MODELLING MOBILE TELECOMMUNICATIONS SERVICES FOR FORECASTING PURPOSES: A CROSS-COUNTRY ANALYSIS

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MODELLING MOBILE TELECOMMUNICATIONS SERVICES FOR FORECASTING PURPOSES: A CROSS-COUNTRY ANALYSIS

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ABSTRACT

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Mobile telecommunications industry has experienced high growth rates for the recent 30 years. Accordingly, forecasting the future of mobile telecommunications services is important not only for mobile operators but also for all stakeholders in this industry ranging from handset manufacturers to vendors. In this thesis, the diffusion of mobile telecommunications services in 20 countries from different regions around the world is examined for the period of 1981 to 2010 with special emphasis on Turkey, in order to address the uncertainty in optimal model selection. The Gompertz, logistic and Bass models are fitted to the observed data of mobile phone penetration by means of nonlinear least squares. The fitness accuracies of the models are evaluated based on root mean square error (RMSE). Empirical results show that S-shaped growth models are capable of explaining the diffusion of mobile telecommunications services. The findings also suggest that there is no superior model in defining the diffusion process and the most suitable model is country-dependent. Finally, we observe that the diffusion in late entrant countries appears to be faster than pioneer countries and peak demands in mobile telephones occur during the period of 1999 to 2006, which suggests a remarkable multinational learning effect and significance of the transition into digital technology.

Keywords: mobile telecommunications, technology diffusion, diffusion forecasting, Bass model

ÖZ

MOBİL HABERLEŞME SERVİSLERİNİN TAHMİNLEME AMACIYLA MODELLENMESİ: ÜLKELERARASI BİR ANALİZ

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Mobil haberleşme endüstrisi son 30 yıldır yüksek oranda büyümektedir. Buna bağlı olarak, mobil haberleşme hizmetlerinin geleceğini öngörmek sadece mobil operatörler için değil, telefon cihazı üreticilerinden tedarikçilere bu sektörün bütün paydaşları için önem taşımaktadır. Bu çalışmada, Türkiye başta olmak üzere dünyanın farklı kesimlerinden 20 ülkenin mobil haberleşme hizmetleri yayılımı 1981 yılından 2010 yılına kadar incelenerek ideal model seçimindeki belirsizlik ele alınmıştır. Cep telefonu penetrasyon verisi kullanılarak Gompertz, logistic ve Bass modelleri doğrusal olmayan en küçük karekökler yöntemi aracılığıyla hesaplanmıştır. Bu modellerin uygunluğu kök ortalama kare hatası kullanılarak değerlendirilmiştir. Ampirik sonuçlar mobil haberleşme hizmetlerinin yayılımının açıklanmasında Sbiçimli büyüme eğrilerinin yeterli kapasiteye sahip olduğunu göstermektedir. Bulgular, yayılım sürecini açıklamada üstün bir modelin varlığına işaret etmemekte; en uygun modelin ülkeye göre değişken olduğunu göstermektedir. Sonuç olarak, pazara geç giren ülkelerde öncü ülkelere nazaran daha hızlı yayılım gerçekleştiğini ve mobil haberleşme hizmetlerine olan talebin 1999 ile 2006 yılları arasında zirve yaptığını gözlemlemekteyiz. Bu sonuçlar çokuluslu öğrenme etkisini ve dijital teknolojiye geçişin önemini işaret etmektedir.

Anahtar Kelimeler: mobil haberleşme, teknoloji yayılımı, yayılım tahminlemesi, Bass modeli

To

My lovely wife and family

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LIST OF ABBREVIATIONS

1G : First Generation
2G : Second Generation
3G : Third Generation
4G : Fourth Generation
ANSI : American National Standards Institute
AMPS : Advance Mobile Phone System
ARMA : Autoregressive Moving Average
ARPU : Average Revenue Per User
CDF : Cumulative Distribution Function
CDMA : Code Division Multiple Access
CEPT : Confederation of European Posts and Telecommunications
DECT : Digital Enhanced Cordless Telecommunications
ETSI : European Telecommunications Standard Institute
EU : European Union
GDP : Gross Domestic Product
GPRS : General Packet Radio Service
GSM : Groupe Spéciale Mobile, Global System for Mobile Communications
HSPDA : High Speed Downlink Packet Access
IMT : International Mobile Telecommunications
ITU : International Telecommunication Union
LTE : Long Term Evolution
MMS : Multi-media Messaging Service
MSE : Mean Square Error
NMT : Nordic Mobile Phone
PDF : Probability Density Function

RMSE : Root Mean Square Error
SMS : Short Message Service
TACS : Total Access Communication System
TDMA : Time Division Multiple Access
UMTS : Universal Mobile Telecommunications Systems
WAP : Wireless Application Protocol
WiMax : Worldwide Interoperability for Microwave Access

CHAPTER 1

INTRODUCTION

1.1. Forecasting the Future of Mobile Telecommunications Industry

Mobile telecommunications industry has evolved in a fascinating way. Although commercial mobile phone's history is less than forty years, mobile-cellular subscriptions reached 5.9 billion and the global penetration reached 87% around the world in 2011. (International Telecommunication Union [ITU], 2011).

Due to the increasing market demand, companies have invested more and more in the mobile telecommunications industry. In 2000, Germany conducted an auction for the frequency blocks to support the 3G services. 50.8 Million Euro was paid for this spectrum in Germany. Similarly, 38.3 Million Euro was paid in the United Kingdom for the radio spectrum required for the 3G services. The results of the bids are higher than expectations of governments and observers (Cable, Henley, and Holland, 2002). Though mobile operators run into debt to buy the spectrums and invest in their infrastructure to offer 3G services, estimated profits could not be gained in the early period. Noan (2002) emphasizes that "During the late 1990s, the network companies over-optimistically projected their market shares over the long term". 3G auction experience of operators in Europe shows that mobile telecommunication services require a forward-looking assessment.

Forecasting the future of mobile telecommunication services is important not only for operators but also for all shareholders in this industry. First of all, operators have to forecast the likely revenues before deciding whether to buy spectrum. For example, while the first GSM-1800 license in Turkey was given to İş-Tim consortium in return for 2.525 billion dollar and the second GSM-1800 license was given to the incumbent fixed operator (Turk Telekom), the third GSM-1800 license could not be operationalized as prospective companies found the first price overvalued and did not participate in the third license agreement.

Secondly, manufacturers all over the world need to decide which technologies to focus on. Mobile telecommunications cover different standards and technologies and some of these technologies run against each other. For instance LTE and WiMax technologies are two candidates in order to become the 4G wireless technology of choice for evolving mobile broadband networks. Accordingly, manufacturers should clearly analyze the demand carefully and make their plans for manufacturing LTE or WiMax capable devices.

Academicians and researchers also need to understand the evolution and future direction in mobile telecommunications industry in order to define the areas that need to be discussed and evaluated. The list can be extended to include regulators, investors and other participants.

1.2. Scope of This Thesis

The main goal of this thesis is to model the diffusion of mobile telecommunication services in different countries around the world. Addressing the uncertainty in optimal model selection is also aimed in the thesis. Additionally, usage of one model may result in substandard forecasting and decision making. As a result of this, Gompertz, logistic and Bass models are fitted to the observed data of mobile phone penetration covering the period of 1980 to 2010 by means of nonlinear least squares. The fitness accuracies of the models are evaluated based on root mean square error (RMSE).

This analysis gives a statistical vision for the future of mobile telecommunications services for 20 countries. Diffusion modeling of the mobile market will provide the following results:

- Short-, medium- and long-term forecasts.
- Estimation of the saturation level
- Estimation of the timing and magnitude of the peak demand

The results in this thesis should be combined with other analysis to come up with a holistic view covering different scenarios.

A special emphasis is given on Turkish mobile market. Turkish market is interesting for several reasons. First of all, for the last eight years Turkish economy has showed an impressive performance with an average annual real GDP growth of 5.2%. (IMF World Economic Outlook, 2012). Considering the 2007-2012 financial crisis, Turkey’s economic growth is significant during this period of time. Studies suggest that there is positive relationship between telecommunication infrastructure and economic growth. (Cronin, Parker, Colleran, & Gold, (1991); Röller, Waverman, (2001)). As a result of this, analyzing the future of mobile telecommunication services in Turkey can provide valuable insight for the evaluation of future economic growth. Secondly, Turkish mobile market was exposed to different levels of competition including monopoly period (1986-1994), duopoly period (1994-2001), quadropoly period (2001-2004) and finally triopoly period (2004- present) after the merger of two mobile operators. To our knowledge, no existing empirical research has addressed the diffusion of mobile telecommunications in Turkey.

1.3. Outline of This Thesis

This thesis consists of 7 chapters. In the first chapter, the importance of forecasting the future of mobile telecommunication services is highlighted. Chapter 2 is dedicated to literature review about the diffusion of innovation and similar researches in the field of the diffusion of cellular phones.

