Finding International Model Views for Studying the Effect of Telecommunications Proliferation on Economic Growth and Social Development

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Abstract: The relationships between factors like general economic freedom, trade freedom, etc., and telecommunications proliferation are often a poorly understood field, and in spite of many papers in reputable journals, they remain a challenge. While many viewpoints have been expressed in literature, the problem that remains is to determine what should be done for a specific country. A situational audit for a specific country is obviously desirable as well as proposals aimed at the improvement of telecommunication proliferation. There is thus a need for a methodology to conduct a situational audit of a specific country aimed at measuring the relevant attributes that are important. One of the contributions envisaged for this paper is the creation of methodologies that can aid a specific country to overcome some of its weaknesses in the telecommunications area and implement specific actions in order to enhance their situation regarding the use of telecommunications and related activities to facilitate a better life through economic growth and social welfare development. The methodology investigated here is data modelling by multiple regression techniques and also the use of interpretive techniques such as Linear Response Surface Analysis. The relative successes and failures of countries could be analyzed by means of these methodologies. This will hopefully help to eventually create a "blue-print" for a country wishing to improve its position regarding valuable telecommunications options. The results are presented and discussed.

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1. Introduction

Telecommunication proliferation is believed to have a positive impact on economic and social development. The relationships between factors like general economic freedom, trade freedom, etc., and telecommunications proliferation are often a poorly understood field, and in spite of many papers in reputable journals, they remain a challenge.

While many viewpoints have been expressed in literature, the problem that remains is to determine what should be done for a specific country. A situational audit for a specific country is obviously desirable as well as proposals aimed at the improvement of telecommunication proliferation. There is thus a need for a methodology to conduct a situational audit of a specific country aimed at measuring the relevant attributes that are important.

From the literature, many empirical studies have been done to find the main determinants of telecommunication technology proliferation in an attempt to determine how best technology growth especially mobile proliferation technology can be used to improve the social and economic welfare of people in a country. However, in analyzing telecommunication proliferation and these factors contributing to its growth, these researchers work at an abstract level and everybody agrees that telecommunication proliferation is desirable but they never come up with recommendations on what the important things are and what the main things that have to be done to improve telecommunication proliferation are.

Few of these papers actually recommend actions towards the improvement of telecommunication proliferation in developing countries hence it is the purpose of this paper to fill this void by suggesting performance improvement proposals (PIPs) for telecommunication proliferation in developing countries. This will be achieved through an empirical analysis based on multiple regression analysis and the application of the linear response surface analysis (LRSA) technique.

A PIP is a Performance Improvement Proposal and means specific proposals to change the levels of the so-called independent variables to levels that are more desirable to give improved values of the dependent variable. The max graph of LRSA is used to accomplish this. This graph gives estimates of the maximum values that can be achieved for the dependent variable at fixed levels of the independent variable (or state variable in many cases) for which the graph is plotted. The PIP values of the independent variables are calculated by using interpolation on the graph when necessary.

One of the contributions envisaged for this paper is the creation of methodologies that can aid a specific country to overcome some of its weaknesses in the telecommunications area and implement specific actions in order to enhance their situation regarding the use of telecommunications and related activities to facilitate a better life through economic growth and social welfare development.

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

2. 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 Hardy (1980), Saunders et al. (1994), Röller and Waverman (2001), Jipp (1963) and Moss (1981) 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 Thompson and Garbacz (2007) 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. Cronin et al. (1991, 1993a, 1993b) and Dutta (2001)).The methodology used by them was mainly the Granger causality and Modified Sims tests. A different approach to the bidirectional relationship was reported in Shiu and Lam (2008), 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. Ahn and Lee (1999) and Gruber (2001) report the discovery of the positive impact of fixed lines on mobile subscription. Sung et al. (2000), Madden and Coble-Neal (2004) and Gruber and Verboven (2001) empirically discovered that fixed lines and mobile services are substitutes while Barros and Cadima (2000) showed that the adoption of mobile telephones slowed the growth of fixed lines but that the reverse was not true. Other investigators such as Sung et al. (2000) have also proved that fixed lines and mobile services are both substitutes and complements in certain situations. The study of Thompson and Garbacz (2007) 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 by Hazlet and Muñoz (2009a) and Hazlet and Muñoz (2009b). Hazlet and Muñoz (2009a) 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. Hazlet and Muñoz (2009a) found that allocating more bandwidth to mobile operators increased competition and resulted in reduction of costs and the accrual of social welfare benefits.

