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Diffusion and Substitution Effect on Telecommunication Technologies in Turkey

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Abstract

Telecommunication technologies show great changes all over the world. Next generation technologies replace older ones. Alternatives of the technologies force the users to make a choice between the competing technologies. Generally, an adverse effect is shown on the usage of older technologies when a new competitor is introduced to the market.

In this paper, substitution effect on telecommunication technologies in Turkey is examined from the perspective of fixed-mobile substitution and next generation mobile technologies. The study uses two different technology diffusion models for each case: Logistic Substitution models and Gompertz model. Generic diffusion model and substitution model are compared in terms of RMSE and MAD. Fixed-line and mobile telecommunication technologies are inspected together to see substitution effect of mobile telecommunication on fixed-line, firstly. In the second step, fast technological change in the mobile telecommunication technology is handled for Turkey. 2G, 3G and 4.5 G technologies are analyzed to see diffusion and substitution process of these technologies. All the results indicate that; Logistic Substitution model is better to simulate the systems in competitive environments. On the other hand, 2G technology is found the most affected technology by the substitution.

Keywords: Logistic Substitution Model, Gompertz Model, Telecommunication Technologies, Substitution Effect

Türkiye'de Telekomunikasyon Teknolojilerinin Yayılımı ve İkame Etkisi

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Öz

Telekomünikasyon teknolojileri tüm dünyada büyük bir değişim içerisindedir. Yeni nesil teknolojiler eski teknolojilerin yerini almaktadır. Alternatif teknolojilerin varlığı, kullanıcıları teknolojiler arasında tercih yapmaya zorlamaktadır. Genellikle, aynı sektörde rekabet eden yeni bir teknoloji piyasaya sunulduğunda eski teknolojilerin kullanımında olumsuz bir etki gözlenmektedir.

Bu çalışmada, Türkiye'deki sabit-mobil ikamesi ve gelecek nesil mobil teknolojilerinin yayılımı incelenmiştir. Çalışmada, her bir durum için Lojistik İkame modeli ve Gompertz Difüzyon modeli kullanılmıştır. Klasik difüzyon modeli ve ikame modeli RMSE ve MAD açısından karşılaştırılmıştır ve öncelikli olarak, sabit hat ve mobil telekomünikasyon teknolojileri, mobil telekomünikasyonun sabit hat üzerinde oluşturduğu ikame etkisini görmek için birlikte ele alınmıştır. İkinci adımda, Türkiye'deki mobil telekomünikasyon teknolojisinde yaşanan hızlı teknolojik değişimler ele alınmaktadır. Bu teknolojilerin difüzyon ve ikame etkilerini görmek için 2G, 3G ve 4.5G teknolojileri analiz edilmiştir. Tüm sonuçlar, Lojistik İkame modelinin rekabetçi ortamları simüle etmekte daha başarılı olduğunu göstermektedir. Diğer taraftan 2G teknolojisi ikame etkisinden en çok etkilenen teknoloji olarak bulmuştur.

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Anahtar Kelimeler: Lojistik İkame Modeli, Gompertz Model, Telekomunikasyon Teknolojileri, İkame Etkisi

1. INTRODUCTION

In recent years, telecommunication technologies have made a dramatic change and a great improvement. With the development of wireless telecommunications technology, fixed-line telecommunications technology shows a sharp decline all over the world. On the other hand, by the end of 2017, global mobile phone subscribers reached 5.7 billion. This equals 62.9% of the world's population [1]. The journey that started with fixed line has now reached 5G technology. Large investments and reasonable profit margins make this market attractive for investors. However, it is one of the most dynamic market segments due to continual technological changes. With the deployment of these new technologies the number of communication options increased. This influenced the way in which people communicate. The rapid increase in the number of mobile users was caused a decline in the number of fixed-line subscribers. Precisely at the point when these technological improvements in the telecommunication sector are considered, understanding diffusion of the new technology becomes very important to evaluate the future of that technology for investors. The effects of innovation on micro and macro-economic growth, competition, future trends of technology and business history have become more visible as a results of detailed diffusion analysis [2].

The diffusion of innovation was defined by Rogers as "The process by which an innovation is communicated through certain channels over time among the members of a social system" [3]. The path that the cumulative adoption of an innovation takes between introduction and saturation is generally modeled by an S curve [4]. On the other hand, many studies have tried to model the diffusion of an innovation so far. Researchers can be referred to Meade and Islam [4] and Geroski [5] for a detailed literature of diffusion models. A diffusion model can easily explain the expected life cycle of an innovation. Also, new technologies and generations are competing with each other because of the consumers' behavior. Technological substitution by its nature produces technological change and consequently, is a component in the creation of new economic value and wealth [6]. The substitution effects on telecommunication technologies have become interesting subjects for researchers for the reasons mentioned above. Table 1 gives the related literature in a chronological order.

As understood from the literature, there has been a focus on the country based cases. Substitution is inspected from different perspectives as seen in the literature. Especially, mobile to fixed-line substitution is the most popular one between them. Results indicated that there is a negative effect of the mobile phone diffusion on the fixed-line telephony penetration rate [7], [8]. Furthermore some studies investigated the next generation effects on telecommunication technologies [9]. Also, substitution specific diffusion models are rarely compared with generic diffusion models [10].

