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MODELING AND FORECASTING THE DIFFUSION OF MOBILE TELEPHONY IN ALBANIA AND TURKEY

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Abstract

Mobile telephony has become a main factor driving the social and economic development of a country. This study examines the diffusion process of mobile telephony in Albania and Turkey. The aim of this research is to model and to forecast the diffusion rate of mobile telephony using Logistic and Gompertz models, and World Bank data. The results of estimated models indicated that the Gompertz model fits best with the actual data of mobile telephony in Albania, and the Logistic model fits best with the actual data of mobile telephony in Turkey. According to the results of the Logistic model, the best model for predicting the diffusion rate of mobile telephony in Albania, the maximum level of the mobile diffusion rate of 131.89% will be achieved in the year 2025. The results of the Gompertz model, the best model for predicting the mobile telephony in Turkey indicate that the maximum diffusion rate of 97.98% is predicted to be achieved after the year 2025. These findings are useful to telecommunication operators, policymakers, and customers.

Keywords: Mobile subscriber, technology diffusion, logistic model, Gompertz model, STATA

1. Introduction

Mobile phones have changed the way of communication and play a substantial role in people lives. Mobile telephony has shown considerable growth and this growth is expected to continue with the introduction of technically advanced mobile cellular networks. In 2017, the number of people connected to mobile services surpassed 5 billion globally (with 3.7 billion in developing markets), that is two out of three people in the world had a mobile subscription. Mobile technologies and services have generated 4.5% of GDP globally, a contribution that amounted to $3.6 trillion of economic value added [1]. By the end of 2017, 85% of the population in Europe, 465 million people, subscribed to mobile services. The total addressable market for the region's mobile operators is approaching saturation point. In 2017, mobile technologies and services generated 3.3% of GDP, a contribution that amounted to €550 billion of economic value added [2].

The number of mobile cellular subscriptions in Albania was 3625699 in 2017, representing an increase of 7.6% compared to 2016 [3]. The number of active users (use in the last 3 months of the year) of mobile telephony in 2017 amounted to about 3.2 million, representing a decrease of 5.9% compared to 2016. Whereas, in Turkey, the number of mobile subscribers was 77800170 in 2017, representing an increase of 3.65% compared to year 2016 [3].

In attempts to model and forecast the diffusion of innovations, a common step is the selection of an S-shaped trend model. Majority of the studies typically examine the penetration of a technological diffusion by means of the estimation of S-shaped growth curves, such as the Logistic and the Gompertz curves, and present estimates of the speed of diffusion and saturation level (or maximum size) of the market. The Logistic and Gompertz model each have their specific characteristics, making them useful models in empirical studies of diffusion. These S-shaped models are suitable enough for accurate fitting and forecasting the diffusion of mobile telephony.

Traditionally, diffusion models have been used in telecommunications for forecasting the demand of a new product, to measure the product lifecycle dynamics, and as a decision tool to make strategic marketing choices [5]. Rouvinen [6], and Wu and Chu [7] suggest that applying an S-shaped diffusion model is the first step to analyze diffusion of telecommunication services. Meade and Islam [8] compare 17 growth models based on time series and find that models that use fewer variables such as Logistic, Gompertz and Bass models provide better estimates and more forecast accuracy.

There are several studies about the growth pattern of mobile telephony markets using the diffusion theory. Some studies examined the diffusion of mobile telephony at country-level and some other empirical studies examined the mobile diffusion in several countries. Gruber and Verboven [9] used the logistic curve to analyze diffusion of mobile telephony in European Union and find that technological progress dominates market structure between 1984 and 1997. According to Botelho and Pinto [10], Logistic model adequately describes the path of mobile phone diffusion in Portugal between 1989 and 2000, and the expected saturation level is 95%. In their study, Frank [11] finds that network coverage is the most influential factor in the diffusion of mobile phones in Finland, based on logistic diffusion function estimation between 1981 and 1998, and the final penetration rate was estimated at 91.7% in 2009.