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. (2010) 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 (2009) examined the diffusion of mobile telephony in Colombia based on the Gompertz and Logistic models and they concluded that the diffusion of mobile telephony is better characterized by the logistic models. A similar approach was adopted by Barros and Cadima (2000) 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.

Andonova (2006) defines the digital divide as the difference between those with permanent, effective access to new ICT and those with none. In this research he quotes Powell (2001) and Wilson III (2001). It refers to the discrepancies or disparities in the adoption and use of information technology both at national and international levels and between countries. In the same work, the digital divide is also described as discrepancies in the adoption and use of ICTs. There is a lot of literature whose aim is to investigate how this gap can be reduced if not closed.

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.

3. Research Methodology

In this section the application of the methodology is described which involves two steps namely the application of the LRSA method as well as the calculation of Performance Improvement Proposals.

The methodology used in this research was an empirical investigation where data were collected for 160 countries, of which 48 are situated in Africa. The paper describes some empirical analyses based on information published in World Bank reports, ITU reports and others. Some of the relationships explored for this global dataset were the telecommunications proliferation (MLT) relative to factors such as total fixed lines (FLT), freedom from corruption (FC), gross national income per capita (GNIC), etcetera. The empirical analysis entailed some regression studies and applications of the linear response surface analysis technique. The LRSA described by Bruwer and Hattingh (1985) is briefly explained in the next section.

The performance of a country will be evaluated and where possible, PIPs (Performance Improvement Proposals) are suggested. These PIPs are recommendations towards the improvement of the response variable, by adjusting some of the levels of the decision variables. The LRSA method aims at interpreting 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.

In simpler terms, LRSA is a technique that explores the behaviour of a linear function over a region of experience. The linear function may often be the estimated regression function or the model that empirically fits the available observations. The region of experience in this research is obtained by investigating the region defined as the convex hull of the data. This investigation is carried out by solving a sequence of linear programs.

The LRSA technique can be summarised as consisting of the following six 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.
- Optimise 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 Bruwer and Hattingh (1985), Terblanche (2001), and Terblanche and Hattingh (1999) for a detailed analysis, including the mathematical formulation of the LRSA method.

A PIP is a Performance Improvement Proposal and means specific proposals to change the levels of the so-called independent variables to levels that are more desirable to give improved values of the dependent variable. The max graph of LRSA is used to accomplish this. This graph gives estimates of the maximum values that can be achieved for the dependent variable at fixed levels of the independent variable (or state variable in many cases) for which the graph is plotted.

The PIP values of the independent variables are calculated by using interpolation on the graph when necessary.

It should be noted that in the discussion given in this thesis explaining the PIP finding procedure, it is argued that the decision variables are under the control of the decision-maker and can be

changed at will. This is of course a very simplistic view and in each case the decision-maker will have to decide which changes can be realistically achieved.

We now attempt to extend the interpretation of the graphs obtained by the LRSA method by illustrating the analysis used to produce PIPs. It must be kept in mind that this presupposes that some regressors used in the regression can be classified as decision variables and others as "state" variables. Obviously, one cannot propose changes in state variables. Some variables are decision variables but are difficult to change in the short term. This has to be handled with care.

The procedure is illustrated below.

Consider a typical graph representation generated by applying LRSA for some dependent variable *y* and some independent variable *xi*.

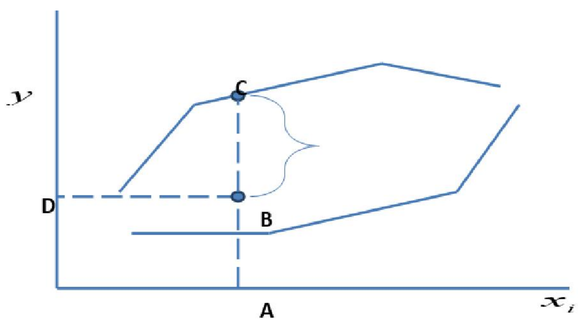

Figure 1. Min/max *y* versus *xi*

Based on Figure 8.1, the following steps can be followed to do the calculation of PIPs. (Examples are given later in the section):

1) Identify the expected response corresponding to a unit under consideration (B in the graph). A is the value of the independent variable corresponding to the variable *xi*.

2) Compare to max graph (at A) denoted by C: Look at the difference C – B.

3) Find the values of the response variable at C by interpolation of the graph if necessary.

4) Identify the values of all the other regressors (except *xi*) at C by means of interpolation if necessary.

5) Based on the result in (4) above, it is possible to define a PIP for the unit by comparing the values of the (optimal) expected response and proposed regressor values at C with the expected response variable value at B and the values at the observed regressor variables at B.