Table 1. Literature about the Substitution Effects on Telecommunication Technologies

Study	Subject	Results
Johnson and Bhatia [6]	Predicting a technological substitution in land mobile radio.	This research has shown that the Norton-Bass model provides better regression output than the best case regression techniques.
Barros and Cadima [7]	Evaluating the impact of mobile phone growth on the fixed-link network.	Entrance of new technologies may induce a sizeable negative effect upon previous generation technologies.
Sung and Lee [11]	Examining the impact of rapid growth in mobile telephones on the access demand for fixed-line telephones in Korea.	The empirical analysis indicates that a 1% increase in the number of mobile telephones results in a reduction of 0.1~0.2% in new fixed connections and a 0.1~0.2% increase in disconnections.
Hamilton [12]	Examining the relationship between mobile and fixed-line telephones by accounting for reverse causality between them.	Mobile telephones act as a competitive force encouraging fixed-line providers to improve access.
Rodini, Ward and Woroch [13]	Estimating the substitutability of fixed and mobile services for telecommunications access using US house hold survey conducted over the period 2000–2001.	Mobile service is a moderate substitute for fixed-line access.

Table 1. Literature about the Substitution Effects on Telecommunication Technologies (contuniues)

Liikanen, Stoneman and Toivanen [9]	Analyzing the role of generational effects in diffusion of mobile telecommunication (1G and 2G)	The results from a generation-specific approach differ significantly from those of a generic model. 1G (2G) has a positive (negative) effect on 2G (1G)

		diffusion. Both generations are substitutes for fixed phones.
Vagliasindi, Güney, and Taubman [14]	Exploring the competition between traditional fixed line and mobile services across Eastern Europe and the Former Soviet Union	It is concluded that adoption of mobile telephony in transition countries is a formidable alternative to fixed line telephony. On the other hand it has already led to significant advantages in terms of increasing coverage and connectivity of the population.
Briglauer, Schwarz, and Zulehner [15]	Estimating own-price elasticities for fixed network voice telephony access and national calls services for private users as well as cross-price elasticities to mobile services using time series data from 2002 to 2007 from the Austrian markets.	Demand for access services is inelastic and that the cross price elasticity to mobile is insignificant.
Srinuan, Srinuan, and Bohlin [16]	İnvestigating whether mobile broadband is a complementary or substitute service to fixed broadband by examining survey data of Sweden in 2009.	The own-price and cross-price elasticities show that mobile is substitute service to fixed in most geographic area of Sweden
Ward and Zheng [17]	A panel data analyses for China (1998 to 2007) is used to estimate own and cross-price elasticities for fixed and mobile telephone service.	Fixed and mobile subscriptions are fairly strong substitutes.
Grzybowski [8]	Inspecting substitution between access to fixed-line and mobile telephony in the EU using cross-section panel data on households' choices of telecommunications technologies in years 2005–2010.	Fixed-to-mobile substitution was slowed down by the spread of Internet but it may continue with the spread of mobile broadband.
Barth and Heimeshoff [18]	Investigating the degree of fixed–mobile call substitution within different European countries.	The estimated cross-price elasticities of the mobile price on the fixed-line call demand are relatively large compared to other studies.
Chang et al. [10]	Investigating the performance of the Lotka-Volterra and Bass models in the saturated mobile phone market of the Republic of Korea.	They concluded from the study that the Lotka-Volterra model shows better performance under competition.
Grzybowski and Verboven [19]	Inspecting substitution from fixed-line to mobile voice access, and the role of various complementarities that may slow down this process for 27 EU countries during 2005-2011.	1. There is significant fixed-to-mobile substitution. 2. The decline in fixed telephony has been slowed down because of a significant complementarity between the fixed-line and mobile connections offered by the fixed-line incumbent operatör. 3. The decline in fixed telephony has also been slowed down because of the entrance of broadband internet.
Lange and Saric [20]	Exploring the access substitution between fixed-lines, mobiles, and managed VoIP in a unified EU cross-country framework.	Strong access substitution between fixed-lines and mobiles and provides indicative evidence on the substitution between fixed-lines and VoIP
Leurcharusmee et. al. [21]	Estimating the impact of users' mobile broadband subscription on their decision to terminate fixed broadband subscription	The regression analysis showed that mobile broadband subscription has a positive significant effect on the decision to cancel fixed broadband service.

In this study, we handle the case of TURKEY. Turkey has increasing population growth and shows a fast economic improvement as a developing country. It is an unexamined country from the perspective of diffusion of the telecommunication sector and there are only a few studies about developing countries in the literature. On the other hand, telecommunication technologies in Turkey show a fast development process which has many effects on consumers. Therefore, we aim to add to contribute to the literature by modeling mobile diffusion and substitution effects on the sector for Turkey. Furthermore, future trends and patterns in the telecommunication technologies are modeled. The data of two time-series showing the number of mobile telecommunication subscribers and fixed-line subscribers are used to examine the diffusion patterns. Procedure of the study is given in Figure 1.