Pereira and Pernias-Cerrillo [12] found that the Logistic curve was a valid representation of the diffusion process in Portugal using quarterly data from 1994 to 2003, but only as a long-term trend. Moreover, they identified significant effects of increased competition on the diffusion process. They also observed that there were seasonal fluctuations that accounted for much of the variation in the early stages of diffusion. Rouvinen [6] studied the factors determining the diffusion of digital mobile telephony across 200 developed and developing countries in the 1990s with the aid of a Gompertz model. The market size and network effects were found to play more important roles in the developing countries. Lee and Cho [13] show that the Logistic model fitted better to the mobile cellular subscribers' data covering 1984 to 2002 in Korea compared to the ARMA model. Results indicated that the speed of diffusion increases with per capita GDP. The final penetration rate was estimated to be 71.3% of the population.

Michalakelis et al. [14] studied the diffusion rate of mobile telephony subscriptions in Greece. Bass model, Fisher–Pry model, the Gompertz models and some representatives of the logistic variants were used. They find a saturation level between 111–126% for Greece and considers the Gompertz model as the most appropriate model for forecasting and Logistic model fits the actual data better. Singh [15] found that the Gompertz model adequately described the path of mobile phone diffusion from 1995-1996 to 2005-2006 in India and the number of mobile phones will exceed the number of people by 2022-2023. The findings of Gamboa and Otero [16] indicate that the diffusion pattern of mobile telephony in Colombia can be best characterised as following a Logistic specification. The estimated saturation level of 103.7 was expected to be reached in five years' time.

Chu et al. [17] found that the most appropriate diffusion model was the Logistic model and the market competition was identified as a primary driver of the diffusion rate of mobile telephony in Taiwan. Dergiades and Dasilas [18] found that the Logistic model describes better the diffusion process of mobile telecommunication services into the Greek market for the period 1993 to 2005, and Logistic model was the best for forecasting. Wu & Chu [7] found that the Gompertz model outperforms the other models before diffusion take-off, and the Logistic model is superior after inflection and over the aggregate range of the diffusion process in Taiwan during 1988–2007. The saturation levels varied from 104.8 % to 105.5 %.

Gupta & Jain [19] found that Gompertz model best describes the mobile diffusion process in India. Xielin et al. [20] found that Gompertz model outperforms the Logistic and Bass models in forecasting the diffusion of mobile telephony in China, and the Gompertz model forecasts higher market potential than the other two models. Karacuka and Catik [21] found that the Gompertz model has better explanatory power for the diffusion process of mobile subscriber data in Turkey for the period 1986-2006. The future forecasted values predict that the mobile diffusion trend will be increasing. Yamakawa et al. [22] indicate that the Gompertz model is the most appropriate model for the diffusion of mobile telephone subscriptions in Peru. The 5-year forecast of subscriptions predicts a further 11.72 million subscribers. Market concentration, population, regulated interconnection tariffs and GDP per capita were determinants of diffusion. Honoré [23] shows that the Logistic model best describes the diffusion of mobile phone technology in Cameroon, and income, openness to competition and SMS usage are key forces driving this diffusion. Braimllari and Kraja [24] examined the diffusion process of mobile telephony in Balkan countries and found that Logistic model outperform Gompertz model in forecasting the diffusion mobile telephony in other countries in the study excluding Greece.

Understanding the diffusion process of new technologies is crucial to strategic planning of economic and social infrastructure. An effective management of mobile services requires an understanding of the factors such as market timing, market potential and adoption speed that underlie the evolution of the market. These factors are of great importance for telecommunications operators for capacity planning. Understanding the evolution of mobile telephony market and its possible future trend is equally important for policy makers [15].

The main objective of this study is to model and predict the diffusion of mobile telephony in Albania and Turkey using the World Bank data in order to help telecommunications operators and policy makers to implement the most suitable strategies. Logistic and Gompertz models were estimated using STATA software.

2. Method and data

2.1. Diffusion models

The literature on the diffusion of emerging technology generally uses S-curves to predict the diffusion process. Because the new technology typically at first grows slowly, then exhibits a growth rate greater than 1, followed by a period of slower growth (growth rate less than 1) and finally the growth rate slows down and converges to some saturation level. The empirical S-curve literature, in the technology-diffusion context has tended to focus on logistic model and Gompertz model [25-26].

The logistic model is represented by the differential equation:

$$\dot{y} = a\, y(c - y) \tag{1}$$

where $y(t)$ represent the total diffusion at time t, c the maximum expected level of the Internet technology and a is the coefficient of diffusion which describes the diffusion speed. The diffusion speed is proportionate to the population that has already adopted the service y and the remaining market potential (c-y).