4. Empirical Experiments

The results given below are PIPs that were calculated from a sample of countries from the dataset consisting of 160 countries. In the examples considered in this paper, examples are given for MLT for illustrative purposes based on the results obtained in the work by Dr. Gasela and myself which is also being presented in this conference. The examples are considered for the following countries: This PIPs of these countries are plotted on the graph but the procedure for calculating these is illustrated for Botswana and Brazil.

- Botswana
- Brazil
- Iraq
- Mexico
- Nigeria
- South Africa
- Zimbabwe

Further empirical analysis (MLT against FLT, MO, TELCOST, TF and ILC with nonsignificant factors eliminated as per LRSA requirements), yielded the results indicated in tables 1, 2, and 3. Table 2 displays the observed values of FLT, MO, TELCOST, TF and ILC and the expected value of MLT denoted by MLT_E. The PIPs obtained for a sample of seven countries are

indicated in Table 3 for the case where FLT is the state variable. MLT_S is the standardised value of MLT which was also considered in our empirical analysis.

We shall consider two cases for the calculation of PIPs where MLT is the response variable.

Table 1. Regression coefficients

Response	Regression Coefficients									
MLT	FLT	MO	TELCOST	TF	ILC	Intercept	2.000	F-value	Probability (Pr>F)
$\hat{y}$	2.328	1373.268	-99.914	946.182	-2169.327	64624.000	78.440	116.720	0.000
t-values	21.490	2.330	-0.550	-3.840	1.860	3.620			

In the next paragraph, we illustrate the calculation of PIPs presented in Table 3 for the same sample of countries indicated above. Table 2 displays the observed values of FLT, MO, TELCOST, TF and ILC.

FLT as the variable used for LRSA

Table 2. Observed values

	Observed							Expected
	FLT	MO	TELCOST	TF	ILC	(MLT_S)	MLT	MLT_E
Botswana	144.200	3.000	3.800	69.600	4.000	0.003	1874.100	11522.830
Brazil	41497.000	8.000	7.700	69.800	6.960	0.233	173959.400	120483.400
Iraq	1108.400	5.000	9.220	56.500	0.000	0.026	19722.000	19689.760
Mexico	19424.900	4.000	3.600	77.600	4.000	0.112	83527.900	50223.990
Nigeria	1419.000	8.000	43.000	61.600	7.520	0.098	73099.300	32645.240
South Africa	4319.800	4.000	4.200	73.800	5.920	0.062	46436.000	22766.310
Zimbabwe	385.100	3.000	7.140	52.600	0.240	0.004	2991.000	19678.250

Table 3. Proposed values

	Observed	Proposed values					
	[FLT]	MO	TELCOS	TF	ILC	(MLT S)	MLT
Botswana	144.200	3.008	9.039	57.650	0.016	0.018	13675.390
Brazil	41497.000	5.393	29.621	13.013	4.779	0.219	163713.000
Iraq	1108.400	3.064	9.519	56.609	0.127	0.023	17173.730
Mexico	19424.900	4.120	18.636	36.838	2.237	0.112	83630.250
Nigeria	1419.000	3.082	9.674	56.274	0.163	0.024	18300.660
South Africa	4319.800	3.249	11.118	53.142	0.497	0.039	28825.430
Zimbabwe	385.100	3.022	9.159	57.390	0.044	0.019	14549.430

The same PIPs can be represented on the graph as follows:

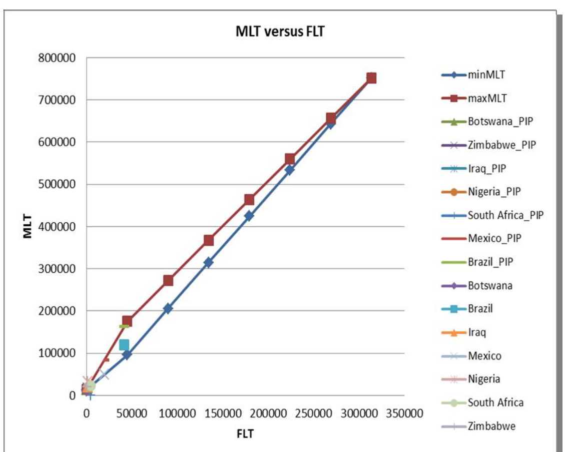

Figure 2. MLT versus FLT observed and proposed values

We consider these results to illustrate, the procedure for calculating PIPs for individual units, using a few examples, namely, Figure 1 and Table 4 given below:

The next section describes how these PIPs were calculated.