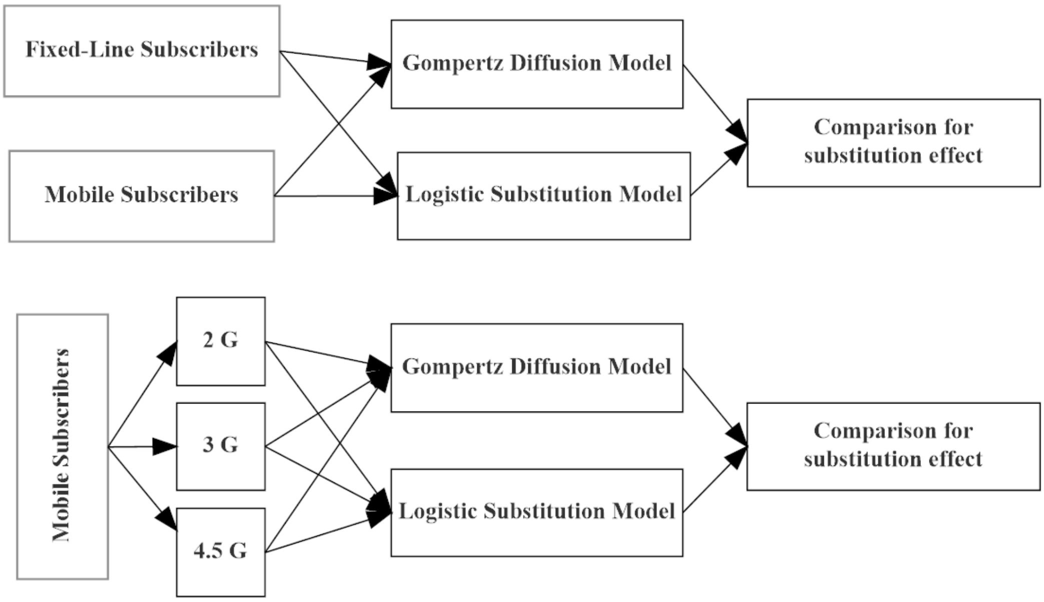

Figure 1. Procedure of the study

Turkey has almost reached saturation level in mobile telecommunication within the last 20 years. The penetration rate of mobile telecommunication was announced as 97.6% in September 2017 (The population of Turkey was 79,814,871 million in 2016 based on the Address Based Population Registration System of Turkey). Decreasing prices and increasing capabilities, in particular, have caused a significant rise in the number of mobile subscribers [22].

A diffusion analysis of telecommunication technologies gives important clues about market potential, current states of the market and saturation level. Using appropriate diffusion models helps to forecast the short-term demand of the market. On the other hand, we expect to find meaningful results for technology investors about the trends of telecommunication technology in Turkey. The rest of the paper is organized as follows. Section 2 sets out the mobile market overview in Turkey. Section 3 inspects the related diffusion models. Section 4 presents the data, model evaluation and results for telecommunication diffusion and substitution effects in Turkey, and Section 5 contains concluding remarks and discussion.

2. TELECOMMUNICATION MARKET OVERVIEW IN TURKEY

In Turkey, while fixed telephony has an almost one hundred years history (1924), the mobile phone was only introduced in 1994. The first GSM (Global System for Mobile Communication) operator, Turkcell, was introduced in March 1994 and had a 900 MHz frequency license. Two months later, Telsim, the second operator in Turkey, was introduced to the communications sector. After 1994, a rapid diffusion process was seen in mobile phone diffusion in Turkey. Furthermore, Turkey has the highest minutes of usage (MoU) value, with 331 minutes, among European countries (ICTA, 2016).

On the other hand, mobile technology has been developing rapidly and 3G technology was introduced to the sector in 2009. The legal framework of the telecommunications sector in Turkey has been guided by the Ministry of Transportation, Maritime Affairs and Communications. However, Law No 4502 dated 27.01.2000, amending Laws No 406 and 2813, which are the basic laws concerning the telecommunications sector, separated policymaking, regulation and operation function (Information and Communication Technologies Authority - Establishment, 2015). While regulation function was given to the Information and Communication Technologies Authority, policy making became the responsibility of the Ministry of Transportation, Maritime Affairs and Communications. Telegraphs, fixed telephony, postal services and, mobile telephony are under the charge of the ministry. For details of the telecommunication policies in Turkey, researchers can be referred to Burnham [24] and Atiyas [25]. In Table 2, the chronological development of the telecommunication sector in Turkey is given.

3. MATERIALS AND METHODS

3.1. Generic Diffusion Models

Rogers [3] classes adopters in to five categories: the innovators (2.5% of adopters), followed by the early adopters (13.5%), and followed by the early majority (34%), the late majority (34%) and the laggards in the rear (16%). These percentages display a normally distributed bell shaped curve, which defines the adoption process of adopters and the cumulative values of these adopters' percentages represent an S-shaped curve. The diffusion of telecommunication technologies follows an S-shaped curve, similar to the diffusion of most other technological innovations [3]. There are many different mathematically formulated S-shaped curves in the literature: Logistic, Gompertz, Logarithmic Logistic, Simple Modified Exponential, Log Reciprocal, etc. These curves are easily adapted for diffusion models. On the other hand, the Bass diffusion model yields an S-shaped curve similar to those of other models and is used in innovation diffusion analysis extensively. We give a detailed explanation of the Gompertz model, which is also employed in this study. The Gompertz [26] curve is given as:

$$y_t = \alpha e^{-\beta e^{-\gamma t}} \quad (1)$$

Table 2. Milestones of Telecommunication Sector in Turkey

Year	Improvements
1924	Fixed lines were used for the first time.
1983	A governmental body responsible for radio frequency management was established.
1994	Post and telecommunication services were separated. The telecommunication side was organized as Turk Telecom (TT). The first GSM operator, Turkcell, was introduced. Telsim started GSM as the second operator.
2000	The telecommunications Authority was established (Information and Communications Technologies Authority - ICTA). Telecom Authority was given licensing authority for the first time. Telsim started GPRS (General Packet Radio Service). Aria and Aycell started GSM 1800.
2003	Turk Telecom started to give ADSL (Asymmetric Digital Subscriber Line) service. Aria and Aycell were merged as Avea.
2005	Turk Telekom was privatized and Telsim was sold to Vodafone.
2008	Mobile number portability was allowed and price cap application on off-net calls started
2009	Third-generation (3 G) services started.
2015	The tender for 4.5 G mobile technology held by the Information and Communication Technologies Authority.

In equations 1, α represents the saturation level or the potential maximum value of the response variable. β and γ are both positive parameters related to the location and speed of diffusion, respectively. γ is defined as the parameter related with the rate at which the response variable reaches its potential maximum [27]. On the other hand, t is a linear time matrix and can be given as $t= [1, \ldots, T]$ [28].

The Gompertz model outperforms if the diffusion process weakly correlates with the number of adopters when the diffusion process slows down [29]. Furthermore, if the growth of the diffusion is quite rapid at an early phase, the Gompertz function is the best method, because Gompertz attains the maximum rate of growth at an earlier phase to the other models.

On the other hand, if the growth is initially slow, the growth speed also affects the inflection point of the curves (t_m). The inflection point, which means the maximum rate of the growth of Gompertz, occurs before 37 % of cumulative adoption. [30].

3.2. Diffusion Models for Substitution Effects

New technologies always force to replace the predecessors and generally superior than older ones. Modelling a next generation technology by generic diffusion models misses some important points, such as competition effect of technologies. Sharing the same market by competitors has adverse effects on the diffusion rate. In the literature, there are many diffusion models developed for inspecting substitution effects on diffusion of technologies. Most popular ones are Logistic Substitution model, Lotka-Volterra model, Fisher-Pry model and Norton-Bass model. Logistic Substitution is explained detail in the below.

One of the other most popular substitution models is Logistic Substitution model which is a derivative of Fisher-Pry model. Logistic Substitution model is defined as "forecasting technological opportunities, recognizing the onset of technologically based catastrophes, investigating the similarities and differences in innovative change in various economic sectors, investigating the rate of technical change in different countries and different cultures, and investigating the limiting features to technological change."by Fisher and Pry [31]. The diffusion cycle of competitive technologies is subdivided as: growth, saturation and decline, where the growth and decline stages are logistic growth processes [32]. Logistic Substitution model is more general form of Fisher-Pry model to deal with more than two competing technologies. Equation [33] is given as:

$$f_{i(t)}= {}^{1}/_{[1+\exp(-\alpha_i t-\beta_i)]} \tag{2}$$

where i=1,…, n (n is the number of competing technologies) and α_i and β_i are the estimated coefficients. α_i is the growth parameter and β_i is the parameter specifies the time (t_m) when the curve reaches midpoint of the growth trajectory. f_i is the diffusion rate of the ith technology. Now we suppose an older technology (j) in the market, new situation can be formulated as

$$f_{j\,(t)}=1-\sum_{i\neq j} f_i(t) \tag{3}$$

$$y_j(t) = log\frac{f_j(t)}{1-f_j(t)} \tag{4}$$

4. ANALYZE ON TELECOMMUNICATION TECHNOLOGIES IN TURKEY

4.1. Present Situation of Fixed-line and Mobile Telecommunication Technologies

The data set considered in this paper comprises 88 quarterly data (last quarter of each year) of total fixed-line subscriber numbers and 23 quarterly data (last quarter of each year) of total mobile subscriptions from Turkey. The number of mobile subscriptions includes both the prepaid and postpaid sectors. Mobile subscription can be defined as an account created by an operator or service provider. Fixed-line subscriptions are also consisting of the values explained by the responsible authorities. Data are obtained from the Turkish Statistical Institute and the ICTA. We only use the end of year (Q4) data from 1994 Q4 to 2017 Q4 for mobile subscription and 1929 Q4 to 2017 Q4 data for fixed-line subscriptions. Gompertz model is used to explain fixed-line and mobile diffusion in Turkey from a generic model perspective. The cumulative number of mobile subscribers and fixed-line subscribers are plotted in Figure 2.

There was a decrease in cumulative subscribers after the year 2008 for two periods (16th and 17th periods) for mobile market. Mobile network operators in Turkey had imposed different charges on "on-net" and "off-net" calls until 2008. The huge price differences between on-net and off-net calls had led many consumers to hold multiple SIM cards for different operators in the Turkish market [34] to avoid high bills. The Turkish regulatory authority, the ICTA, imposed a price cap on off-net calls to all mobile network operators [35] and mobile number portability became available, simultaneously. As a result of these legal arrangements, many subscriptions were cancelled after 2008 by customers. On the other hand, fixed-line technology appears in a standard technological life-cycle. Also, a closer look is given for next generation mobile telecommunication technologies in Figure 3.