In Chapter 3, we concentrate on the evolution of mobile telecommunications services around the world and Turkish mobile communications market. The methodology of our analysis is given in Chapter 4. Chapter 5 is devoted to the results about the cellular penetration in Turkey. In Chapter 6, we evaluate the results of the cross-country analysis. Chapter 7 is devoted to discussion. In the end, we finalize our dissertation in Chapter 8.

CHAPTER 2

LITERATURE REVIEW

2.1. Diffusion of Technology/Innovation

Diffusion of technology/innovation has been widely discussed by academicians. In his book, Rogers (1962) defines diffusion as “the process in which an innovation is communicated through certain channels over time among members of a social system”. Based on Roger’s definition, main elements of diffusion are identified as innovation, communication channels, time and social change.

Innovations may either follow different adoption patterns or they may not be adopted at all. Some of the products introduced as an innovation have not been adopted at all. To illustrate, Dvorak keyboard emerged as an alternative to Qwerty keyboard with the advantages of easier to learn, faster to type with fewer errors (Liebowitz, Margolis, 1995), however, it failed to be adopted by consumers. Previous experiences suggest that innovations have certain characteristics. Rogers (1962) defines the attributes of innovations as “relative advantage”, “compatibility”, “complexity”, “trialability” and “observability”. Tornatzky and Klein (1982) perform a meta-analysis covering seventy-five articles related with the characteristics of innovation and they conclude that compatibility, relative advantage and complexity are the most significant factors for the adoption of innovation.

Relative advantage is defined as “the degree to which an innovation is perceived as being better than the idea it supersedes” (Rogers and Shoemaker, 1971). However, the definition of “being better” is too broad and difficult to measure. Additionally, the relative advantage of the innovation can be economic or social. Dearing (2007) divides relative advantage into two attributes including effectiveness and cost. Studying the diffusion of the Internet across countries, Kiiski and Pohjola (2002) reveal that internet access cost is one of the most significant factors that explain the growth in computer hosts per capita. To illustrate, GSM service in Turkey was launched in 1994 by two operators (Turkcell and Telsim). Table 1 shows the cost of peak rate 3-minute call within the same exchange area using subscriber’s own terminal for both fixed and mobile cellular services in Turkey. The results show that the cost of mobile service is at least 13- to 20-fold higher than the cost of fixed calls during this period.

Table 1: Comparison of Fixed and Mobile Tariffs in Turkey (1993-1997) (Source: ITU Statistics)

TARIFFS	1994	1995	1996	1997
3 minute local call (peak rate)	2	3	5	11
Cellular 3 min. local call (peak rate)	26	48	90	225

Compatibility is defined as the alignment with the norms, values, and needs of the adopters (Rogers, 1962). In parallel with the compatibility, some of the innovations may be rejected due to religious beliefs. In terms of compatibility, mobile phones are consistent with fixed line experience; the only difference is using a different area code when calling someone.

Complexity implies the relative difficulty of understanding and using the innovation (Rogers, 1962). Complexity is expected to have negative relationship with the adoption of innovation. Initial versions of mobile phones provided basic speech and text messaging services and they were not as complex as today’s smartphones.

Trialability means the level of easiness to experiment an innovation. Analyzing the diffusion of mobile phones in Colombia, Gamoa and Otero (2009) highlight the emergence of informal street markets, where mobile phone owners resell their minutes. The case in Colombia reveals that regardless of the cost level of ownership, market conditions can decrease the burdens to try an innovation.

Rogers and Shoemaker (1971) define observability as “the degree to which the results of an innovation are visible to others”. Visibility of the benefits of an innovation is assumed to be directly proportional with the likelihood of their assimilation. Different from fixed lines, mobile phones are usually carried by individuals and this factor creates an advantage for the adoption of mobile phones.

Using the normal frequency distribution, Rogers (1962) defines five adopter categories for the diffusion of innovation including: innovators, early adopters, early majority, later majority and laggards. As seen from Figure 1, the diffusion of innovation typically follows an S shaped curve. One of the important factors in telecommunications sector is that as the number of adopters is increased, the utility of the user is also increased.

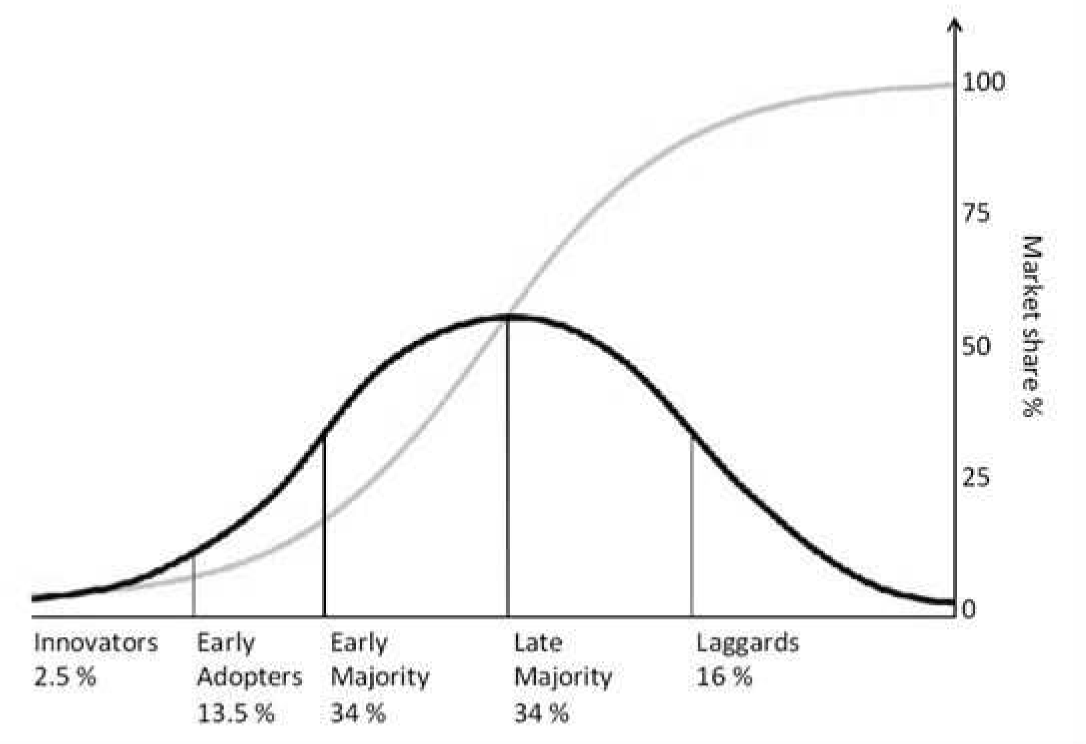


Figure 1: The Diffusion of Innovations (Source: Rogers (1962))

As seen from Figure 1, the adoption of innovations per period demonstrates a bell-shaped curve and the market share follows an S-shaped curve. As a result of this, using linear extrapolation in order to forecast and model the diffusion of innovations is misleading and result in underestimation or overestimation.

A considerable amount of research has been conducted to describe the S-shaped diffusion curves. Griliches (1957) uses the logistic growth function to analyze the diffusion of hybrid seed corn. The fit was extraordinary good and this work was considered as one of the fundamental studies in the literature on diffusion of innovation. Mansfield (1961) emphasizes the considerable importance of imitation rate for the spread of innovations. Bass (1969) develops a new growth model for the diffusion of innovations where the timing of initial purchase of new products is correlated linearly with the number of previous buyers. In the study, the model was applied to eleven consumer durables and the model performed very well in predicting the sales peak and timing of the peak. Fisher and Pry (1971) provide a substitution model for the diffusion of innovation. The study emphasized the importance of superior technology. Lekvall and Wahlbin (1973) propose a general deterministic model and emphasized the relative strength of both internal and external influence in the communication process of innovation together with the distribution of resistance to innovation.

Geroski (2000) surveys the new technology diffusion concept in the literature and classifies the models as epidemic models and probit models. The foundation of epidemic models is the lack of information about the new technology that limits the spread of this technology. Probit models take into account the individual choices.

2.2. Diffusion of Mobile Telecommunication Services

The diffusion of mobile telecommunication services in short period of time has attracted the attention of academicians. As the diffusion of mobile telecommunication services followed an S-shaped curve, different models have been applied to country specific data.

Gruber and Verboven (2001) analyze the diffusion of mobile telecommunications services in the European Union using the logistic model. Analyzing 15 countries in the EU, they found that the shift from analogue to digital technology in the mobile communication services and competition play an important role in the diffusion of mobile phones. In addition to that the study shows that the follower countries catch-up the pioneer countries.

In the literature there are plenty of country specific studies about the diffusion of mobile telecommunication services. Botelho and Pinto (2004) analyze the diffusion of mobile telephones in Portugal by applying exponential, Gompertz and logistic models for the data covering the period of 1988 to 2000. The authors find that diffusion of mobile telephones in Portugal follows an S-shaped curve and logistic model fits best to the data. Lee and Cho (2007) analyze the diffusion of mobile telecommunications in Korea. The performances of logistic model and ARMA (autoregressive moving average) model were compared based of the cellular subscribers' data for the period of 1984 to 2002. Based on the analysis, logistic model fitted better than the ARMA model. In this study, mobile telephones are found to be a substitute to fixed-line telephones in Korea. The results also showed that there is direct proportion between the diffusion speed and per capita GDP.

