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"The broadband diffusion process and its determinants in Algeria: A simultaneous estimation"

Radia Bacha and Farid Gasmi

Toulouse School of Economics

The broadband diffusion process and its determinants in Algeria: A simultaneous estimation*

Radia BACHA
ENSM and TSE-UT Capitole

and

Farid GASMI
TSE-UT Capitole

Abstract

Digital transformation engendered by ICT advances, most notably broadband, pertains to many sectors that are known to drive economic development. This paper seeks to highlight market structure, institutional, and socio-economic factors that influence broadband adoption in Algeria. We apply to a novel 2003-2019 database a procedure that simultaneously, instead of sequentially as typically done, selects the best among the Bass, Gompertz, and Logistic innovation diffusion models estimated with Nonlinear Least Squares and searches for significant determinants of broadband adoption. We find that the data fits reasonably well the Gompertz and Logistic distributions with the latter outperforming the former not only from a statistical standpoint but also and more importantly for it captures Algeria's significant delay in the diffusion of broadband due to the social turmoil of the 1990 years' decade. We identify some policy levers for fostering ICT applications. We find that the degree of concentration has a U-shaped impact on broadband adoption and that institutional quality, mobile broadband introduction, and tertiary education enrollment have a positive impact. These findings suggest that broadband adoption in Algeria can be expected to gain from encouraging entry with differentiated broadband services through higher-generation access technologies, improving regulatory governance, and enhancing digital literacy through higher education.

JEL-Codes: L51, L86, L96, O2, O14, O33, O55.
Key words: Broadband, Digital transformation, Innovation diffusion models, Regulation, Competition.

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1. Introduction

It is by now well recognized that digital transformation enabled by information and communication technology (ICT) is an important driver of economic growth both in developing and developed countries (Niebel, 2018; Nair et al., 2020). The literature that provides evidence on the ICT-growth link is rich and diversified from the conceptual, methodological, and policy implications perspectives. It comprises the early work on the economic role of the telecommunications industry (Röller and Waverman, 2001; Baily, 2002; Waverman et al., 2005) and of the more recent innovations in ICT (Adeleye and Eboagu, 2019; Sarangi and Pradhan, 2020). ICT has indeed been widely recognized as playing an important role in transformations of major sectors of the economy.

For example, an impressively large literature has analyzed the nexus between financial development, financial inclusion, ICT, and economic growth both at international cross-country and specific-country levels (Cheng et al., 2021; Pradhan et al., 2021). This literature has reached the conclusion that Fintech, i.e., ICT that seeks to improve and automate the delivery and use of financial services, is an important channel for development and this is particularly so for developing countries where the availability of digital means of payments is considered as one of the most attractive policy solutions to the weakness of financial inclusion (Chu, 2018; Mas, 2018; Chuen and Deng, 2018).[1]

Finance is only one but many areas of the economy where digitalization has emerged as a major phenomenon. A mushrooming literature has examined the role of ICT in various other key aspects of economic development. For example, some authors have explored the environmental and sustainable development dimension of ICT (Asongu et al., 2017 and 2018; Avom et al., 2020; Lange et al., 2020; Lahoual et al., 2021; N'dri et al., 2021). Others have investigated its impact on health, the practice of medicine, and the provision of medical care (Collste et al., 2006; Donoghue and Herbert, 2012; Ayanlade et al., 2018; Sheikh et al., 2021).

[1] Some studies have focused on the precise form of the digitalization/ICT diffusion-financial inclusion relationship in some specific countries or regions, including Kanungo and Gupta (2021) for India and Mignamissi and Djijo (2021) for African countries. Interestingly enough, using a database on worldwide countries, Chien et al. (2020) find evidence of a nonlinear relationship. While the bulk of this literature has examined the role of the diffusion of global ICT in financial development, some papers, including Bharadwaj and Suri (2020) and Tyce (2020), among others, have focused on mobile innovations applications that have gained much popularity in developing countries, such as the success story of the Kenyan private mobile operator Safaricom's M-Pesa service launched in 2007. Recent contributions along these lines include Lashitew et al. (2019), Phuc Nguyen et al. (2020), and Asongu et al. (2021b). Another interesting stream of this literature has attempted to evaluate the impact of Fintech on the performance of the financial industry. Arner et al. (2017) and Anagnostopoulos (2018) discuss how Regtech, i.e., the use of ICT in the context of monitoring, reporting, and complying with regulatory rules is reshaping financial regulation with the goal of establishing better financial systems. As to Setor et al. (2021), they ask the question of whether or not Fintech reduces corruption in developing countries and Lee et al. (2021) analyze the impact of Fintech innovations on bank efficiency in China.

Education and gender inclusion has also been scrutinized in light of the recent advances in ICT (Tchamyou et al., 2019; Asongu et al., 2021a; Voss et al., 2021). Last but not least, there exists a large stream of the literature that has examined the social contract in the era of digitalization, more specifically, its impact on the quality of institutions (Khan et al., 2021; Park and Kim, 2019; Uyar et al., 2021) and on the governments' provision of public services to citizens (Agostino et al., 2021; Dhaoui, 2021).

This abundant literature on digital transformation that some major economic sectors have experienced points to the importance of ICT for economic development. It thus suggests that the stake of ICT adoption is tremendously large for both developed and developing countries, and particularly so for the latter. This has led to a rich literature that has analyzed the market structure, institutional, and technological factors that affect ICT diffusion in developed and developing countries and a stream of it has used the so-called "innovation diffusion models" (Gruber, 2001; Gruber and Verboven, 2001; Andrès et al., 2010; Lee et al., 2011; Gruber and Koutrompis, 2013; Jha et Saha, 2020; Na et al., 2020). This paper seeks to contribute to this stream of the literature.

More specifically, using a novel database on broadband in Algeria, we attempt to characterize the adoption process of this ICT service and highlight some of its market structure, institutional, and socio-economic determinants.[2] Unlike most developing countries where many important events related to the development of broadband took place in the early 1990s, for social and political instability reasons, in Algeria they got delayed up until late 1990s-early 2000s. Our empirical investigation relies on an algorithm that, in view of the data, searches simultaneously for the best among the Bass, Gompertz, and Logistic models of innovation diffusion and significant predictors of broadband adoption in this country.[3] This procedure turned out to yield results that are superior to those obtained with the standard approach in which the model selection and estimation steps are performed sequentially.

This paper is organized as follows. Section 2 highlights some significant economic and institutional events that led to the emergence of broadband in Algeria. Section 3 discusses some related literature. The next three sections are devoted to the empirical analysis. In section 4 we describe the data and the steps of the empirical analysis. Section 5 presents the econometric regressions that we estimate and Section 6 presents and discusses the results. Section 7

[2] In 2020, The World Bank classified Algeria as a MENA region lower-middle income country with a GDP per capita of 3,310 current USD.
[3] From the empirical tools point of view, we borrow from the standard "harmless" econometric approach discussed in Angrist and Pischke (2008).

concludes by summarizing the paper, addressing policy implications, and pointing to some directions for further research. The appendix gives some complementary material.

2. A brief overview of the reforms that led to the emergence of broadband in Algeria

As in many parts of the planet, the current ICT sector in Algeria has resulted from a series of policy decisions that can be regrouped into four sets according to their objectives.[4] The first set of decisions, that in most developing countries were made in the 1990s but for social and political instability reasons got delayed until the 2000s in Algeria, consisted in deep structural reforms of its traditional telecommunications sector.[5] Indeed, in light of technological advances and the wave of liberalization policies launched around the world, Algeria initiated a path of reforms to meet a number of pressing needs, in particular, to encourage the emergence of effective competition to promote a rich offer of services based on ICT and to reduce the digital divide. The liberalization of the industry led to the licensing of fixed and mobile telephone services from 2001 onwards.

The second set of policy initiatives aimed at paving the road, through the promulgation of legal orders and the deployment of advanced technologies, for the emergence of a modern electronic communications sector supported by the development of Internet services, thus anticipating the transition to a digital economy. This transition was sustained by the promulgation in 1998 of the 98-257 decree that defined the conditions and terms under which any entrant to the Internet segment, that was then in gestation, could offer services for commercial purposes.[6] In parallel with the measures applied in 1998 followed by the reforms of the 2000s that were permitted by the 2000-03 law, in its quest for a prosperous development of a digital economy, Algeria updated its regulatory framework by the promulgation of the 18-04 law. This law has, among other things, paved the road for a partial unbundling of the incumbent Algérie Télécom (AT)'s local loop so as to allow new entrants to use it. This measure was indeed considered as necessary for the development of Internet access.

The third set of policy measures were targeted at accelerating the pace of digitalization by investing in modern networks and creating the structural conditions to further facilitate entry of new actors into the industry. This entailed accelerating the deployment of Internet access

[4] Table A.1 in the appendix provides some landmarks on the evolution of the Algerian ICT sector while Figure A.1 gives a broad picture of how the Algerian ITC industry structure has evolved.
[5] This traditional sector was shaped by more than a century of French colonial heritage and over four decades of a centrally planned economy before getting liberalized in 1988.
[6] Indeed, even though the drafting of liberalization texts was done relatively early, effective entry of new actors remained somewhat weak. One of the reasons invoked is the quasi-absence of Algerian Internet service providers' access to international backbone networks (Noumba Um, 2006).

technologies.[7] Traditionally made possible by the PSTN technology in the early 2000s, Internet access evolved to satellite technologies, including VSAT and GMPCS, and ADSL for broadband in the mid-2000s. Finally came the 4G LTE and FttP offers for superfast broadband in 2014 and 2018 respectively (ARPCE, 2019). In addition to Internet services offered on the fixed network, offers based on 3G and 4G technologies have been introduced via mobile networks in 2013 and 2016 respectively.[8]

Finally, the goal of the fourth set of policy measures was to expand the scope of digitalization. In parallel to the massive investments that have been made to increase access to ICT services, ambitious strategies aimed at strengthening the digitalization of the Algerian economy have been pursued. To encourage innovation in the use of ICT, the government entrusted the realization and management of multiple technological parks. Moreover, to achieve objectives that open up the way to developing a sustainable digital economy, Algeria defined a multi-sectorial plan entitled "e-Algeria" (MPPTN, 2008) that specified a set of actions to implement a strategy aimed at spreading access to and use of ICT by public administrations, businesses, and citizens.[9]

3. Related literature

This paper seeks to contribute to the literature that analyzes the determinants of ICT services adoption, both in developed and developing countries, relying on models of diffusion of innovations. Studies belonging to this literature have typically examined the process of ICT diffusion by estimating the key parameters, in particular, the rate of diffusion, of the Bass, Gompertz, and Logistic models and analyzing how these parameters respond to economic and

[7] Investments were made to upgrade national and international network infrastructures. Regarding the national network, AT first expanded its transport network, particularly in optical fiber, then its access network by gradually replacing copper with optical fiber and replaced obsolete equipment. Regarding the international network, Algeria has invested in its bandwidth supply over the international transport network, which consists of submarine cables in the Mediterranean Sea as well as land and satellite links. These investments were accompanied by efforts to price efficiently network interconnection services. See Bacha and Gasmi (2018) for a first attempt to analyze the properties of AT's leased lines pricing policy.

