF	TF	(TML100)
0.39	26.00	5.93	62.00	-2.88
17.36	48.42	5.04	47.34	5.44
23.96	60.02	5.82	52.62	16.50
30.56	71.61	6.59	57.89	27.55
37.16	83.21	7.37	63.17	38.61
43.76	94.81	8.15	68.45	49.66
50.36	106.40	8.92	73.72	60.72
56.96	118.00	9.70	79.00	71.77

The graph shows the range of expected values of TML100 (Mobil Prolif) over the range indicated for GDPC. Both the maximum expected values and the minimum expected values are indicated. The difference between the two graphs can be attributed to the other factors in the model.

Generally speaking, affluent countries with good infrastructure have better mobile penetration than poor countries. However there are poor countries that manage their mobile proliferation better than some more affluent countries e.g. South Korea has relatively high mobile penetration while the affluent Canada has a relatively low mobile penetration.

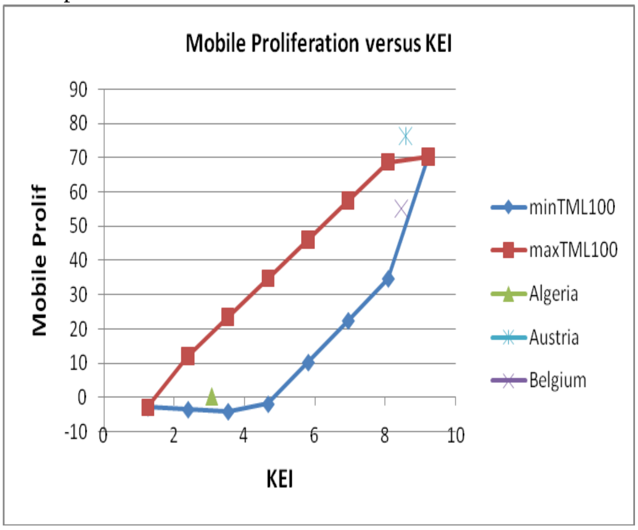

Figure 3
(The tables for figure 3 have been omitted to save space.)

The graph shows the range of expected values of TML100 (Mobile Prolif) over the range indicated for KEI. Both the maximum expected values and the minimum expected values are indicated. The difference between the two graphs can be attributed to the other factors in the model. The KEI appears to be an influential factor due to the small distance between the graphs.

We now attempt to extend the interpretation of the graphs by applying the analysis used to produce performance improvement proposals (PIPs). These PIPs are recommendations towards the improvement of the response variable by adjusting some of the levels of the decision variables. This presupposes that the regressors used in the regression can be classified as decision variables and "state" variables.

From the application of the LRSA method, we obtained the values in the column titled "Suggested" for the Czech Republic as an example in this paper. These are the values that we suggest the country should change to.

	Current	Suggested
TFL100	37.87	37.87
FDI	4987	6452.62
INSTREF	7.74	7.57
TF	72	78.08
TML100	42.51	58.57

Figure 4

In order to improve the Czech Republic mobile proliferation, assuming that one cannot change TelCost, GDPT, GDPC or KEI, but that one only adjusts FDI,INSTREF and TF, then the expected change in the mobile proliferation will be given by the following formula (the formula is based on the coefficient in the regression equation and the difference between the changes in the suggested value and the present value):

Expected change in mobile proliferation (by adjusting FDI, Institutional reforms and Trade Freedom) is (Regression Coefficient of FDI) (Suggested Value of FDI-Current Value of FDI) + (Regression Coefficient of INSTREFS)(Suggested Value of INSTREFS-Current Value of INSTREFS) + (Regression Coefficient of TF)(Suggested Value of TF-Current of TF)

Using our regression results and the data from the dataset for the specific unit (country), we obtain:

Expected change in mobile proliferation = (0.00149) x (6452, 618 – 4987) + (1.49164) x (7.5666 – 7.74) + (0.31787) x (78.07755-72) =4.37.Using this value and 58.57 as the denominator we have:

$\frac{4.37}{58.57}$ x 100 = 7.46 % improvement,

where 58.57 is the maximum achievable figure for mobile proliferation for the Czech Republic.

this implies that the Czech Republic implements the PIPs, it will result in a 7.46% increase in mobile proliferation.

V. CONCLUSIONS

The empirical study carried out in this paper, illustrates that some of the main determinants of mobile proliferation are KEI, GDPC, INSTREFS, TFL100,TF and FDI. Countries that better manage these factors tend to be more successful than others. The model of high mobile proliferation is characterized by high volumes of these factors. It also seems feasible to study the expected effect of performance improvement proposals for individual units.

VI. FUTURE WORK

Many more empirical analyses will have to be done to gain insight of the mechanisms underlying these relationships.

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