Michalakelis, Varoutas, and Sphicopoulos (2008) study the diffusion of mobile telephony in Greece using the different technology diffusion models including Bass, Fisher-Pry and Gompertz model. The results of the logistic family models are quite satisfactory in fitting the data for the period of 1994 to 2005. Dergiades and Dasilas (2010) also analyze the mobile telecommunication services in Greece. This study reveals that launch of pre-paid services in 1997 together with the entrance of a new operator in the market accelerates the diffusion process.

Chu, Wu, Kao and Yen (2009) analyze the diffusion of mobile telephony in Taiwan. Applying the Gompertz, Logistic and Bass model for the period of 1989 to 2007, logistic model is found to be the most appropriate model. In addition to that, results shows that market competition is the primary driver in the diffusion of mobile telephony in Taiwan. Moreover, rather than a complementary service, mobile phone is found to be the substitute of fixed-line telephones. Hwang, Cho and Long (2009) analyze the diffusion of mobile telecommunications services in Vietnam. Using the data from 1995 to 2005, the authors compare the results of logistic, Gompertz and Bass models and logistic model is found to be the best fit for the Vietnam's case. In this study, competition is found to be the main catalyst in the diffusion of mobile telecommunication services. Unlike the Taiwan and Korea case, in Vietnam, fixed-line telephones are found to be complementary to mobile telephones. Gamboa and Otero (2009) study the diffusion of mobile telephones in Colombia. Applying logistic and Gompertz models to the quarter based data from 1995Q4 to 2008Q2, the authors revealed that logistic model best describes the diffusion on Colombia. Liu, Wu and Chu (2010) analyze the mobile telephony diffusion in China using the data from 1987 to 2008. In the case of China, Gompertz model is identified as the best model for diffusion.

As seen from the country-specific analyses on the diffusion of innovations, there is no superior model for all cases. In the articles, while some authors used the number of population in modeling the diffusion, some authors used the percentage of population in modeling the diffusion process. Some of the analyses cover more than 20 years. At this point if the population has grown rapidly, the market potential has been changed. In other words the saturation level in terms of the number of populations has been changed and due to this fact the result of the diffusion model can be misleading.

Diffusion of mobile telecommunication services is one of the largest areas of interest studied on a national basis. However, to our knowledge, no existing empirical research addressed the diffusion of mobile telecommunications in Turkey. Additionally, cross-country analyses in the field of mobile telecommunication services are rare in comparison with the national basis studies in the literature.

CHAPTER 3

THE EVOLUTION OF MOBILE TELECOMMUNICATION SERVICES

3.1. The Evolution of Mobile Telecommunications Industry in the World

Usage of mobile communications was expected to be in a limited area during the early development phase. Fransman (2003) argues that “until the early-1980s it was widely believed that mobile communications would not become a high-growth mass-consumption part of the telecommunications industry”. This underestimation is based on the handsets and technology. At that time, handsets were heavy and large with limited battery-power and wireless technology was believed to be imperfect due to the relatively low capacity and speed together with the high levels of interference.

Today, while the global figures indicate breathtaking pace of advancements in the field of mobile communications, the path to the commercialization of mobile communications industry is different in separate regions of the world. First generation systems, which used different standards like NMT (Nordic Mobile Phone) in Finland, Sweden, Norway and Denmark, TACS (Total Access Communication System) in United Kingdom, Ireland, and Japan and lastly AMPS (Advance Mobile Phone System) in North America, Israel and Australia were analog systems offering simple speech capabilities on the move. Despite the poor quality and capability together with low reliability, the market demand looked promising and annual market growth rates had reached up to 30 to 50 percent by 1990s. (Wakefield, T., McNally, D., Bowlwe, D., Mayne, A., 2007)

As the requirements were towards higher quality of speech and additional services, 2G standards were developed. GSM emerged as a pan-European standard in the European area developed by the ETSI (European Telecommunications Standard Institute). The United States of America witnessed the emergence of different digital cellular standards including CDMAOne and TDMA. Japan followed a different path and developed PDC standard for its digital cellular network.

After the initial launch in 1992, GSM has evolved to provide the voice and data solutions demanded by market. It was expanded over time to include packet data transport through General Packet Radio Service (GPRS). GPRS was described as a technology between the second generation and third generations. For this reason, GPRS is considered as a 2.5G technology. In addition to this, multi-media messaging service (MMS) was launched as an extension to the existing short message service (SMS). Wireless Access Protocol (WAP) was developed to enable browsing from mobile phones. Beginning in 2003, Enhanced Data Rate for Global Evolution (EDGE) technology was deployed on GMS networks proving enhanced data rates up to 300 Kbits/s in certain situations. While EDGE technology is referred as a third generation (3G) technology in International Telecommunication Union reports, 2.75G is used to refer to EDGE data connectivity which is faster than GPRS but slower than typical 3G networks.

Prevailing the mobile communications industry between the period of 1992 and 2004, second generation systems, especially GSM was swiftly adopted by the market. Services provided by through the mobile network played a catalyst role in the expansion of subscription. For instance, SMS proved to be a profitable service for mobile operators. Hillebrand (2010) highlights that a mobile subscriber generated more than 50 SMS in a month and this creates a $100 billion turnover industry in 2010. However all of these services are not success stories. WAP being the first mobile data service is blamed for being too expensive (Webb, 2007). “Above all, perhaps the most important lesson learned from early experience with WAP is that 3G will be nothing but a set of technical standards unless innovative, compelling services are developed and supported for customers.”

By 2001, mobile subscriptions surpassed main lines in European Union (EU). Castells, Fernandez-Ardevol, Qui and Sey (2004) describe this period as a movement of mobile telephony “from being the technology for a priviledged few, to essentially a mainstream technology”. Behind this market demand, the benefit of mobility lies. Schiller (2003) approaches mobility term in two aspects. The first one is user mobility where users can communicate wireless “anytime, anywhere, and with anyone”. The second aspect is device portability where devices can be connected anytime, anywhere to the network. In other words, mobile phones have been swiftly becoming ubiquitous and through sophisticated services they have been transforming into multi-purpose gadgets (Economist, 1999).

Mobile and fixed telephone subscribers in Europe for the period between 1990 and 2002 can be seen in Figure 2. By 2001, the number of mobile telephone subscribers reached 358 million and surpassed the number of fixed telephone subscribers which was 331 million in 2001. After 2001, the penetration of fixed telephone lost its momentum. This figure arouses interest towards the relationship between fixed lines and mobile phones. Additionally it indicates that the diffusion of mobile subscriptions followed an S-shaped curve in the European Union.

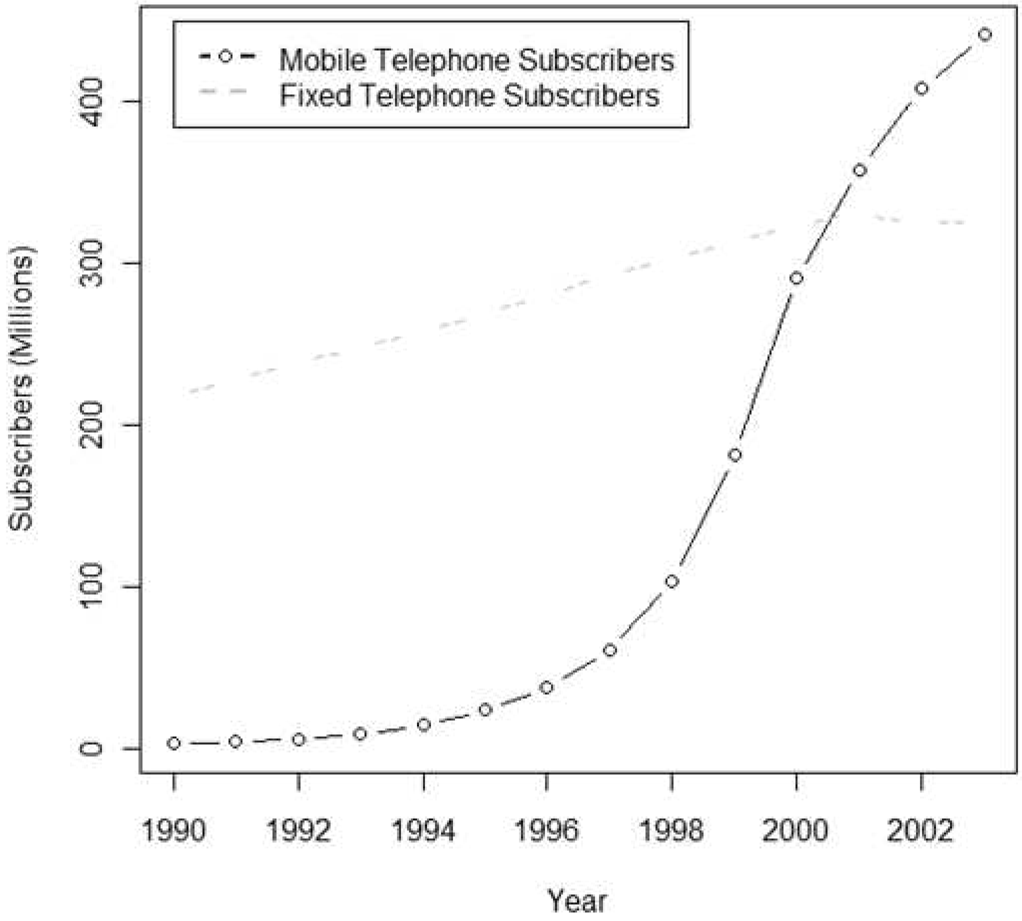


Figure 2: Mobile and Fixed Telephone Subscribers, Europe (1990-2002) (Source: ITU Statistics)