[8] As to the 5G, expected to be launched in 2023, its introduction has been the object of debate for the last couple of years. In 2018 Algérie Télécom Mobile (ATM), a subsidiary company of AT, conducted with success some testing of super high-speed access that reached 1.18 Gbps with the support of its Chinese technological partner Huawei (https://www.do4africa.org/projects/infrastructures-numeriques/6803/5g-en-algerie/).

[9] Some initiatives related to e-administration have been launched, namely, the dematerialization of the procedure of documents request through platforms such as www.interieur.gov.dz and www.mjustice.dz, the digitization of vital statistics files, and the social security card with a significant reduction in the management of care sheets (Jankari, 2014). In addition to online registration platforms available to academics, scientific research has also been able to take advantage of these digitalization initiatives with the creation of the multidisciplinary virtual library SNDL. Finally, schemes for the promotion of e-commerce and digital payment have been implemented.

institutional factors so as to be able to draw some policy implications (Andrés et al., 2010; Gupta and Jain, 2012; Na et al., 2020).

One stream of this literature has sought to track the pattern of this process with, sometime, the purpose of forecasting as accurately as possible future ICT diffusion. Gamboa and Otero (2009) have examined the diffusion pattern of mobile telephony in Colombia using the Gompertz and Logistic models and found that the latter better fits the Colombian data. Using these same models, Singh (2008) has analyzed the pattern and rate of adoption of mobile telephony in India and selected the Gompertz model. The author then has used it to highlight future trends of mobile telephony diffusion in this country.

Michalakelis et al. (2008) have analyzed the diffusion of mobile telephony in Greece by comparing the performance of the Bass, Gompertz, Logistic, Flog, Box-Cox, and the Tonic models and argued that the Bass model fits the data reliably enough to be used to forecast telecommunications penetration in this country. Using data from European countries, Turk and Turkman (2012) have estimated the Bass model that they claim is better suited than the Gompertz model as the former explicitly distinguishes between first adopters and imitators of the innovation whereas in the latter the innovation diffusion occurs solely through imitation.

Using a Logistic model, Gruber and Verboven (2001) have found evidence of a positive impact of competition on the diffusion of mobile telecommunications services in 15 member states of the European Union. This result is supported by Gruber and Koutroumpis (2013) who analyze a data on a sample of 167 worldwide countries by means of a model inspired by the "epidemic" approach used by Gruber and Verboren (2001) and Bouckaert et al. (2010). These authors highlight the debate on the impact on broadband roll out of inter-platfom (network) versus intra-platform (unbundling and retail service) competition.[10] Using the Herfindahl concentration index as a proxy for competition, Hwang et al. (2009) have found that the decrease of market concentration, that may be interpreted as an increase of competition, increases the diffusion speed of mobile telephony in Vietnam.

The quality of institutions and public services to citizens and its impact on broadband adoption has also drawn the interest of researchers. Teklemariam and Kwon (2020) argue that higher quality of e-government services and degree of corruption management have a positive impact on mobile broadband adoption, especially, in the fast growth and saturated stages of the diffusion process. Gulati and Yates (2012) find that more democratic political institutions favor

[10] Bohlin et al. (2010) have used the same model to examine the impact on Internet/broadband penetration of competition accounting for different generations of mobile technologies. These authors found some nonmonotonic effects.

broadband adoption, in particular, in technologically advanced countries. In their analysis of the determinants of mobile broadband adoption in a panel of countries worldwide, Yates et al. (2013) find that some countries have achieved high levels of adoption even though their governments faced significant corruption problems.

Some papers have explored the issue of whether technological change is a significant determinant of ICT diffusion. In their analysis of broadband adoption in India, Jha et Saha (2020) argued that an upgrade of the mobile network infrastructure from the 3G to the 4G should be imminent considering the decline in the speed of diffusion of the former. As to Gruber and Verboven (2001), they found that the transition from analogue to digital technology and the increase of capacity has had a positive and significant impact on the diffusion of mobile telephony in their sample of European Union countries. By contrast, Hwang et al. (2009) provide evidence for a substitution effect from mobile telephony to data services in Vietnam.

The importance of population cultural and educational skills for the promotion of ICT services have also been investigated. Lee et al. (2011) have found that the level of education is an important driver of fixed broadband diffusion in OECD countries but that its impact on mobile broadband is not statistically significant. However, in their more recent study on India, Jha and Saha (2020) argue that introducing initiatives aimed at increasing e-literacy should accentuate the uptake of mobile broadband services across the various social strata of the population. Finally, Na et al. (2020) find that in both developed and developing countries, highly urbanized populations experience greater speeds of diffusion of fixed broadband.

Along the lines of the literature that we have attempted to survey in this section, this paper seeks to analyze the process of adoption of broadband in Algeria as revealed in data from the last two decades. This paper has a double objective. The first is explicit and is to uncover the pattern of this process and some of its market structure and institutional determinants. The second is implicit as the analysis of the process of broadband adoption in Algeria can be seen as an attempt to evaluate the performance of the various policy instruments that this country has implemented to push up this process that is intimately linked to the development of a digital economy.

4. Data and outline of the empirical analysis

Our data collecting endeavor consisted in gathering information on variables that would allow us to estimate policy-relevant market structure (MS) and institutional quality (IQ) factors that significantly influence broadband adoption (BA) in Algeria while controlling for some other factors ($CTRL$) such as the country's population e-literacy and the degree of urbanization. Given the recent social instability in Algeria, we had to rely on national as well as international data sources. Concerning the data sources in Algeria, we were fortunate enough to put our hands on some reports published periodically by the regulatory authority, ARPCE, and to have remote interviews with industry economists that allowed us to complete some missing portions of our database.[11] As to the international sources, we extracted data from databases compiled by various organizations, including the International Telecommunications Union, The World Bank, The United Nations, Transparency International, and The Brookings Institution.

The single most important piece of raw information that we gathered is cumulated broadband adoption in Algeria from 2003 to 2019. This represents the dependent variable of the econometric models that we have specified, and it is denoted A. This stock variable allowed us to calculate the flow variable, denoted a, which represents instantaneous adoption. Thus, given our discussion of the previous paragraph, $BA \in \{A, a\}$. It is worthwhile noting that the 17-year period of our data sample encompasses the two decades in which the main events that have shaped the contemporary Algerian ICT sector discussed in the previous section have taken place.

For market structure, we computed the market shares of the Algerian operators and constructed the Herfindahl-Hirschman index (HHI). Recall that this index measures the degree of market concentration, which typically affects the level of competition, and hence the extent of market power. We also allowed for a possible nonlinear effect of competition as measured by the degree of concentration. Thus, $MS \subset \{HHI, HHI^2\}$. As for institutional quality, we choose to use three candidate-indices that respectively measure corruption perception, $Corrp$, regulatory quality, Reg, and government effectiveness, Gov. Thus, $IQ \in \{Corrp, Reg, Gov\}$.

We also controlled for some possible effects of major improvements in access technology, quality of network, population e-literacy, and rural versus urban population through, respectively, the date of introduction of 3G mobile broadband, Mob, the percentage of people possessing a fixed line, $Fixed$, the percentage of people enrolled at a university, $Educ$, and the percentage of people living in urban areas, Urb. Thus, $CTRL \subset \{Mob, Fixed, Educ, Urb\}$. Table A.2 in the appendix gives the complete list of the variables on which we gathered data, their designations, the sources, and their precise contents. Table A.3 and A.4 in the appendix give respectively some summary statistics of the variables representing our dataset and the correlations between pairs of these variables.

[11] ARPCE: Autorité de Régulation de la Poste et des Communications Électroniques.

We analyzed this dataset in two steps the details of which are described in Figure A.2 given in the appendix. This figure describes our empirical strategy and shows in the extreme right the new procedure that we propose to select the best diffusion model. Starting from the left of the figure, the first two columns show the steps relying on the "reduced"-form approach and the last three show those relying on a "structural"-form approach.

More specifically, an approach is qualified as structural if the process of broadband diffusion is assumed to follow one of the models of diffusion of innovations whereas in the reduced approach this process is at best thought of it as implicit. We perform two reduced-form exercises that consist in searching, through the loop referred to as "Loop 1" in Figure A.2, for the best econometric specification of a model that predicts adoption using the market structure, institutional quality, and control variables discussed above. The selection of the best model is done on the basis of standard statistical performance criteria, namely, significance, goodness-of-fit, and accuracy. As indicated in the figure, these two reduced-form analyses follow Estache et al. (2002) and are differentiated only by the dependent variable used, namely, adoption or relative rate of adoption.[12]

The third column introduces the structural approach, used in Hwang et al. (2009) and Jha and Saha (2020), that allows to investigate the broadband diffusion process using as candidate the popular Bass, Gompertz, and Logistic probability distributions, sometime referred to as "pandemic" diffusion models.[13] In this approach, the analysis is done sequentially in two steps. In a first step, referred to as "static" analysis in the Figure A.2, we perform "Loop 2" that estimates these models by means of nonlinear least squares (NLS) using ordinary least squares (OLS) estimates as initial values and selects the model that best fits the data. In a second step shown in the fourth column, we introduce "dynamics" by expressing the rate of adoption as a linear function of the MS, IQ, and $CTRL$ variables and applying Loop 1 to determine what the best econometric specification of this selected model is.

The fifth column presents the new procedure that we perform. Instead of first determining through Loop 2 the best model prior to parameterization and then its best econometric specification through Loop 1, as typically done in the studies mentioned above, we integrate these two loops into a single algorithm. More specifically, for any of the three models, we parameterize the rate of broadband adoption, run NLS, store the values of the performance criteria, and simultaneously select the best model of broadband adoption and its

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[12] Caselli and Coleman (2001) use a similar reduced-form approach to analyze the diffusion of computers in the US.

[13] See also Gupta and Jain (2012) and Sultanov et al. (2016), among others.

best econometric specification. It turns out that not only the model selected by sequentially running Loops 1 and 2 is different from the one selected by simultaneously running them, but also, the latter outperforms the former from both a statistical and an economic intuition standpoint.

