MODELLING AND PREDICTION OF INTERNET DIFFUSION IN THE AFRICAN CONTINENT: THE S-SHAPED INTERNET DIFFUSION CURVE

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ABSTRACT

Internet is a key technological change which has significant economic effects. This paper tries to study the diffusion processes of Internet users in the African continent, the region of the world with a wider technological gap. In this sense, the main objective of the present research is to predict, ceteris paribus, the maximum level of Internet users in the African continent, in order to help policy makers and firms to adopt the correct policies.

Firstly, it is analyzed whether Internet follows in Africa the usual S-shaped diffusion curve which characterizes the adoption processes of new Information and Communications Technologies (ICT).

Once we confirm that the diffusion of the Internet in Africa follows an S-shaped diffusion curve, we introduce the historical data of this indicator (published by the International Telecommunication Union in its 2010 World Telecommunication/ICT Indicators Database) in SPSS, running a logistic function with three parameters. This funtion is explained in the article by using MATLAB.

The three parameters included in the logistic function offer information on the Internet diffusion speed, slope, and the maximum potential percentage of Internet users in the African continent.

INTRODUCTION, MOTIVATION OF THE RESEARCH AND LITERATURE SURVEY

Access to the Internet in Africa should not be considered a privilege, but a tool for achieving economic development and poverty reduction. Nevertheless, it is still a privilege used by 10.9 percent of Africans according to the *Internet Usage and World Population Statistics* published by the International Telecommunication Union (ITU hereafter). This figure represents a 5.6 percent of the world Internet users (ITU, 2010).

Estimating the diffusion pattern of Internet in African countries and predicting its future (potential) level of use, is a very relevant research topic because Internet diffusion increases the social knowledge network and improves the communication efficiency (Jovanovic and Rob, 1989), makes it easier and provides better political agreements (Norris, 2001), increases the productivity (Brynjolfsson and Hitt, 2003; Dedrick, 2003), and allows the less-developed countries to accelerate the transition from the traditional methods to the new techniques (Steinmuller, 2001).

In his "*Status report about the ICT in Africa*", Mike Jensen explains that the digital divide is larger in Africa than in other regions of the world, because of the lack of ICT infrastructures and the brain drain that deteriorate the technological skills of the African society.

On this issue, Castells (2006) argues that "differences in Internet access among countries and regions in the world are so considerable that they actually modify the meaning of the digital divide, and the kind of issue to be discussed".

The digital divide has been an important research topic. The most important studies are those by Pohjola (2003) and Caselli and Coleman (2001). These authors explain that the main digital divide is due to the heterogeneity of

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personal computers and the differences of Internet diffusion worldwide.

But what is much more important is not the access to ICT in the narrow sense of having a computer on the desk, but rather in a much wider sense of being able to use ICT for personally or socially meaningful ends (Warschauer, 2003).

Up to the date, there are not academic papers modelling Internet diffusion in Africa. Most of the scientific papers on Internet in African countries focus on the digital divide and the determinants of the Internet use. Out of the specialized literature, the article published by McKormick (2002) is outstanding. In "*The Internet access in Africa: A critical review of public policy issues*", McKormick explains that at the end of 1996 only eleven of Africa's fifty-four countries had local Internet access, but by early 2000 all of the countries had secured access, at least in their capital cities.

Banji and Kaushalesh (2005) offer one of the most important sub-regional studies on the Internet diffusion in Africa. By developing a cross-country analysis, they confirm the crucial importance of telecommunication infrastructures. In this sense, these authors prove the existence of a high positive correlation between telephone density and Internet use, irrespective of the per capita income level of each country.

The present study is based on the theory developed by Rogers (1962) in his book "Diffusion of Innovations". This author examines the way in which the diffusion of innovations takes place, and on the researches by Andres (2008:7) and Massenot (2008:6) who explain that the Internet diffusion process follows an S-shaped curve, thus confirming the ideas initially proposed by Rogers.

Although there is not abundant bibliography on the Internet diffusion models, the understanding of these difussion patterns would help to predict its future evolution in countries characterized by very different socioeconomic conditions and telecommunication infrastructures (Dutta et al., 2003).

In this respect, Martin (2000: 170-189) proposes a technological diffusion model for Internet based on the "value creation law" proposed by Briscoe (2006). However, other authors like Pohjola and Kiiski use the Gompertz model to study the Internet diffusion process.