Cooperation of mobile equipment producers and mobile operators enabled GSM standard to overcome the other emerging technologies in the world through offering wide international coverage with relatively low international call rates. Having roots back in 1982 when Groupe Speciale Mobile (GSM) was formed by the Confederation of European Posts and Telecommunications (CEPT) with the idea of creating a pan-European mobile technology, GSM not only defined comprehensive technical standards that are cleverly engineered but also got the European countries and companies together that unified the European market and made it bigger than US market. As a result of this, GSM became the dominant standard all over the world as shown in Figure 3.

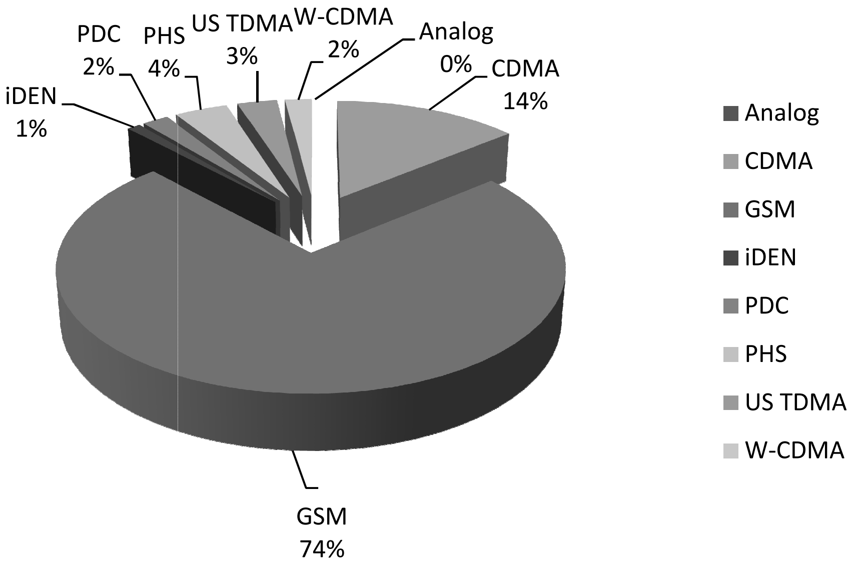


Figure 3: Comparison of Mobile Technologies (Source: Wakefield et al. (2007))

Enhancements to 2G networks were not enough to provide the required bandwidth for the upcoming services provided via mobile network including mobile internet and mobile TV. Hence, in 2000, ITU triggered the process of identification of the required capabilities for the third generation systems through its IMT-2000 initiative. IMT-2000 covers the standards of EDGE, CDMA2000, UMTS and DECT. ITU defined the key features of IMT-2000 as capability of global roaming, commonality of design, compatibility of services, capability for multimedia applications, high quality and small terminals (ITU, 2005). In 2003, 3G services were available in the United Kingdom and Italy. In Canada, mobile operators have released their 3G services in 2005. On 30 July 2009, Turkcell, Avea and Vodafone launched their 3G services in Turkey.

Increasing addition of functionality is the key trend in mobile handsets. Video calling and mobile TV applications are expected to gain momentum in the following years. In order to provide the bandwidth required for these applications, fourth generation (4G) of cellular wireless standards are started to be discussed by the academicians and authorities. In 2008, ITU issued the IMT-Advanced requirements with the aim of providing a mobile broadband solution. 4G standards are expected to provide higher data rates with an IP-based core layer which means that it is expected to be fully packet-switched rather than circuit switched. Today LTE and WiMax are the candidate technologies for the fourth generation. In Table 2, comparison of 3G systems and 4G concept is provided.

Table 2: Comparison of 3G Systems with 4G Concept (Source: Gow and Smith (2006))

3G Networks	4G Concept
Backwards compatible with 2G networks	Extends 3G capabilities by an order of magnitude
Circuit-switched and packet-switched connections	Entirely packet-switched connections
Hybrid of old and new network equipment	All network elements are digital
Data rates up to 2Mbps	Data rates up to 100Mbps

3.2. The Evolution of Mobile Telecommunications Industry in Turkey

3.2.1 Phase I – 1986-2001 Period

Mobile telecommunication services in Turkey were stated in 1986 with the analog NMT (Nordic Mobile Telephone) technology. Based on analog technology (first generation or 1G), NMT's were mount in the trunk of cars. Known also as car phones in Turkey, NMT subscribers reached 84.000 in 1993, which means 0.14% mobile penetration in Turkey.

While 450 MHz and 900 MHz are used in Europe, 415 MHz was allocated for NMT in Turkey. In addition to this, hand apparatus were manufactured special to Turkey. As a result of these, the cost of NMT terminals became higher and it created a burden in the diffusion of NMT technology. Emergence of GSM technology as an alternative also affected NMT negatively. GSM technology is not only technically superior to NMT but also better in terms of service diversification. As a result of this in 1997 NMT subscribers reached 126.000 in 1997 and after that year, the subscriber number diminished.

Due to these facts NMT lost its popularity and number of subscribers decreased to 40.000 in 2002. In 2007, only 17.000 subscribers were remained and most of them are transporters, miners and fishermen due to the lack of GSM coverage in rural areas. After all, in order to utilize the 415 MHz frequency, Telecommunication Authority announced to terminate the NMT service on 31 Dec. 2007.

The important step in mobile telecommunication services of Turkey was the selection of GSM for the mobile communication services in the beginning of 1990s. GSM-900 service was launched in 1994 by Turkcell and Telsim. Being a second generation digital cellular network and a global standard makes GSM advantageous against NMT. Together with the help of better service quality and security, GSM gained popularity over NMT.

During the period 1994-1998, GSM-900 service was provided through revenue sharing agreement between Turk Telekom and two mobile operators, Turkcell and Telsim. Based on the agreement, revenue was shared with Turk Telekom and mobile operator in the ratio of 67.1% and 32.9% respectively. All the investments costs were to be covered by mobile operators and maintenance was to done by Turk Telekom. Mobile operators have to cover 50% of population in order to meet the licensing conditions. In this period, the penetration of mobile communication services reached 5.25 % in 1998 from 0.29% in 1994. On 27.04.1998, as the license conditions constituted, license concession agreements for a period of 25 years were signed with Turkcell and Telsim in return for 500 million $ and they become private entities. This is one of the milestones in the Turkish telecommunications market, alternative operators started to operate for the first time. With this agreement, Turkcell and Telsim had the right to decide the prices on their own.

Table 3: Market Share of Turkcell and Telsim (1994 – 2000 July) (Source: Atiyas and Dogan (2007))

Year	Turkcell		Telsim	
	Per Annum (%)	Total (%)	Per Annum (%)	Total (%)
1994	78	78	22	22
1995	64	68	36	32
1996	90	80	10	20
1997	74	77	26	23
1998	64	69	36	31
1999	68	69	34	31
2000	67	69	33	31

On 16 March of 2000, the Ministry of Transport and Communication started the tender process for 3 GSM-1800 licenses. On 12 April of 2000, the first GSM-1800 license was given to İş-Tim consortium in return for 2.525 billion dollar. İs-Tim consortium provided GSM services under the brand name Aria after 21 March of 2001.

The second GSM-1800 license was given to the Turk Telekom, the incumbent fixed operator, for the same price and Turk Telekom started operation on 15 December 2001 under the brand name Aycell.

While the Ministry of Transport and Communication planned to issue three GSM-1800 licenses, prospective companies found the first price overvalued and did not participated in the third license agreement. As a result of this fifth GSM network was not operationalized.

3.2.2. Phase II –2001 - 2008 Period

Problems related with the intercollection fees and the economic crisis between 2000 and 2001 triggered the merge of Aria and Aycell under a new brand Avea. On 23 June of 2004, Avea started operation and the Turkish mobile telecommunications market transformed from quadropoly to triopoly. In 2005, after the tender process Telsim was sold to Vodafone for 4.55 billon dollars.