5. Econometric specifications

For all practical purposes, we recall in Table 1 below the definition of the different variables of the models that we estimate.[14]

Table 1 - Variables and definitions

Variable	Definition
BA	Broadband adoption
A	Cumulated broadband adoption
a	Instantaneous broadband adoption
MS	Market structure
HHI	Herfindahl-Hirschman index
HHI^2	Herfindahl-Hirschman index squared
IQ	Institutional quality
$Corrp$	Corruption perception index
Reg	Regulatory quality index
Gov	Government effectiveness index
$CTRL$	Controls
Mob	Mobile broadband dummy
$Fixed$	Fixed line penetration rate
$Educ$	Enrollment to tertiary education
Urb	Urban population ratio

As indicated in the previous section, the first two exercises that we perform follow Estache et al. (2002). The first exercise consists in running Loop 1 in order to select the best linear regression, f, of the form:

$$A_t = f(MS_t, IQ_t, CTRL_t, A_{t-1}) + u_t \tag{1}$$

where t refers to the period, A_t is cumulated adoption in that period, $MS_t \subset \{HHI_t, HHI_t^2\}$, $IQ_t \in \{Corrp_t, Reg_t, Gov_t\}$, $CTRL_t \subset \{Mob_t, Fixed_t, Educ_t, Urb_t\}$, A_{t-1} is one-period lagged cumulated broadband adoption, and u_t is an additive error term.[15] The regression

[14] See Table A.2 in the appendix for more details on these variables.

[15] Appending the one-period lagged dependent variable as an independent variable to a fairly standard linear regression allows one to capture network externalities through a reduced form of a Gompertz-type diffusion model with a constant speed of adjustment. A statistically significant coefficient associated with this lagged variable

selection procedure is based on OLS estimation, individual-coefficient and overall statistical significance as tested with t- and F-statistics, goodness-of-fit as measured by the adjusted coefficient of determination, $\bar{R}^2$, and accuracy as measured by the root-mean-square error, $RMSE$.

The second exercise runs Loop 1, but using as a dependent variable the growth rate of cumulated adoption relative to the fraction of potential broadband adopters who have not yet adopted, $\tilde{A}$, given by:[16]

$$\tilde{A}_t = g(MS_t, IQ_t, CTRL_t) + u_t \tag{2}$$

for $t = 1,2,\ldots,T$, where g is a linear function and

$$\tilde{A}_t \equiv \frac{[A_t - A_{t-1}]/A_t}{[A_T - A_t]/A_T} \tag{3}$$

The purpose of these two preliminary exercises is to explore by means of a standard reduced-form regression approach the properties of the data, more specifically, get a sense of the impact of the (independent) variables MS, IQ, and $CTRL$ on the (dependent) variables BA. We now introduce the structural-form approach. We succinctly present the three diffusion models that we use to track the broadband adoption process and spell out the corresponding equations that we estimate with OLS and NLS, the former being applied to obtain estimates that are used as initial values when applying the latter.[17]

A key building block of the Bass model of technology adoption is the assumption that there exists a potential population of adopters constituted of two categories according to what leads them to adopt, namely, "innovators" and "imitators." The innovators are the earliest adopters who gather information about the new innovation through formal channels of communications while the imitators rely on informational sources such as interpersonal interactions and direct observationof the innovation. Formally, this model stipulates that at any

which is positive and less than one is evidence of the existence of such an autonomous process (Kiiski and Pohloja, 2002; Estache et al. 2002; Andrès et al, 2010).

[16] Lee et al. (2011) specify a similar linear equation as a reduced form of a Logistic-type diffusion model.

[17] This presentation of the Bass, Gompertz, and Logistic diffusion models and their econometric implementation is not meant to be exhaustive. The reader interested in the technical details of these diffusion models should refer to Bass (1969), Mahajan et al. (1986), Srinivasan and Mason (1986), and Rogers (1995), among others. Some of those are gathered in the appendix.

given time the fraction of the potential adopter, given that they have not adopted yet, is linear in the population of previous adopters. In our context, this hypothesis is expressed as:

$$\frac{a_t/M}{1-(A_t/M)} = p + \left(\frac{q}{M}\right)A_t \tag{4}$$

where M is the population of potential adopters, i.e., the number of adopters at market saturation and $p, q > 0$ are respectively the coefficients of innovation and imitation.

In the static approach, we estimate the structural parameters of the Bass model p, q, and M using NLS. However, as discussed in Satoh (2000), since the standard errors in the NLS procedure are based on asymptotic approximations, where parameter estimates may sometime be very slow to converge, the final estimates may be sensitive to the starting values. One way to lessen this difficulty is to use OLS estimates obtained from the regression:

$$a_t = Mp + (q-p)A_{t-1} - (q/M)A_{t-1}^2 + u_t \tag{5}$$

as starting values. Given that $a_t \equiv A_t - A_{t-1}$, the regression to which we apply NLS to estimate the Bass model is given by:[18]

$$a_t = h^{Bass}(t; M, p, q) + u_t \tag{6}$$

where

$$h^{Bass}(t; M, p, q) \equiv M\left[\frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}} - \frac{1-e^{-(p+q)(t-1)}}{1+\frac{q}{p}e^{-(p+q)(t-1)}}\right] \tag{7}$$

In the dynamic approach to the estimation of the Bass model, we parameterized the imitation parameter as $q_t = l(MS_t, IQ_t, CTRL_t)$ where, as indicated above, $MS_t \subset$

[18] In addition to taking total error into account and providing a best fit in terms of root-mean-square error, the use of NLS is further justified by its capacity to overcome the time interval bias present in OLS when applied to a discrete time approximation of a continuous model (Mahajan et al., 1986). Jain and Rao (1990) suggest $a_t = [M - A_{t-1}][(A_t - A_{t-1})/M] + u_t$ as an alternative econometric specification. Note that, contrary to Equation (6) that gives an $ex\ ante$ value for a_t, Jain and Rao (1990)'s formulation utilizes $ex\ post$ information on a_t, the probability that an individual who has not adopted up to $t-1$ will adopt in t, namely, $(F(t) - F(t-1))/(1 - F(t-1))$ where F is the Bass cumulative distribution (see the appendix). However, Mahajan et al. (1986) argue that Equation (6) is likely to yield more reliable results, in particular, when focusing on predictions.

$\{HHI_t, HHI_t^2\}$, $IQ_t \in \{Corrp_t, Reg_t, Gov_t\}$, and $CTRL_t \subset \{Mob_t, Fixed_t, Educ_t, Urb_t\}$ and apply NLS to the regression:

$$A_t = k^{Bass}(t; M, p, q_t) + u_t \tag{8}$$

where

$$k^{Bass}(t; M, p, q_t) \equiv M\left[\frac{1 - e^{-(p+q_t)t}}{1 + (q_t/p)\, e^{-(p+q_t)t}}\right] \tag{9}$$

The Gompertz and Logistic models are "internal influence" models in the sense where later adopters learn from early adopters and diffusion is only limited to the process of imitation (Yamakawa et al., 2013).[19] These models' structural parameters are q, M, and K where the later is a shift parameter.[20] In the static approach, the regressions to which we apply OLS to obtain initial values for NLS are given by:

$$a_t = q\, ln(M)\, A_{t-1} - q[A_{t-1}\, ln(A_{t-1})] + u_t \tag{10}$$

and

$$a_t = q\, A_{t-1} - (q/M)\, A_{t-1}^2 + u_t \tag{11}$$

for the Gompertz and Logistic models respectively. As to the nonlinear equations to which we apply NLS, they are given by:

$$a_t = h^{Gompertz}(t; M, K, q) + u_t \tag{12}$$

where

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[19] In the economic literature, the Gompertz and Logistic models have been popularized by Griliches (1957), Mansfield (1961), Chow (1967), Dixon (1980), and Franses (1994a and 1994b), among others. These models have been widely applied in the study of the diffusion of various innovations and products. See Sultan et al. (1990) for a meta-analysis of their applications.

[20] The value of this parameter gives the magnitude of shift of the S-shaped curve upward if it is positive and downward if it is negative. It represents the constant of integration of the differential equations that define the models and, in our context, it corresponds to the initial value of broadband adoption. The larger the value of this parameter, the slower the adoption rate, and the larger the time lag before the adoption process starts (Jaakkola et al., 1998).

$$h^{Gompertz}(t; M, K, q) \equiv M\left[e^{-e^{-(K+qt)}} - e^{-e^{-(K+q(t-1))}}\right] \tag{13}$$

and

$$a_t = h^{Logistic}(t; M, K, q) + u_t \tag{14}$$

where

$$h^{Logistic}(t; M, K, q) \equiv M\left[\frac{1}{1+e^{-(K+qt)}} - \frac{1}{1+e^{-(K+q(t-1))}}\right] \tag{15}$$

In the dynamic approach, the regressions used for the Gompertz and Logistic models are respectively given by:

$$A_t = k^{Gompertz}(t; M, K, q_t) + u_t \tag{16}$$

and

$$A_t = k^{Logistic}(t; M, K, q_t) + u_t \tag{17}$$

where

$$k^{Gompertz}(t; M, K, q_t) \equiv M\left[e^{-e^{-(K+q_t t)}}\right] \tag{18}$$

and

$$k^{Logistic}(t; M, K, q_t) \equiv M\left[\frac{1}{1+e^{-(K+q_t t)}}\right] \tag{19}$$

To conclude this section, recall that the curves corresponding to these three models are S-shaped. In the Bass adoption framework, the maximum rate of adoption, i.e., the inflexion point of its sigmoid curve, is reached when slightly less than half of the total number of potential adopters has effectively adopted. As to the Gompertz adoption distribution, the time at which the rate of adoption switches from increasing to decreasing occurs earlier than at half the saturation level. Finally, the Logistic distribution is symmetric, i.e., the inflection point of its curve located at precisely half the potential market. In short, the maximum adoption rate is attained in the chronological order Gompertz-Bass-Logistic.

6. Results

The objective of the first stage of our empirical analysis is to pin down through simple regressions the relationship between broadband adoption and market, institutional, and control variables while accounting for a possible existence of an autonomous broadband diffusion process. These regressions are similar to the ones used by Estache et al. (2002). However, we should say at the outset that while these authors examine two panels of countries, one worldwide and another Latin American, we are only concerned with Algeria, a lower-middle income developing country. Moreover, while these authors have performed their analysis using two proxies for Internet adoption (the dependent variable), namely, Internet usage and Internet hosting, we only use the former. Consequently, the comparisons of our results to those of Estache et al. (2002) will be at best appropriate when we examine these authors' analysis of Internet use in Latin America.