The solution of the logistic model (1) is given by:

$$y(t) = \frac{c}{1 + e^{-a(t-t_0)}} \tag{2}$$

where $y(t)$ is the estimated diffusion level at time t, c is the maximum level of diffusion; a is the speed of diffusion; t_0 is the moment of time when technology diffusion achieved half of its maximum level.

The Gompertz model is represented by the differential equation:

$$\dot{y} = a\, y(\ln c - \ln y) \tag{3}$$

The solution of the Gompertz model (3) is given by:

$$y(t) = c e^{e^{-a(t-t_0)}} \tag{4}$$

where c is the maximum diffusion rate; a is the speed of diffusion; t_0 is the moment of time when technology diffusion achieved the share 1/e ≈ 36.8% of its maximum level.

Both the Gompertz and Logistic curves involve the estimation of three parameters, and range between a lower asymptote of 0 and an upper asymptote of c. The important feature of the Gompertz path is that the diffusion goes faster at the beginning but becomes slower over time. This leads to a relatively short period of rapid expansion and to a relatively long period of gradual growth up to the maximal level. The logistic curve is more symmetric, the growth rate is initially not as high as in the Gompertz curve and it declines more gradually [27].

2.2. Data

The annual data about mobile cellular subscriptions and mobile cellular subscriptions per 100 people in Albania for the period 1996-2017 and Turkey for the period 1986-2017 are taken from the World Bank database [3]. Parameters of the Logistic and Gompertz models were estimated using the nonlinear least squares method and STATA software. For forecasting, a model that fits best to the in-sample data does not necessarily provide more accurate forecasts. Therefore, the performance of out-of-sample forecasts is used to help for the selection of a diffusion model. The out-of-sample data cover the period 2015-2017.

The choice of functional form for a certain technology helps to characterize the dynamics of the trend. Some specific technologies are described best by one functional form and other technologies by another. Some model selection criteria used here are: Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC). The best model is the model which has the smaller value of AIC and BIC. To evaluate the performance of the best fitted or forecasted model was used the Root Mean Square Error (RMSE):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \qquad (5)$$

3. Results and discussion

The mobile diffusion rates for Albania and Turkey during the study period, shown in figure 1, each following a S-curve pattern. The diffusion rate of mobile telephony in Albania (figure 1) is increased during the period from 1996 to 2007 and then in year 2008 is decreased at 62.16% and the other decrease was in 2014 (115%). The mobile diffusion rate has exceeded 100% in 2011 with 106% and the highest rate for the period 1996-2017 was 126.3% in 2013. At the end of 2017, the diffusion rate was 123.74%, about 7.45% higher compared to 2016.

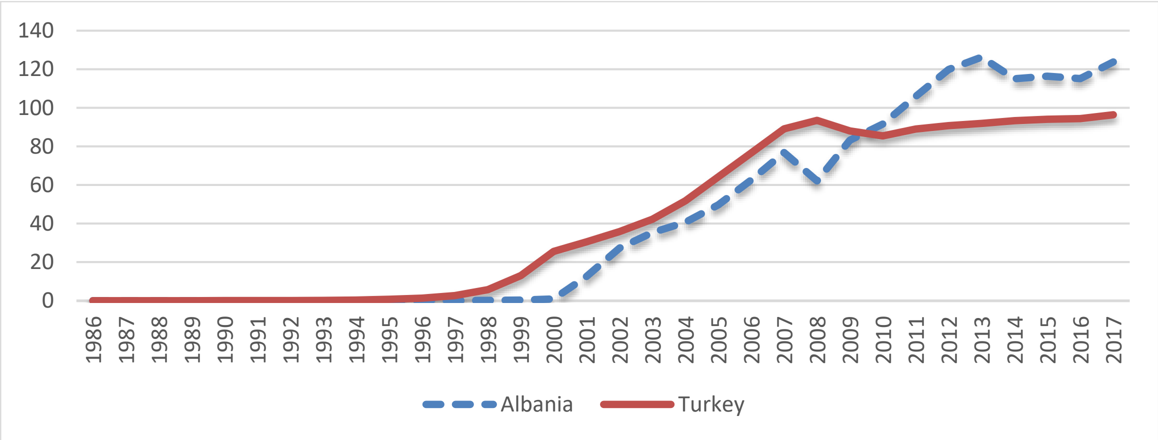

Figure 1. Mobile cellular subscribers (per 100 people) in Albania and Turkey

Diffusion rate of mobile telephony in Turkey is increased from 13% in 1999, to 93.45% in 2008 and to 96.3% in 2017 which is the highest rate in the period 1986-2017. The figure 1 indicates that the diffusion rate is increased during the period from 1986 to 2008 and then in year 2009 is decreased at 88%. At the end of 2017, the diffusion rate was about 2% higher compared with the diffusion rate of 2016. The diffusion rate of mobile telephony was higher in Turkey until year 2009, and after 2009 the diffusion rate was higher in Albania.