3.2.3. Phase III –Post 2008 Period

While mobile phone penetration is in upward trend between the period of 1986 and 2008, in 2009 the penetration rate decreased from 92.81% to 87.38%. The underlying reason of this decrease is the launch of number portability. During this period, the GSM operators entered into competition with minute packages covering all directions. As a result of this, people using more than one SIM card from different operators to enjoy the advantageous on-net offerings started to cancel their excessive subscriptions.

While GSM network was initially designed for the personal voice communication, increasing demand on personal data services make GSM to offer solutions for data services. June 2009 is a milestone in Turkish mobile market due to the launch of 3G services. After the launch of 3G services, the number of subscribers and usage of mobile internet have increased significantly and by the end of 2011 Q3, number of 3G subscribers reached 28.6 millions, which means 44% of total mobile phone subscribers.

Table 4: 3G Service Statistics in Turkey (2010 Q1 – 2011 Q3) (Source: Information and Communication Technologies Authority Quarterly Reports)

Period	Number of Subscribers	Mobile Internet Usage (GB)
2010 Q1	8,717,769	2,105,643
2010 Q2	11,433,031	2,629,253
2010 Q3	16,615,286	3,274,139
2010 Q4	19,407,264	4,387,315
2011 Q1	21,441,318	5,590,910
2011 Q2	24,835,435	5,590,910
2011 Q3	28,608,069	8,766,845

Cellular subscribers per 100 inhabitants are obtained from ITU which was calculated using the population information given by the Turkish Statistical Institute. Based on this description, analog Nordic Mobile Telephones are included in the subscribers. The data covers the period starting in 1986 to 2010. Thus, the study is based on 25 observations. Table 5 demonstrates the year over year adoption of mobile phones in Turkey.

It has to be mentioned that the number of cellular subscribers does not mean the number of mobile phone users. Until the launch of number portability, mobile operators offered advantageous on-net tariffs, which triggered the users to obtain more than one SIM card to enjoy the benefits of different tariffs. As the number portability was enabled in 9th of November 2008, mobile operators reacted by offering fixed minute tariffs covering not only on-net but also off-net calls in order to protect their customer base. As seen in Table 5, the result was the decrease in the cellular penetration due to the cancellation of redundant SIM cards.

Table 5: Cellular subscribers per 100 inhabitants in Turkey, 1986 – 2010 (Source: ITU Statistics)

Time Period	Cellular Subscribers per 100 inhabitants (%)
1986	0.001
1987	0.010
1988	0.018
1989	0.028
1990	0.057
1991	0.084
1992	0.106
1993	0.142
1994	0.291

1995	0.714
1996	1.295
1997	2.542
1998	5.445
1999	12.410
2000	25.356
2001	30.324
2002	35.637
2003	42.038
2004	51.621
2005	63.996
2006	76.253
2007	88.546
2008	92.810
2009	87.380
2010	84.904

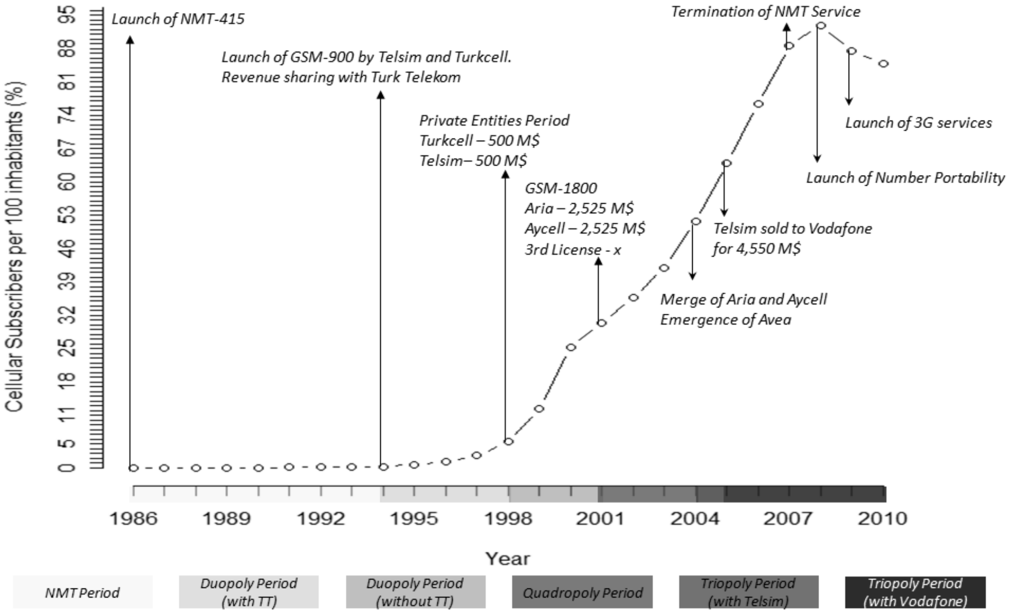


Figure 4: Cellular Subscribers per 100 inhabitants in Turkey

CHAPTER 4

METHODOLOGY

4.1. Data Set

In order to analyze the diffusion of mobile telephones, the percentage of cellular subscribers is used. The data was collected from the ICT Data and Statistics Division of International Telecommunication Union. ITU defines the cellular mobile telephone subscribers as “users of portable telephones subscribing to an automatic public mobile telephone service which provides access to the Public Switched Telephone Network (PSTN) using cellular technology”. This can include analogue and digital cellular systems (including microcellular systems such as DSC-1800, Personal Handyphone System (OHS) and others) but should not include non-cellular systems. Subscribers to fixed services (e.g., Wireless Local Loop (WLL)), public mobile data services, or radio paging services are not included.

4.2. Diffusion Models

The penetration of mobile telecommunication services in the world follows an S-shaped curve. As a result of this, S-Shaped growth models are used in this study. In the literature there are more than a dozen of models for diffusion modeling. Meade and Islam (2001) state that “A reasonable initial set of models should include the logistic, Gompertz and Bass models". Based on the country-specific analyses, Gompertz model, logistic model and Bass model are three most widely used S-shaped growth models. There is no superior model performing best results in all cases. Due to this fact, three models are applied to the historical data of country-specific data and optimal model is determined after comparing the performance of each model.

In the model definitions, the following symbols are used:

t: Time interval.

K: The potential market. In other terms, the ultimate number of adopters and it is constant.

p: In the Bass model, p is defined as the coefficient of innovation.

q: In the Bass model, q is defined as the coefficient of imitation. (Bass, 1969), In the Gompertz and logistic model q is defined as growth rate. It is a measure of diffusion speed.

m: The location or timing variable used in Gompertz and Logistic model. It defines the point of inflection. In our case it defines the timing of the maximum growth rate.

f(t): The portion of the potential market that adopts at time t.

F(t): The portion of the potential market that has adopted up to and including time t.

a(t): The number of adopters at time t. In other terms, it is equal to the number of sales at time t.

A(t): The cumulative adoptions up to and including time t.

F(t) is a cumulative distribution function (CDF). It will approach 1 as t increases. f(t) is the companion probability density function (PDF) of F(t)

$$f(t) = \frac{d[F(t)]}{dt} \tag{1}$$

Cumulative number of adoptions, A(t), is equal to the potential market constant (K) multiplied by the portion of the potential market that has adopted up to and including time t.

$$A(t) = K * F(t) \tag{2}$$

The number of adopters at time t is equal to the potential market constant (K) multiplied by the portion of the potential market that adopts at time t.

$$a(t) = K * f(t) \tag{3}$$

4.2.1. Gompertz Model

Gompertz model was initially published in 1825 by Benjamin Gompertz as a method to determine the value of life contingencies. (Gompertz, 1825) After that, the model has been widely used in academia especially in biological and economical modeling. The equation of the Gompertz model is given in Eq. (4).

$$\frac{d[F(t)]}{dt} = qF(t)In(\frac{1}{F(t)}) \tag{4}$$

Using the Eq.(2), Eq. (4) is transformed to Eq. (5).

$$\frac{d[A(t)]}{dt} = qA(t)In(\frac{K}{A(t)}) \tag{5}$$

Gompertz model can be expressed as follows: the cumulative adoption growth rate (d[A(t)]/dt) is positively proportional to the natural logarithm of the potential market (K) divided by the cumulative adoptions. (A(t)).

The solution of the first order differential equation, Eq. (5), is given as in Eq. (6).

$$A(t) = Ke^{-e^{-q(t-m)}} \tag{6}$$

4.2.2. Logistic Model

Logistic model was initially used by Verhulst in 1838. Griliches (1957) uses logistic model to analyze the diffusion of hybrid seed corn technology in the United States. The successful result of the logistic model in the article makes it a milestone in the usage of logistic model to analyze the diffusion of technologies. The equation of the logistic model is given in Eq. (7).

$$\frac{d[F(t)]}{dt} = qF(t)(1 - F(t)) \tag{7}$$

Using the Eq.(2), Eq. (7) is transformed to Eq. (8).

$$\frac{d[A(t)]}{dt} = qA(t)(1 - \frac{A(t)}{K}) \tag{8}$$

Logistic model can be expressed as follows: the cumulative adoption growth rate (d[A(t)]/dt) is positively proportional to the remaining population growth space ((K-A(t))/K).