Applying Loop 1 to the regression of the general form given in Equation (1) yields the results exhibited in Table 2 below.[21] For the purpose of somewhat comparing these results to those of Estache et al. (2002), except for the dummy Mob, we transformed the variables of this regression into their natural logarithms.[22] An outstanding result is that, in contrast to these authors who found little evidence to support the view that Internet adoption follows an autonomous Gompertz diffusion process in Latin America, our results for Algeria are more in line with those of Andrés et al. (2010) and Kiiski and Pohjola (2002), although the latter used the number of Internet hosts per capita as the dependent variable.[23] Indeed, we found that the diffusion coefficient has a positive value that is smaller than one and is highly significant.[24] More specifically, we found that this coefficient is equal to 0.44 saying that a 10% increase in

[21] In all the tables that show the results, we attach respectively one, two, three, and four stars to a coefficient to indicate that it is statistically significant at the 20, 15, 10, and 5 percent level or less.

[22] Also, given the time-series nature of the data, we run unit-root stationarity and autocorrelation tests and, when needed, took the required differences.

[23] Andrés et al. (2010) provide several explanations of Estache et al. (2002)'s result. They also refer to Kiiski and Pohjola (2002) and Goolsbee and Klenow (2002) that do not reject the hypothesis of the existence of an exogenous Gompertz diffusion process.

[24] See footnote 15.

the number of broadband users at a given period leads to an increase of 4.4% in the following period. Interestingly enough, these figures are of the same order of magnitude as those reported by the above authors.

Table 2 - OLS parameter estimates of broadband adoption (A)

Variable	Coefficient	Std. Dev.
$Cste$	0.17^{****}	0.08
MS		
HHI	-0.47^{**}	0.33
IQ		
Reg	0.07^{**}	0.04
$CTRL$		
Mob	-0.50	0.40
$Diffusion$		
A_{-1}	0.44^{****}	0.11
$Obs.$ 66		
$F(4, 61)$ 7.69		
$\bar{R}^2$ 0.29		
$RMSE$ 0.14		

As to the other independent variables selected by Loop 1, we found that the degree of concentration has a negative and significant impact, suggesting that during the 2013-2019 period spanned by the data the lessening of market power that followed liberalization in Algeria has unambiguously favored broadband adoption. Given that privatization, typically included in a reform package next to liberalization and regulation, is supposed to minimize the adverse effects of market power on users' welfare, this result contradicts to some extent Estache et al. (2002) who have found that it had no effect on Internet diffusion in Latin America.

In the same vein, Kiiski and Pohjola (2002) and Andrés et al. (2010) find no remarkably significant effect of competition in low-income countries, although the former argue that competition can be expected to have a positive effect on adoption solely to the extent that it translates into actual lower access costs and the latter assess this effect only relative to high-income countries.[25] Institutional quality improvement, as reflected in a higher value of the regulatory governance index in our analysis, has also been found to have a positive and significant impact on broadband in the data. This result contradicts Estache et al (2002) too who claim that "… it is difficult to find any independent effect of regulator presence."

A couple of relatively disappointing results came out of this estimation of a reduced form of the Gompertz model. We see from Table 2 that the variable that indicates the

[25] These contradicting results have provided us with further motivation to investigate this competition effect.

introduction of mobile has a negative, albeit not statistically significant, coefficient. For the case of Algeria, this clearly seems counter intuitive. Indeed, given the turmoil in which the market for fixed Internet access was during the first decade of the 2000s and the rather low quality of the service provided during that period, the effective introduction of 3G in 2014 has considerably facilitated broadband adoption. As such, it could be perceived as having lowered access costs and thus be expected to have a positive impact.

Hence, our result somewhat contradicts Estache et al. (2002) who report that Internet access cost is a relevant determinant of adoption. Nevertheless, as we'll see later in our investigation that this variable will become significant. Also, while Estache et al. (2002) and Kiiski and Pohjola (2002) find that access to personal computers has a positive effect, the closest variable that we used, namely, enrollment to tertiary education, turns out not to be picked up by the regression selection loop. Again, we will see later that this variable emerges as a significant determinant of broadband adoption in Algeria.

In the spirit of Lee et al. (2011), we estimate Logistic-type reduced form regression with the growth rate of cumulated adoption relative to the fraction of potential broadband adopters who have not yet adopted as the dependent variable. Table 3 below shows the results obtained by running Loop 1 for Equation (2). We find that despite the fact that, overall, this model performs slightly less than the previous one based on the standard criteria, the degree of concentration has a statistically significant nonlinear effect. This suggests that competition has had an inverse U-shaped impact on broadband adoption, a result that is worth highlighting and to which we will return later. Regulatory quality has also played a role, although only moderately in terms of the level of statistical significance. We should note that, contrary to us, Lee et al. (2011) found that education has a significant effect on broadband adoption.[26] We will later return to this result as well.

We now tackle the second stage of our analysis and present the results of the exploration of the institutional and market structure determinants of broadband adoption in Algeria by means of a structural approach that explicitly accounts for network effects through one of the three diffusion models discussed in the previous sections, namely, the Bass, Gompertz, and Logistic models. We will apply two different estimation algorithms, a sequential two-step model search algorithm and a simultaneous two-step model search algorithm (see Figure A.2 in the appendix). The first algorithm follows Hwang et al. (2009), Gupta and Jain (2012), Sultanov et al. (2016), and Jha and Saha (2020), among others, and consists in first running

[26] Lee et al. (2011) used the United Nations Development Program education index which combines enrollment to primary, secondary, and tertiary education.

Loop 2 that selects a diffusion model and then Loop 1 than selects the best econometric specification of this model. The second algorithm, which to the best of our knowledge has not been used in the literature, consists in merging the two loops into a single one, hence in searching for the best econometric specification across the three diffusion models.

Table 3 - OLS parameter estimates of broadband adoption relative growth ($\tilde{A}$)

Variable	Coefficient	Std. Dev.
$Cste$	1.26^{****}	0.40
MS		
HHI	-3.35^{****}	1.64
HHI^2	2.32^{****}	1.27
IQ		
Reg	0.16^{*}	0.12
$Obs.$ 66		
$F(5, 59)$ 5.39		
$\bar{R}^2$ 0.17		
$RMSE$ 0.17		

When applying the sequential algorithm using Equation (6), (12), and (14), we first run Loop 2 to search for the diffusion model fits best the Algerian data on broadband adoption. This static estimation, using NLS and OLS estimates as initial values, yields the parameter estimates of the three models given in Table 4 below. Examining these results, we see that the Gompertz model slightly outperforms the two other models.[27] Given this outcome, we then express the key parameter of the Gompertz model, namely, the rate of broadband adoption, as a linear combination of the market structure, institutional quality, and control variables and perform a dynamic NLS estimation procedure by applying Loop 1 to Equation (16). This yielded the best econometric specification for the rate of broadband adoption that is presented in Table 5 below.

Table 4 - Static NLS parameter estimates of the Bass, Gombertz, and Logistic models (a)

Model Parameter	Bass	Gompertz	Logistic
M	102^{****}	106^{****}	-102^{****}
p	$7.60\ E-07$	-	-
K	-	-7.94^{****}	12.68^{****}
q	0.24^{****}	0.16^{****}	-0.24^{****}
$Obs.$	67	67	67
$\bar{R}^2$	0.73	0.76	0.73
$RMSE$	1.51	1.41	1.51

[27] Two possible explanations for why we obtain an estimate for potential adoption greater than 100%. First, our data includes multiple users' subscriptions, which might be due to the unavailability of number portability. Second, our data aggregates fixed and mobile access to broadband services.

Table 5 - Dynamic sequential NLS parameter estimates of the Gompertz model (A)

Parameter/Variable	Coefficient	Std. Dev.
M	111.71^{****}	4.30
K	-2.54^{****}	0.27
q		
$Cste$	0.09^{****}	0.01
MS		
HHI	-0.10^{****}	0.02
HHI^2	0.07^{****}	0.11
IQ		
Reg	0.06^{****}	0.01
$CTRL$		
$Educ$	0.14^{****}	0.02
$Obs.$ 68		
$\bar{R}^2$ 0.99		
$RMSE$ 2.02		

We see from Table 5 that, as found in the reduced-form analysis of the Logistic model, this structural-form analysis of the Gompertz model using the sequential algorithm shows a nonlinear effect of market concentration. Interpreted as an inverse-U shaped effect of competition, this result says that as broadband adoption approaches saturation in Algeria, competition seems to exert less impact on the rate of adoption. An interpretation of this result may be that the Algerian broadband market is mature enough and that competition with differentiation, e.g., through the provision of very high-speed access technology is now needed to boost Broadband adoption.[28] From Table 5 we also see that the improvement of institutional quality, as reflected in better regulatory governance, and greater enrollment in tertiary education both have a significant and positive impact on the rate of broadband diffusion. These results are typically consistent with what has been reported in the related literature.[29]

When applying the simultaneous two-step model search algorithm, instead of running Loop 1 under dynamic conditions only for the Gompertz model that has been selected by Loop 2 under static conditions, we internalize Loop 1 into Loop 2. In practice, we use Equations (8), (16), and (17) to select among the Bass, Gompertz, and Logistic models under dynamic conditions. The end result of this algorithm turns out to be the choice of the Logistic functional

[28] See OBG (2018).

[29] See, e.g., Gulati and Yates (2012) and Teklemariam and Kwon (2020) for a discussion of the role of regulation.

form over the two others to describe the pattern of broadband adoption in Algeria.[30] Table 6 below exhibits the complete estimation results obtained.

Table 6 - Dynamic simultaneous NLS parameter estimates of the Logistic model (A)

Parameter/Variable	Coefficient	Std. Dev.
M	108^{***}	3.21
K	-7.63^{****}	0.83
q		
$Cste$	0.20^{****}	0.04
MS		
HHI	-0.11^{***}	0.58
HHI^2	0.09^{****}	0.05
IQ		
Reg	0.09^{****}	0.01
$CTRL$		
Mob	0.03^{***}	0.02
$Educ$	0.10^{****}	0.03
$Obs.$ 68		
$\bar{R}^2$ 0.99		
$RMSE$ 1.78		

Besides the fact that the goodness-of-fit and the overall statistical performance of the dynamic Gompertz (s eeTable 5) and Logistic (see Table 6) models are somewhat comparable, it is interesting to see that the sequential and simultaneous two-step model search algorithms produced results that convey similar broad messages. First, the nonlinear effect of market concentration suggests that competition in differentiated (higher technology) access service is expected to emerge in order to foster adoption. Second, institutional quality has also a positive impact and thus good regulatory governance should favor broadband adoption. Third, the positive impact of tertiary education enrolment puts forward the need for authorities to strengthen human development policies. We need to mention two differences though. First, the Logistic model improves accuracy by decreasing the $RMSE$ by about 12%. Second and more importantly, the introduction of mobile broadband access technology becomes a significant determinant of broadband adoption when we use the simultaneous model search algorithm that led to the Logistic model.