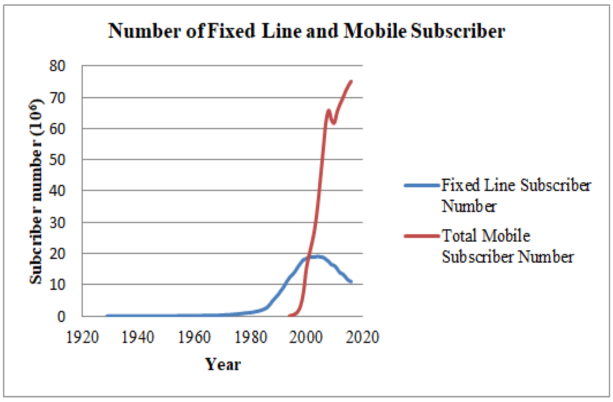

Figure 2. Total mobile and fixed-line subscriber in Turkey

4.2. Substitution Effect of Mobile on Fixed-Line

In this part, we estimate the Gompertz and Logistic Substitution model by using the available data. Gompertz and Logistic Substitution models are tested by the Nonlinear Least Square method (NLS) with the help of the Loglet Lab Software [36]. In the literature, many techniques have been used for testing the diffusion curves. The Ordinary Least Square method [37], Maximum Likelihood Estimation (MLE) [38], and NLS [39] are frequently used in the parameter estimation of diffusion curves. It is indicated that NLS outperforms the OLS and MLE methods in terms of forecasting performance because of the nature of the diffusion equations [40]. The NLS estimation procedure overcomes the time-interval bias; the bias results from estimating a continuous-time model by using discrete time-series data in the OLS [41]. We estimate the diffusion models over the whole data set for comparison purposes. The MAD and RMSE are selected as forecasting performance criteria. The NLS method needs initial parameters to start the search procedure. Wrong starting values result longer iteration, greater execution time, and non-convergence of the iteration [27]. An efficient order to specify starting values is α, γ and β for Gompertz model. The formulas of starting values for Gompertz is calculated as the mentioned in the literature [27]. The results of the growth curves are given in Table 3, and Figure 4 depicts the related results of Gompertz curves of the actual and predicted data sets for both technologies. Gompertz diffusion model for fixed-line and mobile subscribers have a significance value (*p*) smaller than 0.05, as indicated in Table 3. According to the performance criteria, the models seem appropriate to depict the diffusion of fixed-line and mobile telecommunication in Turkey. On the other hand, a sharp decline for fixed-line after the mobile telecommunication entrance to market can be shown clearly and this is an important clue for substitution effect on fixed-lines. tm which the inflection point for that technology is found as 1989 for fixed-lines and 2002 for mobile technology. Maximum adopters for the related technologies are 16.5x106 users and 75.9x106 users for fixed-line and mobile technology, respectively.