Cuberes (2007) carries out an empirical study of the Internet diffusion process in different countries during the period 1990-2004. In the first part of this article, Cuberes demonstrates empirically, at an aggregate level, that this process is characterized by an S-shaped pattern. In the second part, Cuberes shows that Internet diffusion processes follow an S-shaped curve both in the developed countries and in the developing ones. Finally, in order to reduce the digital divide, this author stresses the importance of implementing new policies to liberalize the telecommunication markets in the less developed countries.

Telecommunication markets, and specially the Internet market, are growing very fast with continuous innovations due to massive investments into terrestrial fibre backbone infrastructure to take the new bandwidth to population centers in the interior and across borders into landlocked countries. For instance, large parts of Africa gained access to international fibre bandwidth for the first time via submarine cables in 2009 and 2010, and more cables are expected to go online in 2011 (Lange, 2010).

Although technological changes are inherent to Internet evolution, in this paper we assume the ceteris paribus hypothesis, what carries with an error given that it is foreseeable that this abstract conceptual hypothesis will not be kept in the future. In fact, what we do want to demonstrate in this research is the crucial importance of breaking the ceteris paribus hypothesis via public and private investments. A higher level of investment in the future growth and development of the African Internet market will have as main effect, a higher level of Internet users' percentage, and the increase in the percentage of African Internet users would imply, on one hand, more clients and profits for companies and, on the other hand, new means for policy makers to collaborate with the achievement of the UN Millennium Development Goals. More specifically, the achievement of the goal number eight: "Develop a global partnership for development".

Within this eighth goal, the Target 8F establishes: "in cooperation with the private sector, make available the benefits of new technologies, especially information and communications". This particular target is monitored by three indicators: telephone lines (per 100 people), mobile cellular subscriptions (per 100 people), and "Internet users" (per 100 people). (UN, 2000).

On 17th December 1998, the General Assembly of the United Nations adopted the resolution 53/202, by which it decided to designate the fifty-fifth session of the General Assembly, which was opened on 5th September 2000, as "*The Millennium Assembly of the United Nations*" and to convene a "*Millennium Summit of the United Nations*" from 6 to 8 September 2000.

Ten years after the UN's Millennium Development Goals, adopted during the Millennium Summit of the United Nations, many of these objectives have not been achieved. In this respect, it is possible to observe the evolution of the internationally agreed development goals in the following two reports: the *2005 General Assembly Outcome Document* (UN, 2005) and the

Millennium Development Goals Report 2010. It must be said that the 2010 UN Summit on the Millennium Development Goals concluded with the adoption of a global action plan to achieve the eight anti-poverty goals by their 2015 target date (UN, 2010).

Taking into consideration the indicator under study and the geographical area of study, it is even more relevant to analyze the *World Telecommunication/ICT Development Report 2010 –Monitoring the WSIS targets: A mid-term review* published by the ITU, which is the leading United Nations agency for information and communication technology issues, and is committed to connecting the world.

ITU has a high commitment with development; in fact, one of its three main divisions is the ITU Telecommunication Development Sector (ITU-D).

Some ITU-D key activities are:

- Cybersecurity: Building confidence and security in the use of ICTs.
- Saving lives: Telecommunication is critical at all phases of disaster management.
- Accessibility: Achieving equitable communication for everyone.
- Partnerships: Working together for results!
- Connecting the Unconnected by 2015: Actions in all regions.

The World Summit on the Information Society (WSIS) was held in two phases. The first phase took place in Geneva hosted by the Government of Switzerland from 10 to 12 December 2003, and the second phase took place in Tunis hosted by the Government of Tunisia, from 16 to 18 November 2005 (WSIS, 2005).

Within the connectivity targets of the WSIS, ITU set an Internet connectivity target of a 50 percent of the global population.

ITU Program "Connect the World", campaign which is aimed at "connecting the unconnected by 2015", aims to mobilize human, financial and technical resources for the implementation of the connectivity targets of the World Summit on the Information Society (WSIS) and the Regional Initiatives adopted by Member States at the ITU World Telecommunication Development Conference 2006.

ITU and partners are organizing a series of regional Summits to mobilize resources and forge partnerships. The Connect Africa Summit, the first in the series, was held in Kigali, Rwanda in October 2007.

Connecting Africa aims to mobilize the human, financial and technical resources needed to expand ICT infrastructures and services. Fifty-five billion USD were committed at Summit, and leaders set the following ambitious goals: Connecting capitals with broadband by 2012, rural communities by 2015, plus enabling environment, capacity building, applications and services (ITU, 2007).

The ITU website contains the 2008, 2009 and 2010 reports on "Connect Africa Follow - Up Activities" (www.itu.int/ITU-D/connect/africa/2008/index.html).