It is also worthwhile making a few remarks on the estimates of the parameters M and K, which reflect respectively the level of adoption at market saturation and the shift of the S-

[30] In terms of the selection of the adequate model to track the pattern of adoption of innovations, while typical country-panel data studies have privileged the Gompertz model, e.g., Andrés et al. (2010), country-specific data studies have also given consideration to the Logistic model, e.g., Chow (1967), Jaakkola et al. (1998), and Hwang et al. (2009).

shaped diffusion process. We have already alluded to what could explain the fact that the estimated value of the saturation level is greater than 100%. In fact, the empirical value achieved in the last period of our sample, namely, the fourth quarter of the year 2019, is 104%. Thus, the simultaneous algorithm outperforms the sequential algorithm in terms of estimating this parameter as can be seen from Tables 5 and 6 (108% versus 111.71%).

As to the shift parameter, we see from these two tables that the adoption process is translated downward when using both approaches, sequential and simultaneous. However, given that in the Gompertz model adoption achieves its maximum rate earlier than in the Logistic model and that the absolute value of the estimated shift parameter is greater when using the latter (2.54 versus 7.63), it appears that the process of broadband adoption in Algeria, which for political instability reasons got significantly delayed relative to most developing countries, is better described by the estimated Logistic model as shown in Table 6.[31]

7. Conclusion

This paper has estimated three of the most popular innovation diffusion models, namely, the Bass, Gompetz, and Logistic models using data on broadband in Algeria with the double purpose of highlighting the key characteristics of this ICT service's process of diffusion and the economic institutional factors that influenced it. Two features of this country's experience with ICT have drawn our attention and convinced us that its empirical analysis is worthwhile undertaking.

First, unlike most developing countries that launched the modernization reforms of their telecommunications sectors in the 1990s decade, Algeria was considerably delayed by a socially unstable situation that had severely hampered the functioning of its institutions. Second, this country has undertaken massive technological investments and a myriad of policy initiatives with the aim of filling in the digital gap of its economy vis a vis the rest of the world. These two peculiar aspects of the Algerian experience make it a not so "common" natural experiment and the econometric assessment of the role that policy makers have played in the digitalization of the economy is thus particularly challenging.

Our empirical strategy is based on a new model-search procedure that selects the best model on the basis of standard significance, goodness-of-fit, and accuracy criteria. We found that the data on the process of temporal diffusion of broadband in Algeria could be described reasonably well by a sigmoid corresponding to either a Gompertz or Logistic curve. However,

[31] Andrés et al. (2010) provide an interesting discussion of the initial phase of the diffusion of Internet worldwide during the 2000s.

the latter is found to slightly outperform the former from a statistical standpoint, but more importantly in our view, because it better reflects the historical context of Algeria, in particular, the delay of the adoption process imposed by the social turmoil in which this country was caught during the 1990s, a period referred to as the "black decade."

Our results have shown that competition has attained its diminishing returns and that institutional quality, introduction of mobile broadband, and education have all positive impact on broadband adoption. These results suggest some policy implications. On the supply side, this paper suggests that there should be large social benefits to tap on from encouraging entry of operators providing higher-generation broadband access technologies. Such a policy requires transparency and accountability which can be achieved through improving quality of regulatory governance. On the demand side, improving the level of digital literacy through higher education is clearly necessary to accompany these expected technological upgrades.[32]

A few extensions of the work accomplished in this paper are needed to consolidate the lessons learned and those entail gathering data on important variables that we couldn't put our hands on in the course of this initial empirical analysis on Algeria. First, given the recent events in this country, it seems important to give greater consideration to political economy variables.[33] We have used indices that capture corruption perception and government effectiveness, but those are likely to be too general to capture local political conditions.

Second and relatedly, it should be interesting to examine if there exists a revenue inequality effect. To be sure, we have attempted, with no success, to capture this effect through an urban population ratio, but a GINI-type index would most likely be better. Third, although the introduction of the mobile dummy variable could be seen as a way to capture the effect of facilitating Internet access, it should be better to explicitly incorporate end-user access or leased-lines cost indices. Finally, the robustness of the procedure introduced in this paper for model and econometric specification simultaneous selection should be tested with data on other developing countries.

[32] Gelvanovska et al.'s World Bank report released in 2014 has emphasized the role that regulation can play in boosting the Algerian ICT sector growth through fiber-optic infrastructure capacity increase.

[33] For the last three years or so, the Algerian authorities have carried out a large anti-corruption campaign concerning many infrastructure industries including the ICT industry and many observers have wondered aloud whether this phenomenon wasn't the cause of the current Algerian digital lag.

Appendix

Table A.1 - Some historical landmarks of the Algerian ICT sector[34]

Reforming a traditional telecommunications sector	
2000	Law 2000-03: Breakup of PTT and creation of AT, AP, and ARPT
2001	Creation of the first mobile operator Algérie Télécom Mobile (ATM), a subsidiary of AT
2002	Entry of the second mobile operator Orascom Telecom Algérie (OTA)
2003	Entry of the third mobile operator Wataniya Telecom Algérie (WTA)
2005	Entry of the second fixed operator the Compagnie Algérienne des Télécommunications (CAT)
2006	Creation of Algérie Télécom Satellite (ATS), a subsidiary of AT
2009	Closing of CAT
Paving the road for a modern electronic communications sector	
2001	Setting up of Djaweb by the MPT to provide low-speed Internet services[35]
2006	Subsidiarity of Djaweb
2010	Closing of Djaweb activity (reintegrated into AT's)
2016	Creation of Algérie Télécom Europe (ATE), subsidiary of AT
2017	Creation of GTA (AT, ATM, ATS, ATE, with participations in CDTA, SATICOM, and COMINTAL)
2018	Adoption of Law 18-04; ARPCE renaming of ARPT
Accelerating the pace of digitalization	
2002	Deployment of Alpal-2 submarine cable; Launching of the Trans-Saharan Ridge project
2003	Launching of ADSL, high-speed fixed broadband services by EEPAD
2004	Launching of VSAT and GMPCS satellite services
2005	Launching of ADSL, high-speed fixed broadband services by AT
2005	Deployment of the submarine optical fiber cable-segment SMW4
2013	Launching of 3G mobile broadband services
2014	Launching of 4G LTE broadband services
2015	Launching of the AlVal and OrVal submarine optical fiber cables
2016	Launching of 4G mobile broadband services
2017	Launching of the first communications satellite Alcomsat-1
2018	Launching of FttP, very high-speed fixed broadband services
2019	Deployment of the Medex submarine optical fiber
Expanding the scope of digitalization	
2004	Creation of ANPT for the realization and management of technology parks
2009	Launching of the e-Algeria plan
2012	Creation of SNDL, the Algerian multidisciplinary virtual library
2014	Creation of GIE-Monétique, the Algerian interbank monetary system regulatory
2015	Adoption of Law 15-04 on electronic signature and certification
2018	Adoption of Law 18-05 on e-commerce
2020	Creation of AGCE, the Algerian electronic certification authority
2021	Launching of electronic signature and certification services
2021	Setting up of practical arrangements for implementing mobile number portability[36]

[34] The new acronyms introduced in this table are PTT for Poste, Télégraphe et Télécommunications, ARPT for Autorité de Régulation de la Poste et des Télecommunications that was renamed in 2018 ARPCE, AP for Algérie Poste, MPT for Ministère de la Poste et des des Télécommunications, GTA for Groupe Télécom Algérie, EEPAD for Établissement d'Enseignement Professionnel à Distance, CDTA for Centre de Développement des Technologies Avancées, SATICOM for Société Algérienne des Technologies de l'Information et de la Communication, COMINTAL for Compagnie des infrastructures des Télécom Algérie, and ANPT for Agence Nationale de développement des Parcs Technologiques.

[35] From 2001 to 2003, Djaweb's activity remained linked to MPT before being transferred to AT. In July 2006, Djaweb became a subsidiary of AT, Algérie Télécom Internet, but its activity was reintegrated into AT's in 2008. In April 2008, MPT imposed a 50% reduction on the retail offer of ADSL service, a measure that affected the economic viability of Djaweb, which ended up being dissolved two years later by the ARPT Decision 07/SP/PC/ARPT/2010 (ARPT, 2010). Several other Internet Services Providers (ISP) found themselves unable to compete with AT or even unable to meet the costs of their licenses (OBG, 2012). Failing to liberalize some elements of the national fiber optic network and lift AT's monopoly on the international market, EEPAD exited the market in 2009 followed by almost half of the ISPs in 2011.

[36] See ED 21-199 of 05/05/2021 and Decision 18/SP/PC/ARPCE/2021.

Table A.2 - Data and sources[+]

Variable	Designation	Source and content
A, a	Cumulated and instantaneous broadband adoption	ITU. Number of subscribers to broadband, through both fixed and mobile technologies, per 100 people.
HHI	Herfindahl-Hirschman index	ARPCE. Authors' calculation of operators' market shares squared. The closer to 1 the index, the higher the market concentration.
$Corrp$	Corruption perception index	Transparency International. Index comprised between 0 and 1. The higher the value, the less corruption there is.
Reg	Regulatory quality index	NRGI, Brookings, The World Bank (Kaufman and Kraay): Worldwide Governance Indicator. Index with values between -0.25 and $+0.25$. Higher values means better regulatory quality.
Gov	Government effectiveness index	Idem with higher values corresponding to better government effectiveness.
Mob	Mobile broadband dummy	Authors' coding. This is a $0-1$ variable taking on the value 1 starting at the mobile broadband introduction period, i.e., year 2014, quarter 1.
$Fixed$	Fixed line penetration rate	ITU. Number of fixed lines per 100 people.
$Educ$	Enrollment ratio to tertiary education	United Nations. Number of students enrolled at a university per 100 people.
Urb	Urban population ratio	The World Bank. Number of people living in urban areas per 100 inhabitants.

[+] The raw data on the variables A, HHI, $Fixed$, $Educ$, and Urb is on an annual frequency. We transformed it into a quarterly frequency by computing for each variable and each year its rate of change and smoothening it across the quarters. The motivation for doing so is twofold. First, most of the papers related to our work dealing with a specific country have used annual data with sample sizes typically not going beyond 20 observations. Second, for high-tech industries, the market dynamics should be better reflected in quarterly rather than yearly frequency data. Concerning the IS variables, which are indices, i.e., $Corr$, Reg, and Gov, we merely applied the value of the index of each year for the quarters of that year. The data analyzed in this article will be shared on reasonable request to the corresponding author.