The models obtained for both countries in the study are statistically significant and the parameters of the models are statistically significant at 1% level (table 1).

The results of Logistic model for the diffusion rate of mobile telephony in Albania indicate a maximum level of 131.9% and the speed of convergence to the saturation (maximum) level is 0.338. Mobile technology diffusion has achieved half of its maximum level in 2006. The results of Gompertz model indicate a maximum diffusion rate of 155.25%, the speed of diffusion is 0.178 and half of its maximum level is achieved in 2005.

The fit of each model is measured by the values of AIC, BIC, and RMSE. The results of both models show that Gompertz model has the best performance in describing the mobile technology diffusion, whereas the Logistic model is the best to predict the diffusion rate of mobile technology in Albania.

The Gompertz model is found appropriate to describe the diffusion process of mobile telephony in India ([15], [19]), Taiwan ([7]), China ([20]) and Peru ([22]).

Table 1. Estimated parameters of the mobile diffusion models

	Albania (n = 22)		Turkey (n = 32)	
Parameter	Logistic	Gompertz	Logistic	Gompertz
c	131.89*	155.25*	93.56*	97.98*
a	0.338*	0.178*	0.472*	0.286*
t_0	2006.84*	2005.83*	2003*	2001.69*
R^2	0.9886	0.9912	0.9962	0.9949
R^2 adj	0.9864	0.9896	0.9958	0.9944
AIC	135.74	**130.70**	**157.36**	165.59
BIC	138.58	**133.54**	**161.46**	169.69
RMSE				
In-sample	7.355	**6.441**	**3.289**	3.791
Out-of-sample	**8.087**	13.479	1.852	**1.546**

Note: Significance level: *, $p < 1\%$.

The results of Logistic model for the diffusion rate of mobile telephony in Turkey indicate a maximum level of 93.56% and the speed of convergence to the saturation (maximum) level is 0.472. Mobile technology diffusion has achieved half of its maximum level in 2003. The results of Gompertz model indicate a maximum diffusion rate of 97.98%, the speed of diffusion is 0.286 and half of its maximum level is achieved in 2001. Values of AIC, BIC, and RMSE indicate that Logistic model has the best performance in describing the mobile technology diffusion in Turkey, whereas the Gompertz model is the best to predict the diffusion rate of mobile technology.

Logistic model is found appropriate to describe the process of mobile diffusion in Portugal ([10],[12]), in Korea ([13]), Taiwan ([17]), Colombia ([16]) and Cameroon ([23]). The Gompertz model is found to fit best to the data and to give accurate forecasts for the mobile diffusion process in Turkey ([21]).

Comparing the estimated parameters of the best fitted models, results indicate that Turkey has the highest estimated speed of diffusion (0.472), whereas Albania has the highest maximum diffusion rate (155.25%).

In the figures 2 and 3 are shown the actual and predicted data of mobile diffusion rates for two countries.

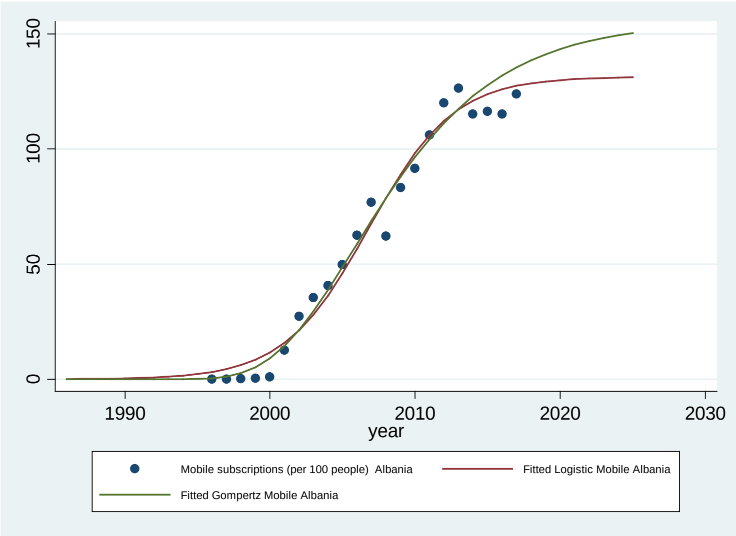

Figure 2. Actual and predicted number of mobile subscribers in Albania using Logistic and Gompertz models