Within the framework of "Connect Africa", ITU Telecom Africa 2008 served as a major networking platform for Africa's top ICT names to come together and focus on core issues relating to ICT expansion across the region. ITU Telecom Africa 2008 encompassed an exhibition featuring the latest technologies and innovations, and an extensive forum that explores key technologies, policies and applications driving Africa's ICT sector.

METHODOLOGY

Since the publication of "Diffusion of the innovations" (Rogers, 1962), specialized academic literature tries to search for regularities and patterns that serve as the foundations for the prediction of the future adoption of new technologies by the society. Most widespread and contrasted opinion is that this adoption process follows a pattern of behavior represented by a logistic S-shaped curve.

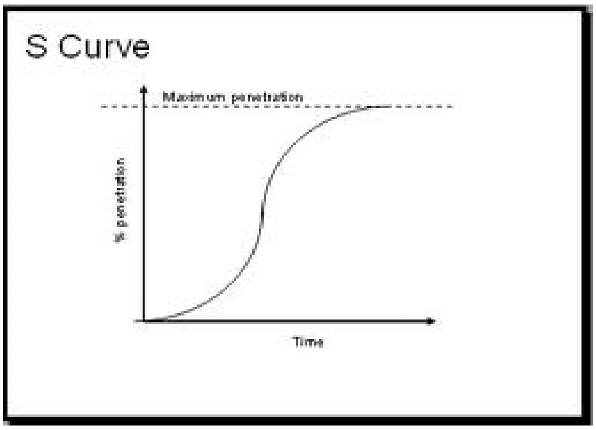

Figure 1. S-shaped diffusion curve: Percentage and maximum penetration of technology

Following the mainstream of specialized academic literature we try to model the diffusion process represented in the previous figure. To this aim, we use the Statistical Package for Social Sciences (SPSS). Besides visualizing the evolution of the data series, SPSS allows us to obtain precise and detailed statistical information. In other words, after introducing the corresponding logistic function to estimate the percentage of Internet users, this statistical program allows us to get a numerical and graphical prediction of the future evolution of this variable. Moreover, SPPS allows us to calculate, *ceteris paribus*, the maximum (potential) percentage of Internet users that could be achieved over time.

Lopez et al. (2006) define a generalized logistic model by using a function whose behavior depends on the values adopted by the adjustment parameters. In 2005, the same authors carried out a very interesting compilation of the most representative models inside the logistic family of diffusion models.

In their publication "Diffusion of the Internet", published by the World Bank in December 2007, Andres et al. present a formula based on the logistic model. This formula has a higher adjustment capacity which significantly overcomes the prediction level of the previous models.

Due to the higher prediction capacity of the formula developed by Andres et al. (2007), both in the developed and in the developing countries, we use this last expresion.

Therefore, following Andres et al. (2007) the formula that will be used to determine the Internet difussion process, as well as to predict its maximum (potential) level, will be:

$$\mathrm{Int}_t = \frac{\delta_0}{1+e^{-(\delta_1+\delta_2 t)}} + \varepsilon_t$$

To calculate the parameter values, we need to introduce in the previous expresion the historical data series of Internet users. To that aim, we use the "Internet users per 100 inhabitants" indicator from the World Telecommunication/ICT Indicators Database CD-ROM (14th edition, 2010).

The data series used to calculate the average percentage of Internet users in the African continent have been obtained from a set of 41 African States.

The growth and diffusion phenomena over time can be modelled by S-shaped curves. There are many families and subfamilies of S-shaped curves, and it is not trivial to opt for one that allows us to accurately predict the technology diffusion phenomena.

One of the studies clarifying the matter is the one carried out by Lopez (2007), where there is a classification of the logistic family of curves based on the number of free parameters and their interrelation. The data set from ITU for African countries exhibit an S-shaped curve behavior.

To understand the reasons for this behavior, it is firstly necessary to know the specific function, its origin and parameters. The family of basic logistic functions is described by the first-order nonlinear differential equation:

$$\frac{d}{dt}y(t) = k.y(t).(L - y(t)) \qquad (1)$$

Where L is the long-term convergence and k is the positive feedback gain. The corresponding solution is given by:

$$y(t) = \frac{L}{1+L\cdot C\cdot e^{-L\cdot k\cdot t}} \qquad (2)$$

Where C is an integration constant determined by the boundary conditions. Rearranging terms, it is possible to get a more compact and convenient formulae that we will use to estimate the nonlinear logistic regression with SPSS:

$$y(t) = \frac{\delta_0}{1+e^{-(\delta_1+\delta_2\cdot t)}} \qquad (3)$$

The parameters δ_0, δ_1 and δ_2 can be estimated and have a very precise meaning within the expression.