The solution of the first order differential equation, Eq. (8), is given as in Eq. (9)

$$A(t) = \frac{K}{1+ e^{-q(t-m)}} \tag{9}$$

4.2.3. Bass Model

Bass model was initially developed by Frank Bass in 1969 as a growth model describing the timing of initial purchase. In its article, Bass applied its formula to model and forecast the diffusion of consumer durable goods. The paper was so influential that it was elected as one of the Top 10 Most Influential papers of the Management Science journal in its 50-year history. (Bass, 2004).

In his model, Bass divide the population into two and named them as innovators and imitators. Innovators are those with a constant propensity to purchase and imitators' propensity to purchase is influenced by the number of previous adopters. Bass proposed that "the probability of adopting by those who have not yet adopted is a linear function of those who had previously adopted." The mathematical expression of this proposal is given in Eq. (10).

$$\frac{f(t)}{1-F(t)} = p + \frac{q}{K}[A(t)] \tag{10}$$

As F(t) is a cumulative distribution function, where it will approach to 1 as time increase therefore "1 – F(t)" can be defined as the number of portion of adopters at time t that has not adopted yet. f(t) is the portion of population that adopters at time t. Combining these two definitions f(t)/1-F(t) can be restated as the portion of adopters that adopt at time t given that they have not adopted yet. This explanation also reveals the assumption made in this model. Bass model doesn't take into account the repetitive adoptions.

In the Eq. (10), p parameter is defined as the coefficient of innovation. The major reason is that p parameter's contribution to the adoptions is not related with the number of prior adoptions A(t). q parameter is identified as the coefficient of imitation. It is an indicator of the previous adopters influence and its effect is directly proportional to cumulative adoptions A(t). As the number of adopters increases, the effect of q is also increased. It can be referred as the word-of-mouth effect.

Using Eq. (1), Eq. (2) and Eq. (3), Eq. (1) can be transformed into Eq. (11) with a little algebraic calculation.

$$\frac{d[A(t)]}{dt} = Kp + (q-p)A(t) - \frac{q}{K}A(t)^2 \tag{11}$$

The solution of this first order differential equation, Eq. (11) is expressed as:

$$A(t) = K \frac{1 - e^{-(p+q)t}}{1 + \frac{q}{p} e^{-(p+q)t}} \tag{12}$$

Figure 5 shows the graphical representation of the Bass, Gompertz and Logistic models with pseudo parameters.

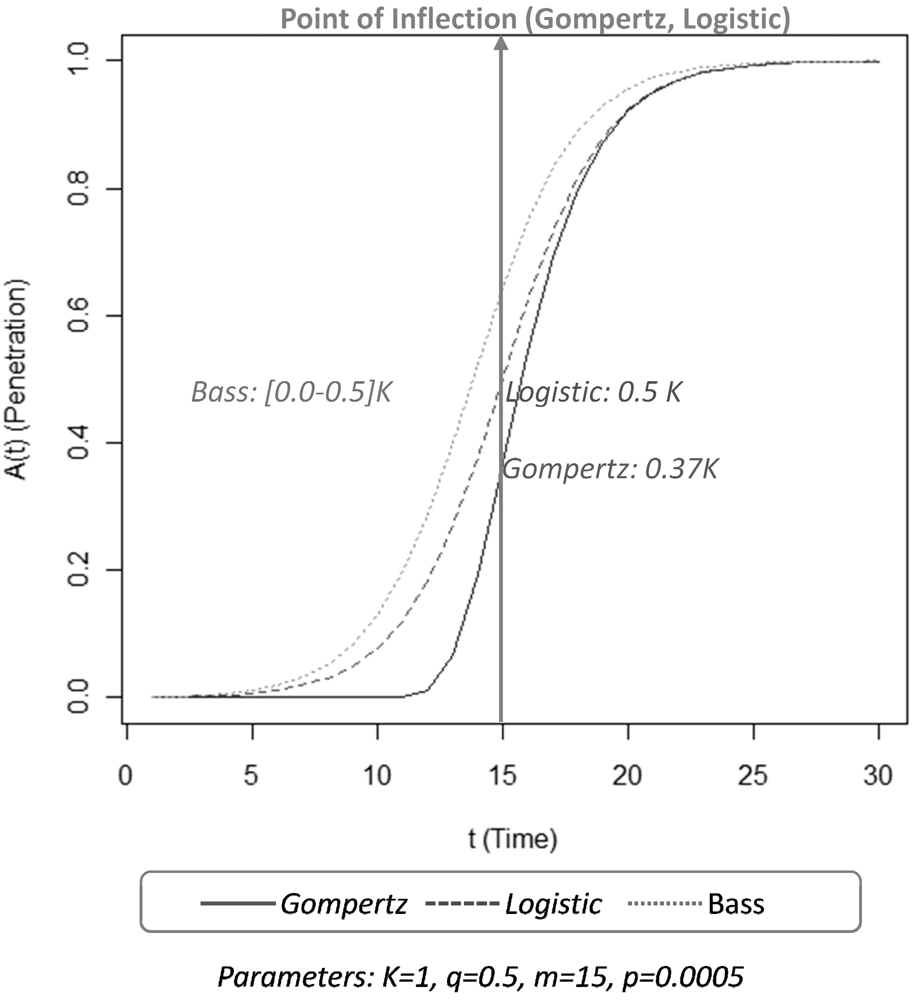
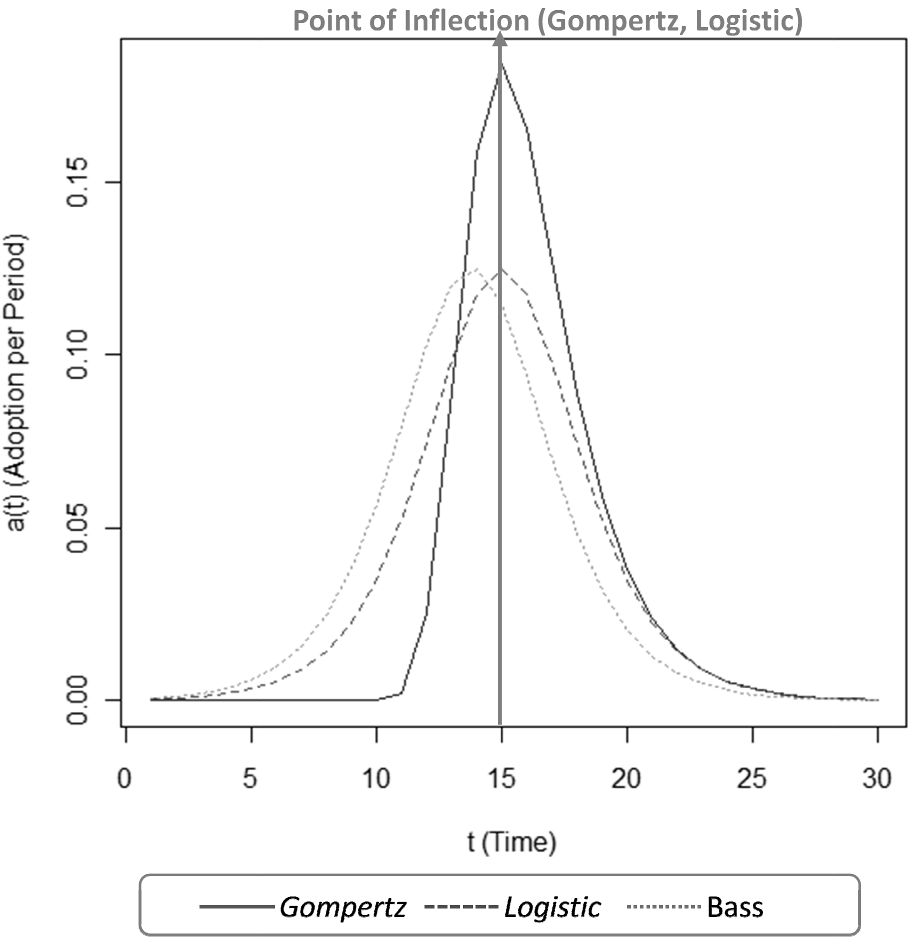


Figure 5: The Graphical Representation of Cumulative Adoption for Bass, Gompertz, and Logistic Models

The point of inflection is an important indicator. First of all, it shows the magnitude of the peak demand. In addition to this, it gives the timing of peak demand. Peak demand is an important indicator as it shows the historically highest point in the sales record of the mobile services. Analyses show that the forecasts before the point of inflection have higher error rates in comparison with the forecasts after the point of inflection.

As seen from Figure 5 and 6, logistic model is symmetric about its point of inflection. In other words, 50% of potential adopters have adopted the product at the point of diffusion. Gompertz model is not symmetric about its point of inflection. %37 of potential adopters has adopted the product at the point of inflection. Bass model is flexible as the point of inflection is not fixed. In other words, the percentage of the number of adopters that have adopted the product at the point of inflection is prone to change based on the values of the coefficient of innovation, p, and q, the coefficient of imitation.