The saturation rate of mobile telephony diffusion in Albania (131.9%), generated by logistic model, is predicted to be achieved after year 2025.

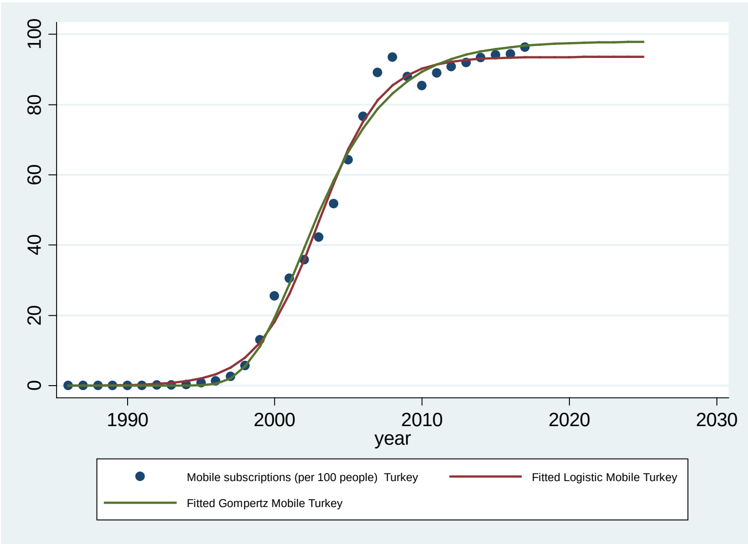

Figure 3. Actual and predicted number of mobile subscribers in Turkey using Logistic and Gompertz models

For Turkey, the saturation rate of mobile telephony diffusion (97.98%), generated by Gompertz model, is predicted to be achieved after year 2025.

4. Conclusions

Growth models are appropriate to model the mobile telephony diffusion. Developing models that explain the growth process is critical for capacity planning, policy formulation and introduction of new products and technologies. Mobile diffusion (growth) projection give useful information to providers of these services/products about the potential consumer base.

In this study, the diffusion of mobile telephony is analysed using S-Shaped growth curve models such as Logistic and Gompertz models. This study examines the mobile telephony diffusion in Albania and Turkey using the World Bank data for mobile cellular subscriptions per 100 people.

Results of descriptive analysis indicated that the data for each country follow a S-shaped curve. The diffusion rate of mobile telephony was higher in Turkey until year 2009, and after 2009 the diffusion rate was higher in Albania. In Albania, the highest rate of mobile diffusion was 126.3% in 2013, whereas in Turkey was 96.35% in 2017.

The results of estimated models indicated that:

- Gompertz model fits best to the actual data and Logistic model is the best model to predict the diffusion rate of mobile telephony in Albania;
- Logistic model fits best to the actual data and Gompertz model is the best model to predict the diffusion rate of mobile telephony in Turkey.

Comparing the estimated parameters of the best fitted models, results indicate that Turkey has the highest estimated speed of diffusion, whereas Albania has the highest maximum diffusion rate.

The results of Logistic model, the best model for prediction, indicate that the maximum level of mobile telephony diffusion in Albania of 131.89% will be achieved in 2025. The results of Gompertz model, the best model for prediction of the mobile telephony diffusion in Turkey, indicate that the maximum diffusion rate of 97.98% is predicted to be achieved after year 2025.

Once identified, the accurate forecasting model, Logistic or Gompertz, can be useful for modeling aspects, such as the saturation level, of the future path of a new technology. Business managers can utilise such models to develop strategies that increase the potential customer base. True market size and diffusion coefficients estimates can help the telecommunication operators to assess their options for the introduction of future technologies (5G).

In the future research, the factors influencing the diffusion process of mobile telephony such as income, openness to competition, tariffs, GDP per capita, etc., can be studied.

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