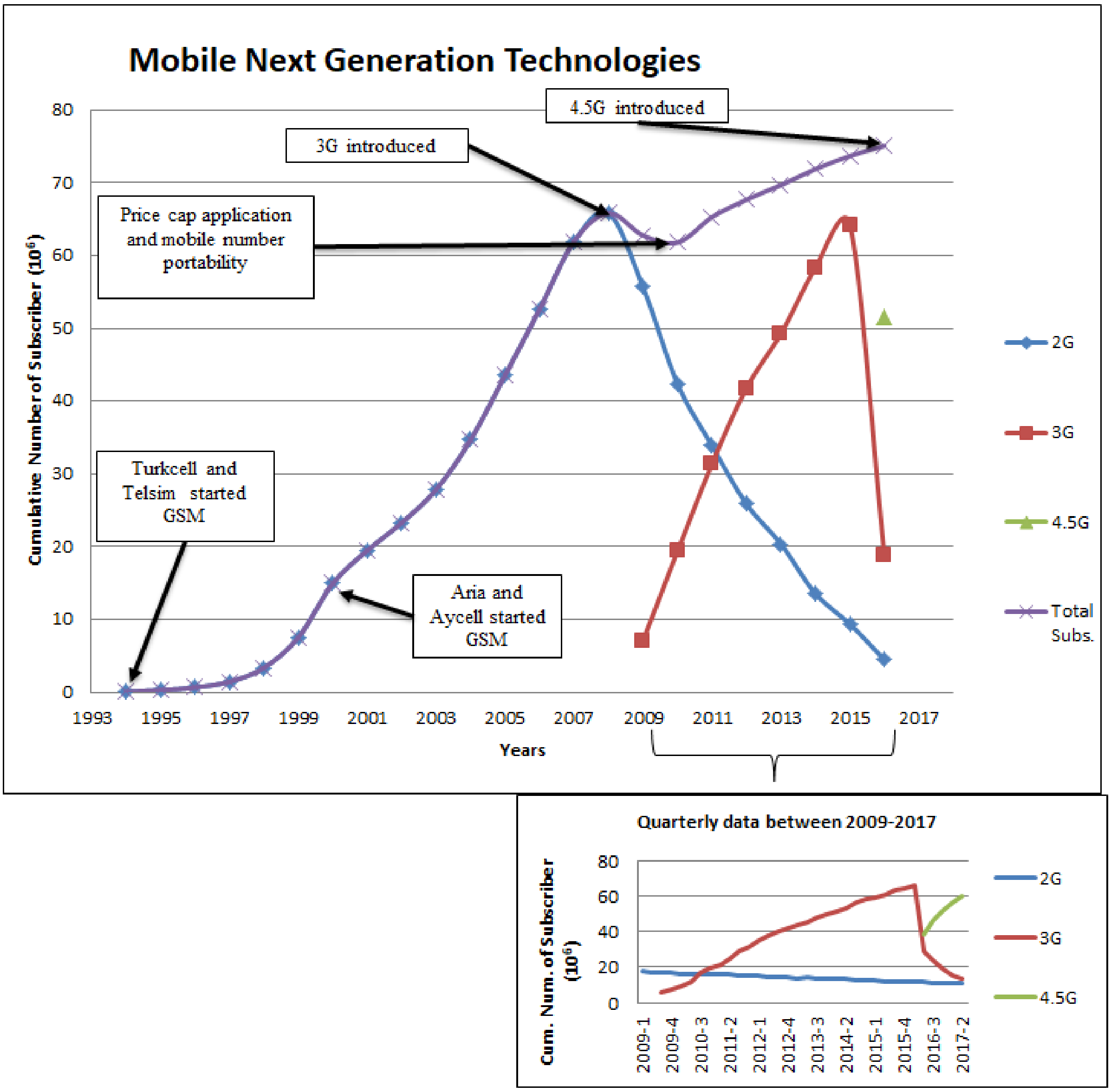

Figure 3. Cumulative Mobile Subscribers depending on the next generation technologies(x10^6)

Table 3. Results of the Gompertz Curve Fitting

Gompertz Curve	α	β	γ	t_m	RMSE	MAD	MAPE	R^2	P
Fixed-line	16.5	5.2	0.28	1989	1.7	1.46	0.52	0.92	6.42xe^{-8}
Mobile	75.9	5.8	0.26	2002	2.9	2.17	0.07	0.96	4.8xe^{-14}

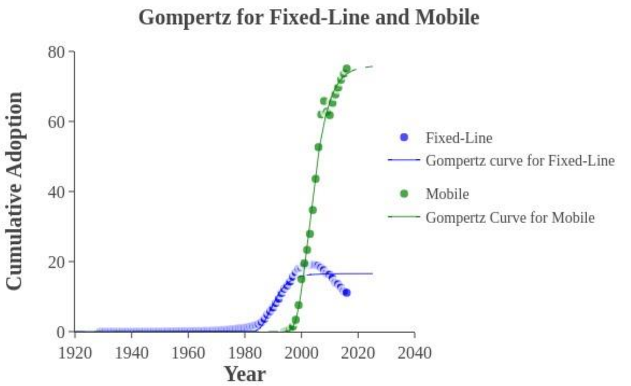

Figure 4. Gompertz Curve Fitting

Growth rates of these two technologies are given in Figure 5. Sharp declines of the rate in the years around the years 2000 and 2007 prove that technological improvements and entrance of new competitors to the market changed the penetration rate and that these exogenous interventions manipulated the structure of the diffusion process, and caused to the diffusion curves deviate from the conventional S-shaped curve. Furthermore, Gompertz results show that change of growing rate of fixed-line has already been slow down before the entrance of mobile technology to the market as seen Figure 5. This does not imply that fixed-line reached the maximum adopter number before the entrance of mobile technology to the market. But it means that diffusion acceleration of fixed-line technology also slowed down before the entrance of mobile technology
to the market. The findings support that the Gompertz model inflection point occurs before 50% of the curve. 1989 and 2002 years represent the 37% of the adoption for these technologies. On the other hand, the years 2005 and 2020 are found the 99% adoption of fixed-line and mobile technologies, respectively.

In the second step, to see the substitution effect on the fixed-line, we apply Logistic Substitution model to fixed-line and mobile telecommunication data. Results of the Logistic Substitution model are given below in Table 4 and Figure 6.

p values of Logistic Substitution models are smaller than 0,05 as seen in Table 4. Both of the cases fit to the data almost in the same performance. Also, the error values of Logistic Substitution fitting show better performance than Gompertz curves for both technologies while R^2 values are smaller than the Gompertz curve fitting. Logistic Substitution fitting also shows that a clear substitution effects can be shown on fixed-line after the first year of mobile telecommunication in the market. On the other hand, both of the technologies show almost the same diffusion rate in the market. Mobile technology shows a positive acceleration while fixed-line shows a negative acceleration because of the substitution effects on it. As a result of two analyses, Gompertz curves have better R^2 values, but Logistic Substitution models gives smaller error functions. This implies that fluctuations on the diffusion of telecommunication technologies are better represented by the Logistic Substitution model because of the substitution effect of mobile technology on fixed-line causes unexplained variances on the diffusion rates.