Parameters: K=1, q=0.5, m=15, p=0.0005

Figure 6: The Graphical Representation of Adoption per Period for Bass, Gompertz, and Logistic Models

4.3. Transformation of Bass Model into Logistic Curve

Considering the Bass equation given in Eq. (11), if the p value approaches to zero, Bass model is transformed into logistic curve. Eq. (13) shows the Bass equation with p value approaching to 0.

$$\frac{d[A(t)]}{dt} = K\cancelto{0}{p} + (q - \cancelto{0}{p})A(t) - \frac{q}{K}A(t)^2 \tag{13}$$

Eq. (14) shows the equation of the Bass model when p is equal to 0.

$$\frac{d[A(t)]}{dt} = qA(t) - \frac{q}{K}A(t)^2 \tag{14}$$

Putting qA(t) into parenthesis as a factor, the equation is transformed into Eq. (15) which is equal to the logistic formula given in Eq. (8)

$$\frac{d[A(t)]}{dt} = qA(t)(1 - \frac{A(t)}{K}) \tag{15}$$

4.4. Calculation Methodology

For the statistical computing and graphics, the open source programming language and software environment of R with version number 2.12.1 is used. The user manual of “An Introduction to R” is followed in the analyses (Venables, Smith, R Core Team, 2012). Gompertz model, Bass model and logistic model are directly fit to the country-specific data using non-linear regression.

In the results, the following parameters are used:

Estimate: It shows the calculated value for the relevant parameter.

Std. Error: It is the acronym of the standard error. It measures the variability around the predicted value.

t value: It is the ratio of the coefficient to its standard error. It is used to determine how probable it is that the true value of the coefficient is really zero.

Pr(>|t|): It is the (two-sided) p-value.

Signif. Codes: It is the significance code for the coefficient. ‘***’ is used for the p-values between 0 and 0.001; ‘**’ is used for the p-values between 0.001 and 0.01; ‘*’ is used for the p-values between 0.01 and 0.05; ‘.’ is used for the p-values between 0.1 and 0.05; and finally ‘ ’ is used for the p-values between 0.1 and 1

RMSE: It is the acronym of the root-mean-square error and is a measure of the differences between predicted values and actual values.

Residual standard error: Square root of the sum of squares for error divided by the degree of freedom

Number of iterations to convergence: It defines the number of iterations initiated by the starting estimates till the final values.

Achieved convergence tolerance: Level of convergence when the equilibrium residual is below the displacement tolerance value

CHAPTER 5

MODELLING MOBILE TELECOMMUNICATIONS SERVICES IN TURKEY

5.1. Results of the Bass Model

The diffusion models are estimated using the non-linear least squares and the data given in Table 5 is used for the analysis. In Table 6, the estimation results of the Bass model are given.

Table 6: Estimation Results of the Bass Model

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	9,55E+01	3,55E+00	26,892	< 2e-16	***
p	1,12E-04	6,31E-05	1,778	0,0893	.
q	4,58E-01	3,98E-02	11,507	8,86E-11	***

RMSE: 3.40588

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.631 on 22 degrees of freedom

Number of iterations to convergence: 14

Achieved convergence tolerance: 3.202e-06

Based on the results of the Bass model, at equilibrium the number of cellular subscribers per 100 inhabitants will reach 95.5%. The coefficient of innovation

(p) is calculated to be 0.000112 and the coefficient of imitation (q) is calculated to be 0.458 for Turkey. Figure 7 and Figure 8 shows the graphical representation of the Bass model. Significance codes for coefficients show that p value is not statistically significant. Table 7 shows the iteration results of the Bass model with the starting values of 100, 0.003, and 0.3 for K, p, and q respectively.

Table 7: Iteration Results of the Bass Model

RSS		K	p	q
6,851.2140	:	1.00000E+02	3.00000E-03	3.00000E-01
892.3224	:	1.02037E+02	1.17282E-03	3.02068E-01
640.0567	:	9.89057E+01	6.16402E-04	3.37650E-01
627.6491	:	9.63333E+01	3.59059E-04	3.70425E-01
578.4102	:	9.48495E+01	2.42128E-04	3.96696E-01
495.1383	:	9.42217E+01	1.85396E-04	4.15994E-01
403.7014	:	9.39312E+01	1.25433E-04	4.43104E-01
291.7751	:	9.48620E+01	1.01989E-04	4.63693E-01
290.1606	:	9.55942E+01	1.13664E-04	4.56386E-01
290.0034	:	9.54555E+01	1.11414E-04	4.58288E-01
290.0007	:	9.55038E+01	1.12432E-04	4.57635E-01
290.0005	:	9.54906E+01	1.12171E-04	4.57810E-01
290.0005	:	9.54943E+01	1.12246E-04	4.57761E-01
290.0005	:	9.54933E+01	1.12226E-04	4.57775E-01
290.0005	:	9.54936E+01	1.12231E-04	4.57771E-01

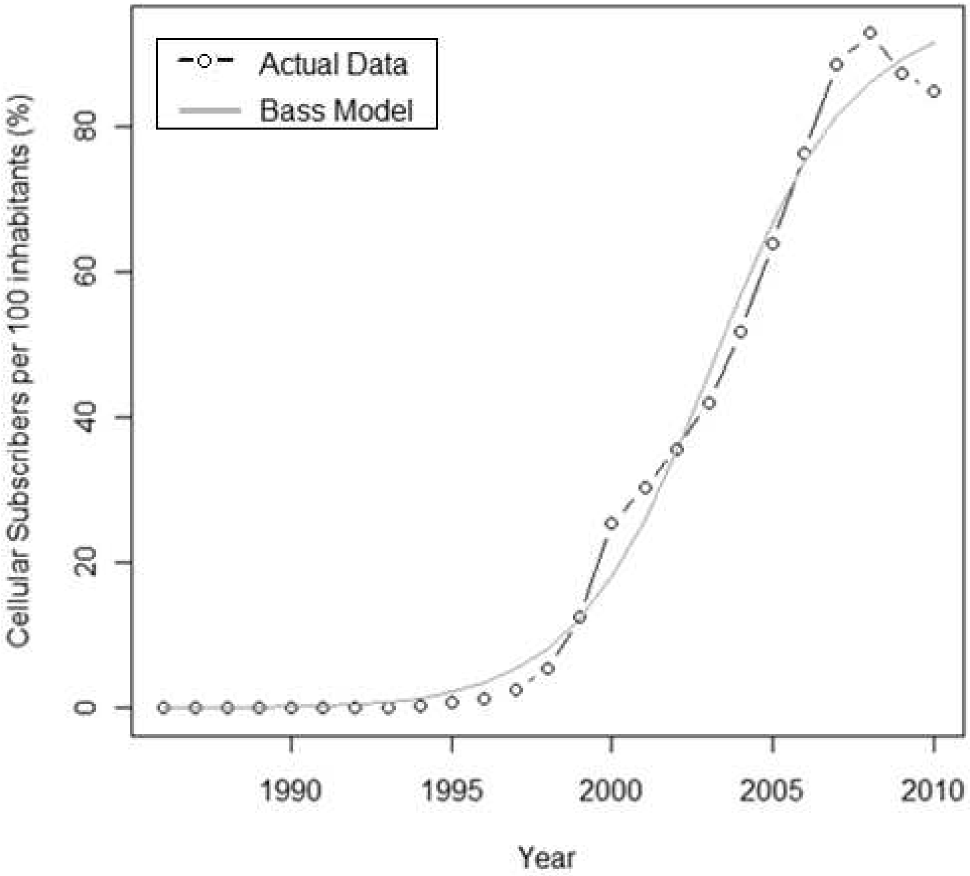


Figure 7: Cellular Subscribers per 100 inhabitants (%): Bass Model vs. Actual Values