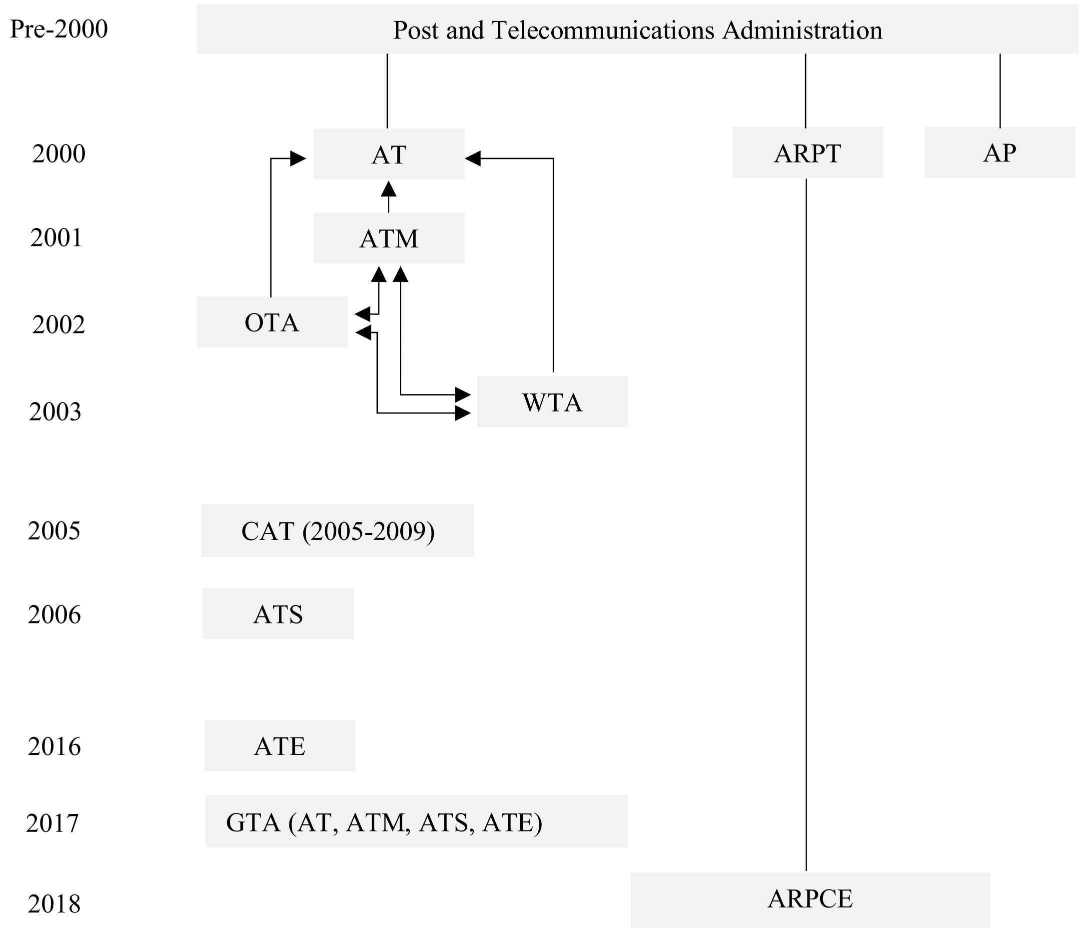
Table A.3 - Summary statistics

Variable	Designation	Obs.	Mean	Std. Dev.	Min.	Max.
A	Cumulated broadband adoption	68	23.92	35.06	0.03	104.31
a	Instantaneous broadband adoption	68	1.53	2.47	0.01	8.88
HHI	Herfindahl-Hirschman index	68	0.74	0.34	0.27	1.00
$Corrp$	Corruption perception index	68	0.32	0.03	0.26	0.36
Reg	Regulatory quality index	68	-0.98	0.32	-1.30	-0.38
Gov	Government effectiveness index	68	-0.53	0.05	-0.63	-0.44
Mob	Mobile broadband dummy	68	0.35	0.48	0.00	1.00
$Fixed$	Fixed line penetration rate	68	0.08	0.01	0.06	0.11
$Educ$	Enrollment to tertiary education	68	0.32	0.11	0.18	0.57
Urb	Urban population ratio	68	0.68	0.03	0.62	0.73

Table A.4 - Correlations

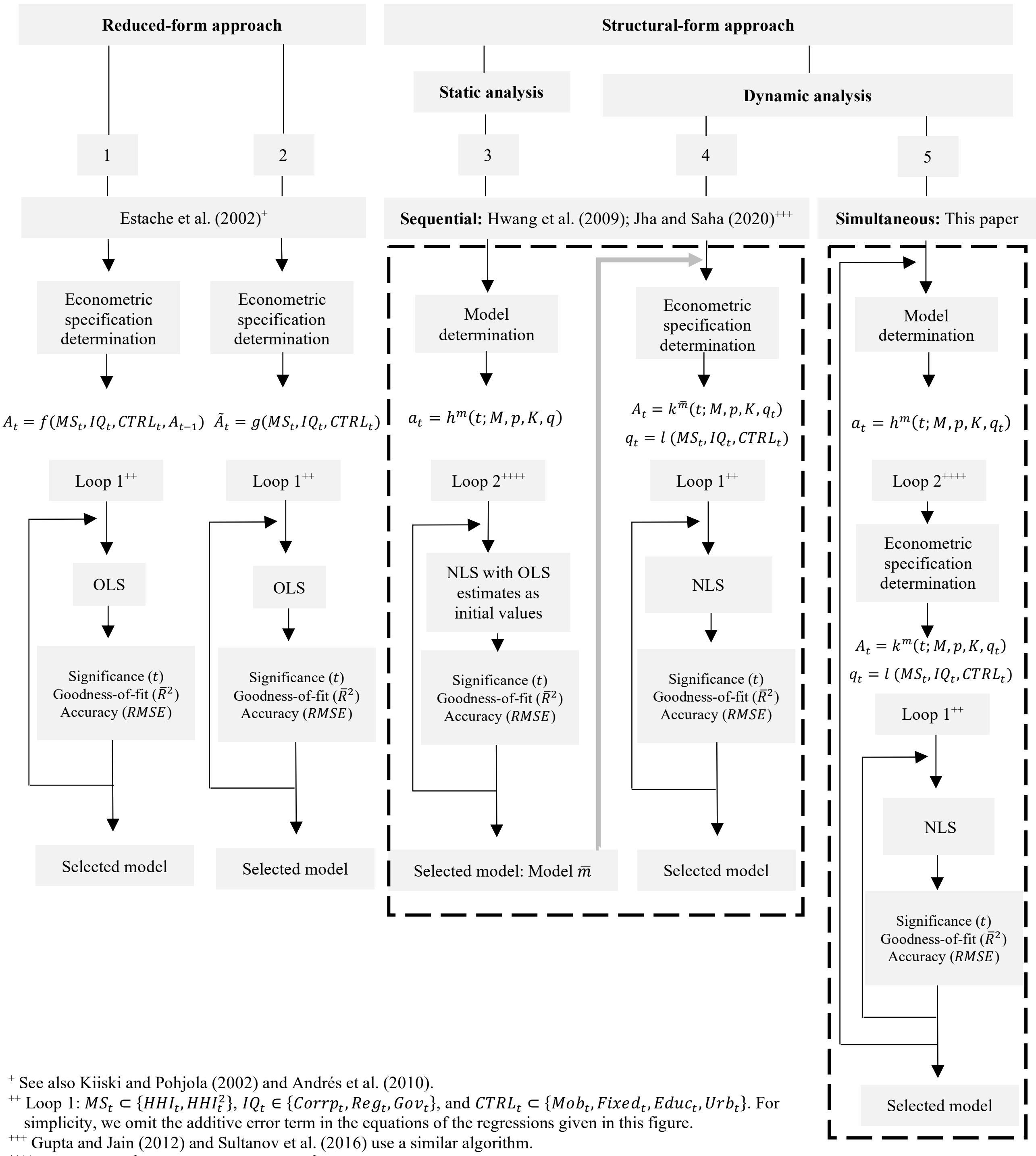
	A	a	HHI	$Corrp$	Reg	Gov	Mob	$Fixed$	$Educ$	Urb
A	1.00									
a	0.56	1.00								
HHI	-0.86	-0.80	1.00							
$Corrp$	0.56	0.57	-0.71	1.00						
Reg	-0.54	-0.46	0.59	-0.70	1.00					
Gov	0.24	0.19	-0.33	0.39	-0.21	1.00				
Mob	0.87	0.80	-0.99	0.69	-0.58	0.33	1.00			
$Fixed$	0.71	0.22	-0.50	0.63	-0.54	0.21	0.51	1.00		
$Educ$	0.91	0.52	-0.81	0.72	-0.80	0.28	0.81	0.79	1.00	
Urb	0.81	0.60	-0.82	0.83	-0.89	0.32	0.81	0.74	0.96	1.00

Figure A.1 - Broad view of the evolution of the Algerian ICT industry[37]



[37] In the current market structure, the historical (vertically integrated) operator AT is still in an upstream monopoly position for certain elements of its network infrastructure. In the downstream market, particularly mobile, AT's subsidiary ATM competes OTA and WTA. AT offers an interconnection service, which is an intermediate service in the downstream market, under terms and conditions, including pricing, that are under the control of the regulator.

Figure A.2 - Outline of the empirical analysis



[+] See also Kiiski and Pohjola (2002) and Andrés et al. (2010).

[++] Loop 1: $MS_t \subset \{HHI_t, HHI_t^2\}$, $IQ_t \in \{Corrp_t, Reg_t, Gov_t\}$, and $CTRL_t \subset \{Mob_t, Fixed_t, Educ_t, Urb_t\}$. For simplicity, we omit the additive error term in the equations of the regressions given in this figure.

[+++] Gupta and Jain (2012) and Sultanov et al. (2016) use a similar algorithm.

[++++] Loop 2: $m \in \{\text{Bass}, \text{Gompertz}, \text{Logistic}\}$.

Econometric specification of the Bass, Gompertz, and Logistic models

The point of departure of the Bass (1969) model is the assumption that the probability that an initial adoption of an innovation will be made at time t given that no adoption has yet been made, $\Pr(t)$, is linear in the number of previous adopters:[38]

$$\Pr(t) = p + \left(\frac{q}{M}\right) A_t \tag{A.1}$$

where A_t is the cumulated number of adopters at time t and p, q, and M are parameters that characterize the innovation diffusion process. A few words on the interpretation of these parameters are in order.