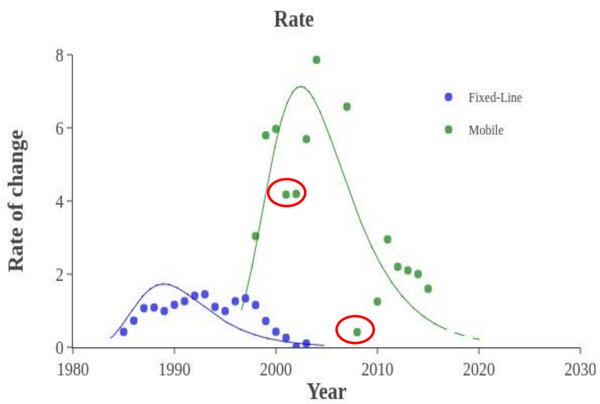

Figure 5. Growth rates of Gompertz Curves

Table 4. Results of the Logistic Substitution Model

Logistic Substitution	α	β	γ	t_m	RMSE	MAD	MAPE	R^2	P
Fixed-line	1	-16.6	-0.26	2003	0.07	0.06	0.50	0.81	$5.20xe^{-9}$
Mobile	1	17.4	0.25	2002	0.08	0.07	0.23	0.81	$8.49xe^{-9}$

4.3. Adoption of Next Generation Telecommunication Technologies in Turkey

Mobile telecommunication in Turkey has not a long history when it is compared to fixed-line. A fast technological improvement is shown in mobile telecommunication technology since 1994 in Turkey. Three generational changes had completed in the market so far. On the other hand, infrastructural changes do not always imply a certain adoption of users because of the compatibility of users' devices. In this section substitution effect on the mobile GSM technologies are investigated to see the effects of infrastructural changes. 2G, 3G and 4.5G mobile technologies are compared by using Gompertz model and then Logistic Substitution model is used to see the substitution effect on different generation of mobile technologies. Quarterly data are used for prediction. Results of Gompertz model are given in Table 5 and Figure 7.

Inflection points of the diffusion processed of mobile generation technologies are found as the years 2002, 2011 and 2019 for 2G, 3G and 4.5G, respectively. 2G technology has the biggest diffusion rate (γ=0.85) and this implies availability of the ready users in the market for this technology. On the other hand, 3G and 4.5G have same diffusion rates in the market. Best fit is supplied for 4.5G technology depending on the Gompertz curve fitting. Change rates of adopter numbers are represented in Figure 8. As seen in the Figure 8, largest change occurs on 4.5G, while the smallest change occurs on 3G. 3G is an intermediate technology for mobile market and it is sharing the market with 2G during seven years. Competition has an adverse effect on 3G technology as seen in the Figure 8, but this can be easily shown in the next, Logistic Substitution step. In the next step, we investigate the substitution effect on mobile telecommunication technologies by using Logistic Substitution model. Results are given in Table 6 and Figure 9 depicts the market share of three generational technologies. When 4.5G introduce to the market, almost 0.50% of 3G users had switched to the 4.5G as seen in the Figure 9. Diffusion rates (γ) imply that 2G is the most affecting technology from competition. On the other hand, market is dominated by 4.5G technology as expected. Furthermore, Figure 9 depicts that 2G technology saturated before the entrance of 4.5G. Switching between 2G and 3G is slower than switching between 3G and 4.5G. This can be a result of the device compatibility or a resistance to a new technology. Because, major differences of two technologies, especially transmission with MMS, may have caused a late adoption process for 3G. On the other hand, need for changing the SIM cards for new GSM technology is another issue for adopters. After the year 2012, market is captured by 3G until 2017 as seen in Figure 9.