Recall that to calculate PIPs, use the max graph is used. Extracted from LRSA, the max graph for MLT versus FLT is given below in Figure 3 and the corresponding max table (Table 4).

We then illustrate the procedure for calculating the PIPs in Table 3 through interpolation based on a few selected countries from the same table:

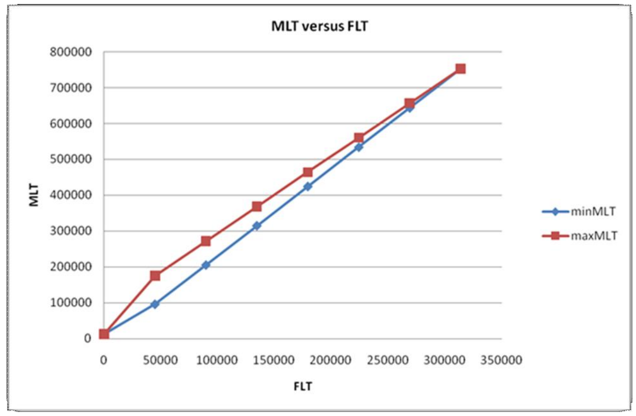

Figure 3. MLT versus FLT

Table 4. For max graph

[FLT]	MO	TELCOST	TF	ILC	(MLT_S)	MLT
4.800	3.000	8.970	57.800	0.000	0.018	13169.610
44815.540	5.584	31.273	9.431	5.161	0.235	175753.400
89626.290	5.153	26.794	19.192	5.701	0.364	271844.500
134437.000	4.723	22.315	28.954	6.241	0.493	367935.600
179247.800	4.292	17.836	38.715	6.781	0.621	464026.700
224058.500	3.861	13.358	48.477	7.320	0.750	560118.500
268869.300	3.431	8.879	58.238	7.860	0.878	656209.600
313680.000	3.000	4.400	68.000	8.400	1.007	752300.700

Calculating PIPs for Botswana

At present Botswana has an FLT of 144.2 According to the LRSA maximum graph, the potential for MLT (at a fixed FLT of 144.2), is given by 13675.386 which is obtained by the following interpolation:

$$13169.61 + \frac{144.2 - 4.8}{44815.54 - 4.8} \times (175753.4 - 13169.61) = 13675.386$$

The way this expected MLT can be achieved is by adjusting the values for MO, TELCOST, TF and ILC to the proposed values.

They are obtained by calculating (in the same manner as above) the interpolated values

Let $\beta = \frac{144.2-4.8}{44815.54-48}$

MO = 3 + β (5.583934 – 3)
= 3.0080382

TELCOST = 8.97 + β (31.27292 – 8.97)
= 9.04

TF = 57.8 + β (9.430827 – 57.8)
= 57.65
ILC = 0 + β (5.161469 – 0)
= 0.02

Thus the PIP for Botswana consists of a proposed set of values for the variables and the resulting expected MLT (maximum) value of 13675.386.

Calculating PIPs for Brazil

At present Brazil has an observed FLT of 41497 (See Table 3).According to the LRSA max graph (See table 4), the potential MLT for Brazil at a fixed FLT of 41497 is given by

$$MLT = 3169.61 \quad \frac{41497-4.8}{44815.54-4.8} + x\ (175753.4 - 13169.61)$$

= 163712.9648
= 163713
See Table 4, last column).

The way this expected MLT can be achieved is by adjusting the values for MO, TELCOST, TF and ILC to the proposed values of the decision variables.

They are obtained by calculating (in the same way as above) the interpolated values

$$\frac{41497-4.8}{44815.54-4.8} \qquad \text{Let } \beta =$$

MO = 3 + β (5.583934 – 3)
= 5.392576117
= 5.392576
TELCOST = 8.97 + β (31.27292 – 8.97)
= 29.61902525
= 29.62
TF = 57.8 + β (9.430827 – 57.8)
= 13.01289316
= 13.0129
ILC = 0 + β (5.161469 –0)
= 4.779227124
= 4.779227

5. Conclusion

Performance improvement proposals (PIPs) were described and the procedure for the calculation of these was illustrated for a sample of some countries (what they are doing right or wrong and how to improve it). The performance of a unit/country was evaluated and where possible PIPs were suggested.

6. Future work

We are planning the extension of the linear response surface analysis methodology to non-linear response functions. It is postulated that often a "good thing" helps at first but the benefits deteriorate at too high levels. Automation of the procedures into customized decision support systems is another aim of our research group.

The methodology to use graphs to analyze a specific country and produce (suggest) performance improvement proposals seems to be a practical way to give specific recommendations to countries that have certain attributes that are not at optimal levels.

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