They are strongly linked to the phenomenon of diffusion we try to explain and predict:

- δ_0: This parameter determines the long-term behavior of the function. Analyzing the function when time goes to infinity, we note that the function tends asymptotically to δ_0:

  $$\lim_{t\to\infty} y(t) = \delta_0 \qquad (4)$$

  Referring to the differential equation (1), we find that δ_0=L. This parameter is very important because some high-quality data allow us to obtain the long-term rate of technology diffusion. As we shall see, the increase rate is directly related to this parameter.

  To facilitate the understanding of the influence of δ_0, figure 2 shows the long-term evolution of the S-shaped curve for several δ_0 values.

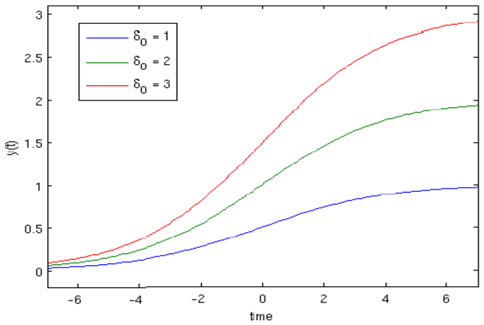

Figure 2: Long-term evolution of the S-shaped curve for several values of δ_0

- δ_1: This parameter controls the time shift of the curve. It allows us to compare a particular shift of the curve with others. Thus, we can see where the penetration of a technology begins to be relevant to other countries. Referring to the differential equation (1), we find that $\delta_1 = -\log L * C$. The inflection point of the curve is determined by this parameter, as we can see:

$$\frac{d^2}{dt^2} y(t) = 0 \Rightarrow t = \frac{-\delta_1}{\delta_2} \qquad (5)$$

To facilitate the understanding of the influence of δ_1, figure 3 shows the time shift for several values of δ_1.

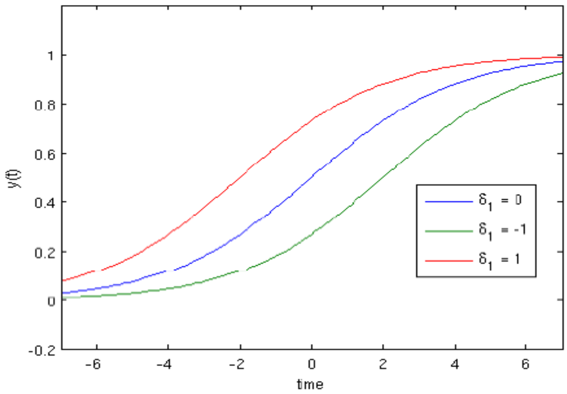

Figure 3: Time shift for several values of δ_1

- δ_2: Finally, this parameter determines the growth rate of the curve. Thus, the higher the value of δ_2 the faster will be the asymptotic approach to δ_0. This parameter can also be written in terms of the differential equation (1), so that $\delta_2 = L * k$. The growth rate is due not only to δ_2. If we find the point of maximum growth of the S-shaped curve at the point of inflection and we analyze the slope of the curve at that point, we will find that:

$$\frac{d}{dt} y(t) = \frac{\delta_0 \cdot \delta_2}{4 \cdot (\cosh \frac{\delta_2 \cdot t + \delta_1}{2})^2} \qquad (6)$$

$$\frac{d}{dt} y(t = \frac{-\delta_1}{\delta_2}) = \frac{\delta_0 \cdot \delta_2}{4} \qquad (7)$$

The result of the last expression is straightforward: The interdependence of the parameters shown in equations 5 and 6 makes the basic logistic function a good predictor of the "saturation point" for a given set of initial conditions.

This allows us to foresee not only the behavior of the rate of Internet penetration in a certain continent or country, but also to predict, ceteris paribus, what will be the maximum penetration level.

Finally, to summarize and to emphasize the importance of the combined influence of δ_0 and δ_2 in the overall rate of the Internet diffusion, figure 4 represents the combined effect of these two parameters for different values of δ_2.