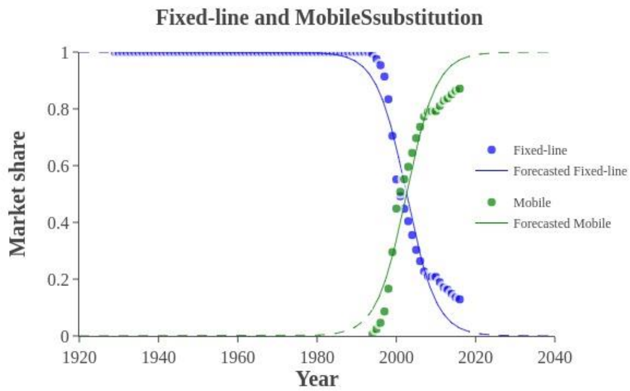

Figure 6. Logistic Substitution Fitting

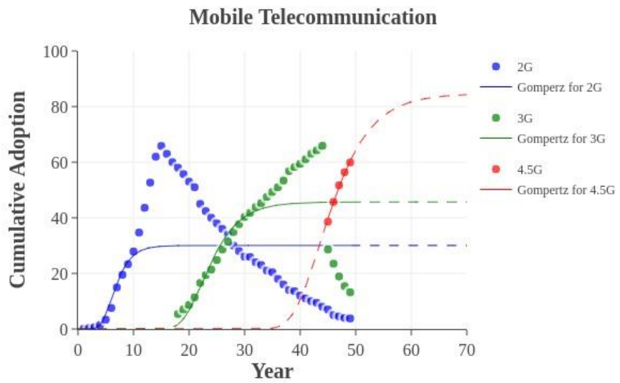

Figure 7. Gompertz curves for mobile next generation technologies

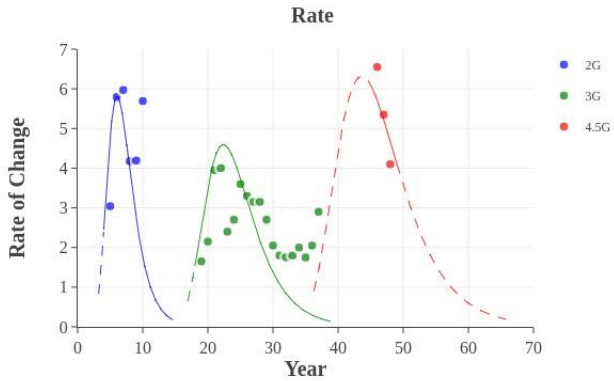

Figure 8. Growing rates for mobile next generation Technologies

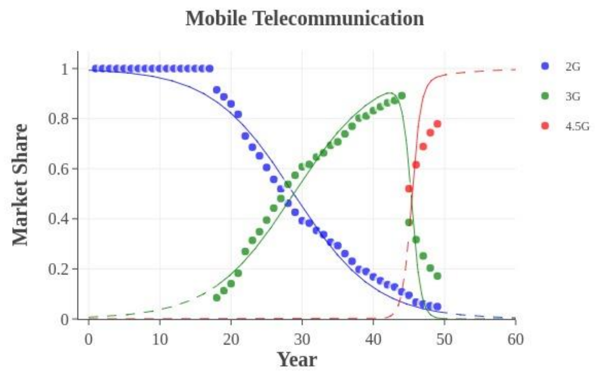

Figure 9. Market share of mobile technologies

Table 5. Results of the Gompertz Model for Mobile Generation Technologies

Gompertz Curve	α	β	γ	t_m	SSE	RMSE	MAD	MAPE	R^2	P
2G	29.9	1.73	0.85	2002	58.2	2.9	2.36	0.63	0.97	0.000385
3G	46.6	6.79	0.22	2011	1225	7.0	4.77	0.13	0.95	$1.52xe^{-10}$
4.5G	81.2	6.62	0.22	2019	1.40	0.53	0.51	0.01	0.99	0.000138

Table 6. Results of the Logistic Substitution Model for Mobile Generation Technologies

Logistic Substitution	A	B	γ	t_m	SSE	RMSE	MAD	MAPE	R^2	P
2G	1	-25.5	-0.17	2012	0.08	0.045	0.03	0.15	0.97	$2.96xe^{-21}$
3G	1	23.7	0.19	2012	0.05	0.05	0.04	0.11	0.96	$2.80xe^{-14}$
4.5G	1	13.2	0.33	2017	0.0001	0.006	0.006	0.01	0.99	0.00319

Achieving the mentioned adoption processes of new generations means that Turkey probably has a matured telecommunication market which is adequately open to next generation technologies. Switching between the new generations is faster than before. Users generally show a fast adoption process as seen in the results.

5. CONCLUDING REMARKS AND DISCUSSION

In this paper, the growth of the telecommunication market in Turkey is analyzed. The hypothesis that the adoption of the fixed-line and mobile telecommunication in Turkey follows an S-curve is proved by Gompertz curve fitting. On the other hand, Logistic Substitution model is used to understand the substitution effects between these technologies. Al the results indicates that; Logistic Substitution model is better to simulate the systems in competitive environment. In the fixed-line and mobile telecommunication analysis, all models are quite capable of describing the diffusion process. Calculated statistical errors and performance characteristics for the models show that both models appropriate for market.

On the other hand, fluctuations on the diffusion of telecommunication technologies are better represented by the Logistic Substitution model because of the substitution effect of mobile technology on fixed-line causes unexplained variances on the diffusion rates. Competition is considered to explain change of diffusion rates and gives better results for Logistic Substitution model. Furthermore, the regulatory framework has been very effective in the diffusion process of telecommunication services in Turkey. The decrement and increment in the number of adopters after the regulations cannot be ignored in Turkey in the mobile telecommunication market. As seen in Figure 5, the highest amounts of changes in the growing rate are detected when the external interventions of the regulatory authority affect the market.

In the diffusion of mobile technologies in Turkey, both of the models are very suitable to represent the cases, but the Logistic Substitution models have smaller error values for each generation. On the other hand, 3G technology as an intermediate technology has not a fast diffusion process because of the radical changes that it brought to the communication process. But 4.5G has the fastest adoption process as a result of infrastructural sufficiency and device compatibility. Most mobile devices of 3G users were ready for use with 4.5G technology and adopters shifted to the new technology to maximize the utility, easily. 2G technology was already saturated before 4.5G.

The study also has some limitations. The use of more diffusion models would be better to simulate the market. Especially, the diffusion models like Norton-Bass which was specially developed for the substitution of successive generation products should be used in the cases may give better results. Also, considering the determinants of mobile telecommunication while modeling the diffusion process, would give more meaningful results to understand the general framework of diffusion of telecommunication in Turkey. On the other hand, inspecting the prepaid and postpaid subscriptions separately would provide a deeper insight into the telecommunications sector in Turkey. As a future work, diffusion modeling with the determinants of mobile telecommunication could be done. In particular, the effect of regulations could be included in the models as a smoothing factor of the diffusion process.

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