Assuming that $A_0 = 0$, i.e., that at the initial time of innovation there are no previous adopters, we have $\Pr(0) = p$. Thus, the parameter p represents the probability of initial adoption, i.e., adoption at the launch of the innovation and its magnitude reflects the importance of first adopters called population "innovators." It is directly related to the initial critical mass of adopters and it significantly influences the rest of the diffusion process involving the rest of the population yet to adopt.

The parameter M represents the population of potential adopters or the ultimate number of adopters, i.e., the number of adopters at market saturation. Thus, A_t/M gives this population's cumulated fraction that has adopted the innovation.

As to the parameter q, note that it is equal to $\partial \Pr(t)/\partial(A_t/M)$. It thus expresses the marginal effect of previous adopters on current initial adoption, i.e., it reflects the pressure exercised by those adopters on the population "imitators." Given that it is related to the size of the rest of future possible adopters, this parameter captures the dynamics of the imitative behavior (Michalakelis et al., 2008).

Equation (A.1) can be written as follow:

$$\frac{a_t/M}{1 - (A_t/M)} = p + \left(\frac{q}{M}\right) A_t \tag{A.2}$$

which is Equation (4) in the text. Equation (A.2) is an empirical form of the differential equation that defines the Bass process of diffusion of innovations:

$$\frac{f(t)}{1 - F(t)} = p + qF(t) \tag{A.3}$$

where f and F are respectively the Bass density and cumulative distribution. Equation (A.3) equation rewrites as:

$$dt = \left(\frac{1}{p + (q-p)F(t) - q[F(t)]^2}\right) dF(t) \tag{A.4}$$

and integrates to yield:

$$F(t) = \frac{1 - e^{-(p+q)t}}{1 + (q/p)\, e^{-(p+q)t}} \tag{A.5}$$

For estimation purposes, Equation (A.2) is written in its continuous form as:

$$a_t = Mp + (q-p)A_t - (q/M)A_t^2 \tag{A.6}$$

Provided that a discrete time-series of finite size T is available, the discrete analogue of Equation (A.6) to which an additive error term is appended is Equation (5) given in the text and Equation (A.5) is used to obtain Equations (7) and (9) in the text.

Unlike the Bass model, the Gompertz and Logistic models assume that diffusion occurs only through imitation, i.e., later adopters learn from early ones. The differential equation that defines the Gompertz model is given by:

$$f(t) = qF(t)\, ln\left(\frac{1}{F(t)}\right) \tag{A.7}$$

[38] In the survival literature this probability is termed the "hazard rate."

It rewrites as:

$$dt = \left(\frac{1}{-qF(t)ln(F(t))}\right) dF(t) \qquad \text{(A.8)}$$

and integrates to yield:

$$F(t) = e^{-e^{-(K+qt)}} \qquad \text{(A.9)}$$

where K is a constant of integration. For estimation purpose, Equation (A.7) allows one to write:

$$a_t = qA_t \, ln\left(\frac{M}{A_t}\right) = q \, ln(M) - qA_t \, ln(A_t) \qquad \text{(A.10)}$$

in a continuous form and its discrete analogue to which an additive disturbance term is added is Equation (10) in the text. Equation (A.9) is used to obtain Equations (13) and (18) in the text.

As to the differential equation that defines the Logistic model it is given by:

$$\frac{f(t)}{1 - F(t)} = qF(t) \qquad \text{(A.11)}$$

It rewrites as:

$$dt = \left(\frac{1}{qF(t)[1 - F(t)]}\right) dF(t) \qquad \text{(A.12)}$$

and integrates to yield:

$$F(t) = \frac{1}{1 + e^{-(K+qt)}} \qquad \text{(A.13)}$$

where K is again a constant of integration. For estimation purpose, Equation (A.11) allows one to write:

$$a_t = qA_t - (q/M)A_t^2 \qquad \text{(A.14)}$$

in a continuous form and its discrete analogue to which an additive disturbance term is added is Equation (11) in the text. Equation (A.13) is used to obtain Equations (15) and (19) in the text.

References

Adeleye, N. and C. Eboagu, 2019, "Evaluation of ICT development and economic growth in Africa," *Economic Research and Electronic Networking*, 20(1): 31-53.

Agostino, D., Saliterer, I., and I. Steccolini, 2021, "Digitalization, accounting and accountability: A literature review and reflections on future research in public services," *Financial Accountability & Management*, D0I 10.1111/faam.12301: 1-25.

Anagnostopoulos, I., 2018, "Fintech and regtech: Impact on regulators and banks," *Journal of Economics and Business*, 100: 7-25.

Andrés L., Cuberes, D., Diouf, M., and T. Serebrisky, 2010, "The diffusion of the Internet: A cross-country analysis," *Telecommunications Policy*, 34: 323-340.

Angrist, J.D. and J.S. Pischke, 2008, *Mostly Harmless Econometrics: An Empiricist's Companion*, Princepon University Press.

Arner, D.W., Barberis, JN., and R.P. Buckley, 2017, "Fintech, regtech, and the reconceptualization of financial regulation," *Northwestern Journal of International Law and Business*, 37, 371.

ARPCE, 2019, *Rapport d'activité annuel*.

Asongu, S., Amari, M., Jarboui, A., and K. Mouakhar, 2021a, "ICT dynamics for gender inclusive intermediary education: Minimum poverty and inequality thresholds in developing countries," *Telecommunications Policy*, 45, 102125.

Asongu, S.A., Biekpe, N., and D. Cassimon, 2021b, "On the diffusion of mobile phone innovations for financial inclusion," *Technology in Society*, 65, 101542.

Asongu, A.A., Le Roux, S., and N. Biekpe, 2017, "Environmental degradation, ICT, and inclusive development in Sub-Saharan Africa," *Energy Policy*, 111: 353-361.

____, 2018, "Enhancing ICT for environmental sustainability in Sub-Saharan Africa," *Technological Forecasting and Social Change*, 127: 209-216.

Avom, D., Nkengfack, Fotio, H.K, and A. Totouom, 2020, "ICT and environmental quality in Sub-Saharan Africa: Effects and transmission channels," *Technological Forecasting and Social Change*, 155: 120028.

Ayanlade, O.S., Oyibisi, T.O., and B.A. Kolawole, 2018, "Development of ICT-based framework towards sustainable optimal diabetes management in Nigerian health sector," *Informatics in Medicine Unlocked*, 11: 36-43.

Bacha, R. and F. Gasmi, 2018, "Tarification de l'accès aux éléments de réseau d'Algérie Télécom : Une analyse des données 2008-2016 sur les liens loués," *Revue des réformes économiques et intégration dans l'économie mondiale*, 12(26): 1-20.

Baily, M.N, 2002, "The new economy: Post-modern or second wind? Distinguished lecture on economics in government, " *Journal of Economic Perspectives*, 16(2): 3-22.

Bass, F.M, 1969, "A new product growth model for consumer durables," *Management Science*, 15 (05): 215-227.

Bharadwaj, P. and T. Suri, 2020, "Digital financial services in Africa: Improving financial inclusion through digital savings and credits," *American Economic Association Papers and Proceedings*, 110: 584-588.

Bohlin, A., Gruber, H., and P. Koutroumpis, 2010, "Diffusion of new technology generations in mobile communications," *Information Economics and Policy*, 22: 51-60.

Bouckaert, J., Dijk, T., and F. van Verboven, 2010, "Access regulation, competition, and broadband penetration: An international study," *Telecommunications Policy*, 34: 661-671.

Caselli, F. and W.J. Coleman II, 2001, "Cross-country technology diffusion: The case of computers," *American Economic Review*, 91: 328-335.

Cheng, C.Y., Chien, M.S., and C.C. Lee, 2021, "ICT diffusion, financial development, and economic growth: An international cross-country analysis," *Economic Modeling*, 94: 662-671.

Chien, M.S, Cheng, C.Y., and M.A. Kurniawati, 2020, "The non-linear relationship between ICT diffusion and financial development," *Telecommunications Policy*, 44, 102023.

Chow, G.C., 1967, "Technological change and the demand for computers," *American Economic Review*, 57(5): 117-1130.

Chu, A.B., 2018, "Mobile technology and financial inclusion," Chapter 6 of *Handbook of Blockchain*, *Digital Finance*, *and Inclusion*, *Volume 1 Cryptocurrency*, *FinTech*, *InsurTech*, *and Regulation* edited by David Lee Kuo Chuen and Robert Deng.

Chuen, D.L.K. and R. Deng, 2018, *Handbook of Blockchain*, *Digital Finance*, *and Inclusion*, *Volume 1 Cryptocurrency*, *FinTech*, *InsurTech*, *and Regulation*.

Collste G., Duquenoy P., George C., Hedström K., Kimppa K., and E. Mordini, 2006, "ICT in Medicine and Health Care: Assessing Social, Ethical and Legal Issues," in Berleur J., Nurminen M.I., and J. Impagliazzo (eds) *Social Informatics: An Information Society for all?* In Remembrance of Rob Kling. HCC 2006. *IFIP International Federation for Information Processing*, vol 223. Springer, Boston, MA.

Decision 07/SP/PC/ARPT/2010 of 08/24/2010, *Final withdrawal of the authorization for the establishment and operation of Internet service granted to Algérie Télécom Internet (Djaweb)*.

Decision 18/SP/PC/ARPCE/2021 of 06/27/2021, *Laying down of the practical arrangements for implementing mobile number portability*.

Dhaoui, I., 2021, "E-government for sustainable development: Evidence from MENA countries," *Journal of Knowledge Economy*, part of the Digital Transformation and Disruption collection.

Dixon, R.J., 1980, "Hybrid corn revisited," *Econometrica*, 48: 1451-1461.

Donoghue, O and J. Herbert, 2012, "Data Management within *mHealth* Environments: Patient Sensors, Mobile Devices, and Databases," *Journal of Data and Information Quality*, 4(1): 1-20.

Estache, A., Manacorda, M., and T.M. Valletti, 2002, "Telecommunications reforms, access regulation, and internet adoption in Latin America," *Economia*, 2(2): 153-203.

Executive Decree 21-199 of 05/11/2021, *Specification of the terms and conditions for implementing mobile number portability*.

Franses, P.H., 1994a, "Fitting a Gompertz curve," *Journal of Operational Research Society*, 45(1): 109-113.

Franses, P.H., 1994b, "A method to select between Gompertz and Logistic trend curves," *Technological Forecasting & Social Change*, 46: 45-49.

Gamboa, L.F., and J. Otero, 2009, " An estimation of the pattern of diffusion of mobile phones: The case of Colombia," *Telecommunications Policy*, 33 (10-11): 611-620.