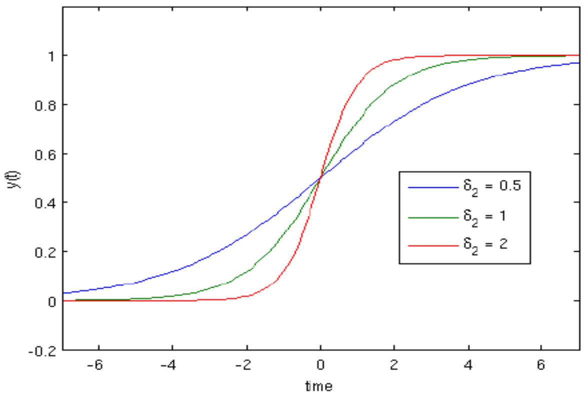

Figure 4: Slope at the inflection point is directly related to δ_2. The combination of δ_0 and δ_2 gives the overall rate of diffusion.

RESULTS AND CONCLUSIONS

This section shows graphical and statistical results of the Internet S-shaped diffusion path. These results were generated by using SPSS.

Figure 5 shows the historical evolution of this indicator in different regions of the world. Due to the existence of enormous divergences in the rate of Internet penetration among these regions, it is not very intuitive to infer that the diffusion process of Internet in the African continent responds to an S-shaped behavior pattern.

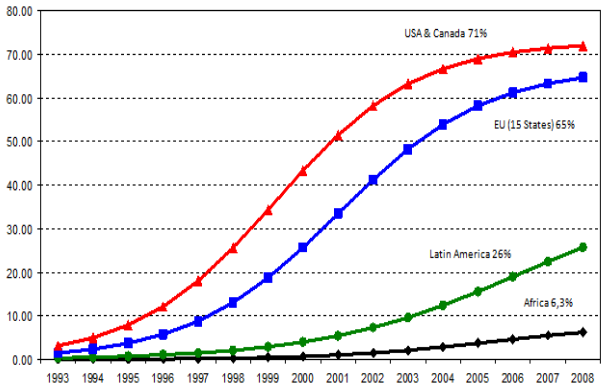

Figure 5. Comparison of Internet S-shaped diffusion in different world regions.

Once we represent only the African curve, then it becomes clear that there is also an S-shaped diffusion pattern in Africa.

The main reason of this apparent contradiction is that in the African continent Internet is still being used only by innovator-early-adopter people, while that in other regions of the world Internet is used by the majority of the population. In other words, Internet diffusion rates in all the regions of the world show an S-shaped behavior pattern. However, each of these areas are in different phases of the diffusion process.

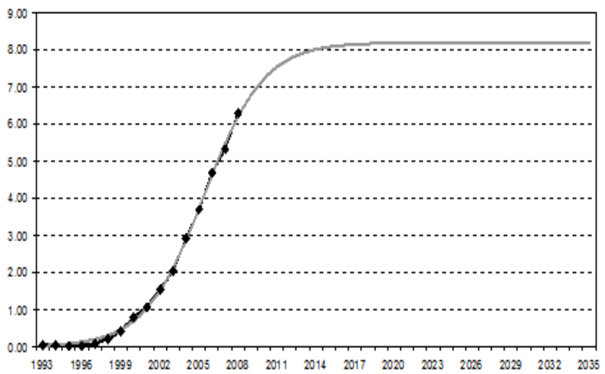

Figure 6. Internet S-shaped diffusion and prediction of future Internet users´ percentage in Africa.

Figure 6 not only shows the evolution of the Internet diffusion process in Africa, it also reflects the prediction of the future percentage of Internet users in Africa, which is the core added value of this paper. In this figure, the black curve represents the historical data of the Internet diffusion in African countries, while the grey line reflects the prediction of the future evolution of the Internet diffusion process in the African continent.

Table 1 contains the information concerning to the estimated parameters of the Internet diffusion model per regions. By using SPSS we have predicted the maximun (potential) percentage of Internet users not only in Africa, but also in Latin America, the European Union (15 States), and the USA and Canada.

The estimated parameters of the Internet diffusion model per regions can be observed in the following table.

Estimated parameters of Internet diffusion model per regions				
Region	δ_0	δ_1	δ_2	R^2
Africa	8.199	-5.903	0.440	0.999
Latin America	39.596	-5.356	0.352	0.990
EU – 15 States	67.086	-5.672	0.472	0.999
USA&Canada	72.956	-5.101	0.498	0.997

Table 1. Estimated parameters of the Internet diffusion model per regions

The most relevant results of the estimated parameters included in table 1 is that, *ceteris paribus*, the maximun percentage of Internet users (represented by δ_0) will be an 8.199 percent in Africa, a 39.596 percent in Latin America, a 67.086 percent in the European Union of 15 States, and a 72.956 percent in USA and Canada.

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