Gelvanovska, N., Rogy, M., and C.M. Rossotto, 2014, *Broadband network in the Middle East and North Africa: Accelerating high-speed Internet access*, The World Bank Report.

Goolsbee, A. and P.J. Klenow, 2002, "Evidence on learning and network externalities in the diffusion of home computers", *Journal of Law and Economics*, 45: 317-343.

Griliches, Z., 1957, "Hybrid corn: An exploration in the economics of technical change," *Econometrica*, 25: 501-522.

Gruber, H., 2001, "Competition and innovation: The diffusion of mobile telecommunications in central and eastern Europe," *Information Economics and Policy*, 13 (1): 19-34.

Gruber, H. and P. Koutroumpis, 2013, "Competition enhancing regulation and diffusion of innovation: The case of broadband networks," *Journal of Regulatory Economics*, 43: 168-195.

Gruber, H. and F. Verboven, 2001, "The diffusion of mobile telecommunications services in the European Union," *European Economic Review*, 45: 577-588.

Gulati, G.J. and D.J. Yates, 2012, "Different paths to universal access: The impact of policy and regulation on broadband diffusion in the developed and developing worlds," *Telecommunications Policy*, 36: 749-761.

Gupta R. and K. Jain, 2012, "Diffusion of mobile telephony in India: An empirical study," *Technological Forecasting & Social Change*, 79: 709-715.

Hwang, J., Cho, Y., and N.V. Long, 2009, "Investigation of factors affecting the diffusion of mobile telephone services: An empirical analysis for Vietnam," *Telecommunications Policy*, 33: 534-543.

Jaakkola, H., Gabbouj, M., and Y. Neuvo, 1998, Fundamentals of technology diffusion and mobile phone case study, *Circuits Systems and Signal Processing*, 17(3): 421-448

Jankari, R., 2014, *Les technologies de l'information au Maroc, en Algérie et en Tunisie : Vers une filière euromaghrébine des TIC* ?, Institut de Prospective Économique du Monde Méditerranéen (IPEMED) Report.

Jain, D.C. and R.C. Rao, 1990, "Effect of Price on the Demand for Durables: Modeling, Estimation, and Findings," *Journal of Business & Economic Statistics*, 8(2): 163-170.

Jha, A. and D. Saha, 2020, "Forecasting and analyzing the characteristics of 3G and 4G mobile broadband diffusion in India: A comparative evaluation of Bass, Norton-Bass, Gompertz, and logistic growth models," *Technological Forecasting & Social Change*, 152, 119885.

Kanungo, R.P. and S. Gupta, 2021 "Financial inclusion through digitalization of services for well-being," *Technological Forecasting & Social Change*, 167, 120721.

Khan, A., Krishnan, S., and A. Dhir, 2021, "Electronic government and corruption: Systematic literature review, framework, and agenda for future research," *Technological Forecasting & Social Change*, 167, 120737.

Kiiski, S. and M. Pohjola, 2002, "Cross-country diffusion of the Internet," *Information Economics and Policy*, 14: 297-310.

Lahouel, B.B., Taleb, L., Ben Zaied, Y., and S. Managi, 2021, "Does ICT change the relationship between total factor productivity and CO2 emissions? Evidence based on a nonlinear model," *Energy Economics*, 101, 105406.

Lange, S., Pohl, J., and T. Santarius, 2020, "Digitalization and energy consumption. Does ICT reduce energy demand?," *Ecological Economics*, 176: 106760.

Lashitew, A.A., van Tulder, R., and Y. Liasse, 2019, "Mobile phones for financial inclusion: What explains the diffusion of mobile money innovations?," *Research Policy*, 48: 1201-1215.

Law 98-257 of 08/25/1998, *Definition of the terms and conditions for setting up and operating Internet services*.

Law 2000-03 of 08/05/2000, *Setting of general rules for post and telecommunications*.

Law 18-04 of 05/10/2018, *Setting of general rules for electronic communications*.

Lee, C.C., Li, X., Yu, C.H., and J. Zhao, 2021, "Does fintech innovation improve bank efficiency? Evidence from China's banking industry," *International Review of Economics and Finance*, 74: 468-483.

Lee, S., Marcu, M., and S. Lee, 2011, "An empirical analysis of fixed and mobile broadband diffusion," *Information Economics and Policy*, 23: 227-233.

Mahajan, V., Mason, C.H., and V. Srinivasan, 1986, "An evaluation of estimation procedures for new product diffusion models," in V. Mahajan and Y. Wind (eds.), *Innovation Diffusion Models of New Product Acceptance*, Cambridge, MA: Ballinger, 203-232.

Mansfield, E., 1961, "Technical change and the rate of imitation," *Econometrica*, 29: 741-765.

Mas, I., 2018, "Using broadband to enhance financial inclusion," Chapter 5 of *Handbook of Blockchain*, *Digital Finance*, *and Inclusion*, *Volume 1 Cryptocurrency*, *FinTech*, *InsurTech*, *and Regulation* edited by David Lee Kuo Chuen and Robert Deng.

Mignamissi, D. and A.J. Djijo T., 2021, "Digital divide and financial development in Africa," *Telecommunications Policy,* 45, 102199.

Michalakelis, C. Varoutas, D., and T. Sphicopoulos, 2008, "Diffusion models of mobile telephony in Greece," *Telecommunications Policy,* 32: 234-245.

MPTTN, 2008, *E-Algérie 2013 : Synthèse*, E-Commission.

Na, H.S., Hwang, J., and H. Kim, 2020, "Digital content as a fast Internet diffusion factor: Focusing on the fixed broadband Internet," *Information Development*, 36(1): 97-111.

Nair, M., Pradhan, R.P., and M.B. Arvin, 2020, "Endogenous dynamics between R&D, ICT and economic growth: Empirical evidence from the OECD countries," *Technology in Society*, 62, 101315.

N'dri, L.M., Islam, M., and M. Kahinaka, 2021, "ICT and environmental sustainability: Any differences in developing countries?," *Journal of Cleaner Production*, 297, 126642.

Niebel, T., 2018, "ICT and economic growth: Comparing developing, emerging, and developed countries," *World Development*, 104(C): 197-211.

Noumba Um, P., 2006, "A policy note on telecommunications reform in Algeria," *Les Cahiers du CREAD*, 76: 83-109.

Oxford Business Group (OBG), 2012, *The Report: Algeria 2012*.

Oxford Business Group (OBG), 2018, *The Report: Algeria 2018*.

Park, C.H. and K. Kim, 2019, "E-government as an anti-corruption tool: Panel data analysis across countries," *International Review of Administrative Sciences*, DOI 10.1177/0020852318822055, 0(0): 1-17.

Phuc Nguyen, C., Dinh Su, T. and N. Doytch, 2020, "The drivers of financial development: Global evidence from Internet and mobile usage," *Information Economics and Policy*, 53, 100892.

Pradhan, R.P, Arvin, M.B., Mahendhiran, S.N., Hall, J.H., and S.E. Bennett, 2021 "Sustainable economic development in India: The dynamics between financial inclusion, ICT development, and economic growth," *Technological Forecasting & Social Change*, 169, 120758.

Rogers, E.M., 1995, *Diffusion of innovations*, Free Press.

Röller, L.H. and L. Waverman, 2001, "Telecommunications infrastructure and economic development: A simultaneous approach," *American Economic Review*, 91(4): 909-923.

Sarangi, A.K. and R.P. Pradhan, 2020. "ICT infrastructure and economic growth: A critical assessment and some policy implications," *DECISION* 47(4): 363-383.

Satoh, D., 2001, "A discrete Bass model and its parameter estimation," *Journal of the Operations Research Society of Japan*, 44(1): 1-18.

Setor, T.K., Senyo, P.K., and A. Addo, 2021, "Do digital payment transactions reduce corruption? Evidence from developing countries," *Telematics and Informatics*, 60, 101577.

Sheikh, A., Anderson, M., Albala, S., Casadei, B., Franklin, B.D., Richards, M., Taylor, D., Tibble, H., and E. Mossialos, 2021, "Health information technology and digital innovation for national learning health and care systems," *Health Policy*, 3: 383-396.

Singh, S.K., 2008, "The diffusion of mobile phones in India," *Telecommunications Policy*, 32: 642-651.

Srinivasan, V. and C.H. Mason, 1986, "Nonlinear least squares estimation of new product diffusion models," *Marketing Science*, 5(2): 169-178.

Sultan, F., Farley, J.U., and D.R., Lehmann, 1990, "A Meta-Analysis of Applications of Diffusion Models", *Journal of Marketing Research,* 27(01): 70-77.

Sultanov, A., Lee, D.J., Kim, K.T., and L.A.P. Avila, 2016, "The diffusion of mobile telephony in Kazakhstan: An empirical analysis," *Technological Forecasting & Social Change*, 106: 45-52.

Tchamyou, V.S., Asongu, S.A., and M. Odhiambo, 2019, " The role of ICT in modulating the effect of education and lifelong learning on income inequality and economic growth in Africa," *African Development Review*, 31 (3): 261-274.

Teklemariam, M.H. and Y. Kwon, 2020, "Differentiating mobile broadband policies across diffusion stages: A panel data analysis," *Telecommunications Policy*, 44, 102006.

Tyce, M., 2020, "Beyond the neoliberal-statist divide on the drivers of innovation: Apolitical settlements reading of Kenya's M-Pesa success story," *World Development*, 125: 1-14.

Turk T. and P. Trkman, 2012, "Bass model estimates for broadband diffusion in European countries," *Technological Forecasting & Social Change*, 79: 85-96.

Uyar, A., Nimer, K., Kuzey, C., Shahbaz, M., and F. Schneider, 2021, "Can e-government initiatives alleviate tax evasion? The moderation effect of ICT," *Technological Forecasting & Social Change*, 166: 120597.

Voss, R.C., Jansen, T., Mané, B., and C. Shennan, 2021, "Encouraging technology adoption using ICTs and farm trials in Senegal: Lessons for gender equity and scaled impact," *World development*, 146, 105620.

Waverman, L., Meschi, M., and M. Fuss, 2005, "The impact of telecoms on economic growth in developing countries," *Political Science*: 1-23.

Yamakawa, P., Rees, G.H., Salas, J.M., and N., Alva, 2013, "The diffusion of mobile telephones: An empirical analysis for Peru", *Telecommunications policy*, 37: 594-606.

Yates, D.J., Gulati, G.J., and J.W., Weiss, 2013, "Understanding the impact of policy, regulation and governance on mobile broadband diffusion," *Hawaii International Conference on System Sciences*, 46: 2852-2861.