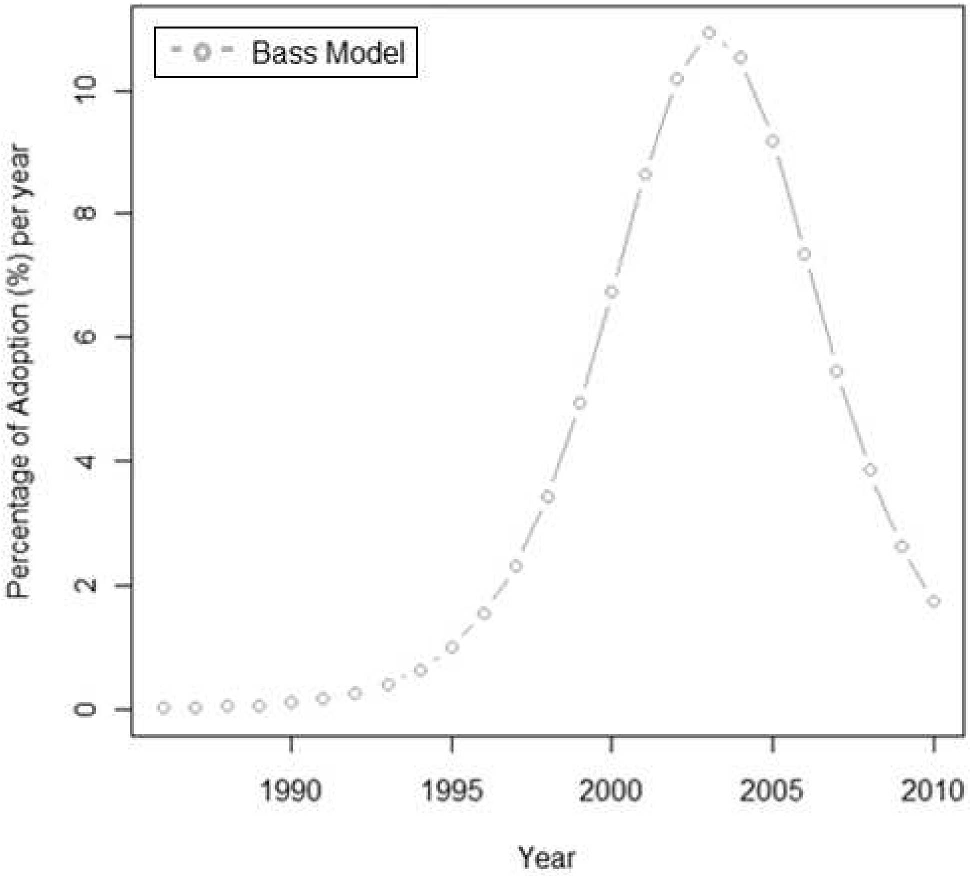


Figure 8: Percentage of Adoption (%) per Year in the Bass Model

Figure 8 shows that the peak demand occurred in 2003 with 10.92% of adoption. Considering the population of Turkey, which was 66.3 million in 2003, new mobile subscription is estimated to be near 7.3 million in 2003. Based on the results of the Bass model, adoption rate decreased after 2003.

5.2. Results of the Gompertz Model

In Table 8, the estimation results of the Gompertz model are given.

Table 8: Estimation Results of the Gompertz Model

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1,08E+02	7,40E+00	14,525	9,37E-13	***
q	2,49E-01	3,17E-02	7,855	7,99E-08	***
m	1,72E+01	3,79E-01	45,303	< 2e-16	***

RMSE: 3.660136

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.902 on 22 degrees of freedom

Number of iterations to convergence: 19

Achieved convergence tolerance: 2.283e-06

Based on the results of the Gompertz model, at equilibrium the number of cellular subscribers per 100 inhabitants will reach 108%. The growth rate (q) is calculated to be 0.000112 and the point of inflection (m) is calculated to be 17.2 for Turkey. Figure 9 and Figure 10 show the graphical representation of the Gompertz model.

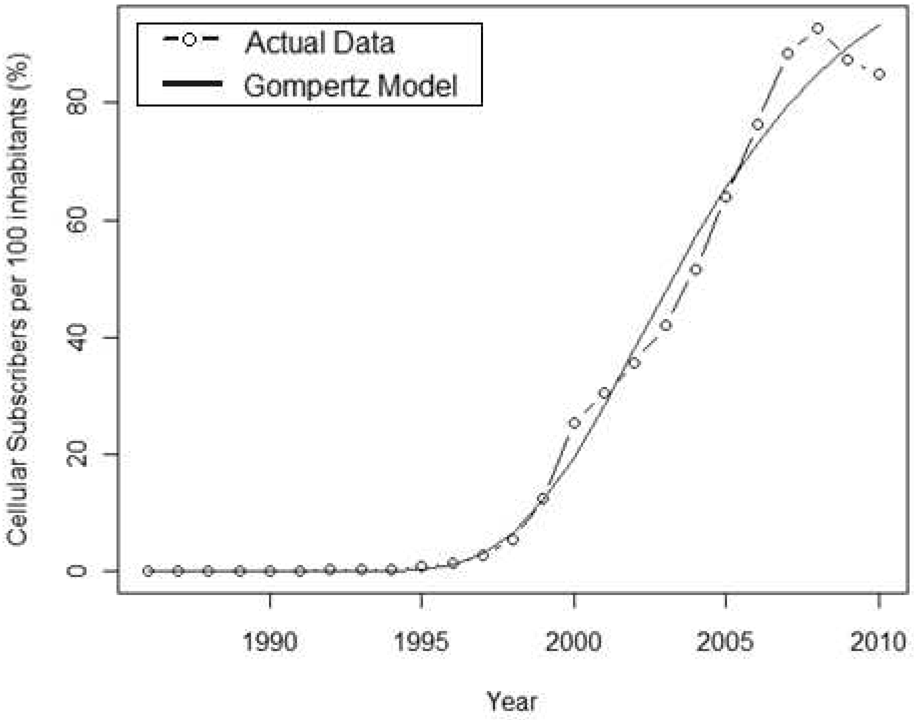


Figure 9: Cellular Subscribers per 100 inhabitants (%): Gompertz Model vs. Actual Values

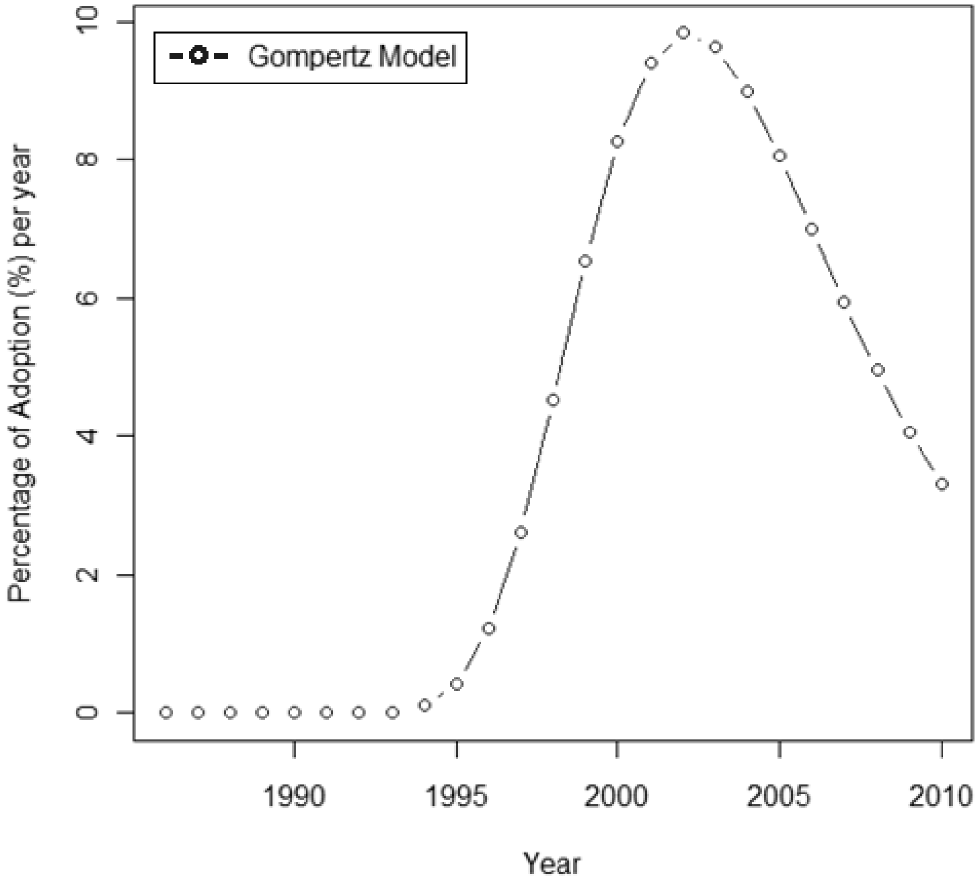


Figure 10: Percentage of Adoption (%) per Year in the Gompertz Model

Figure 10 shows that the peak demand occurred in 2002 with 9.82% of adoption. Considering the population of Turkey, which was 65.4 million in 2002, new mobile subscription is estimated to be near 6.42 million in 2002. Based on the results of the Gompertz model, adoption rate decreased after 2002.

5.3. Results of the Logistic Model

In Table 9, the estimation results of the logistic model are given. Based on the results at equilibrium the number of cellular subscribers per 100 inhabitants will reach 95.5%.

Table 9: Estimation Results of the Logistic Model

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	9,55E+01	3,54E+00	26,980	< 2e-16	***
q	4,58E-01	3,95E-02	11,600	7,57E-11	***
m	1,82E+01	2,67E-01	67,890	< 2e-16	***

RMSE: 3.407494

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.632 on 22 degrees of freedom

Number of iterations to convergence: 14

Achieved convergence tolerance: 6.825e-06

Based on the results of the logistic model, at equilibrium the number of cellular subscribers per 100 inhabitants will reach 95.5%. The growth rate (q) is calculated to be 0.000112 and the point of inflection (m) is calculated to be 17.2 for Turkey. Figure 11 and Figure 12 shows the graphical representation of the logistic model.

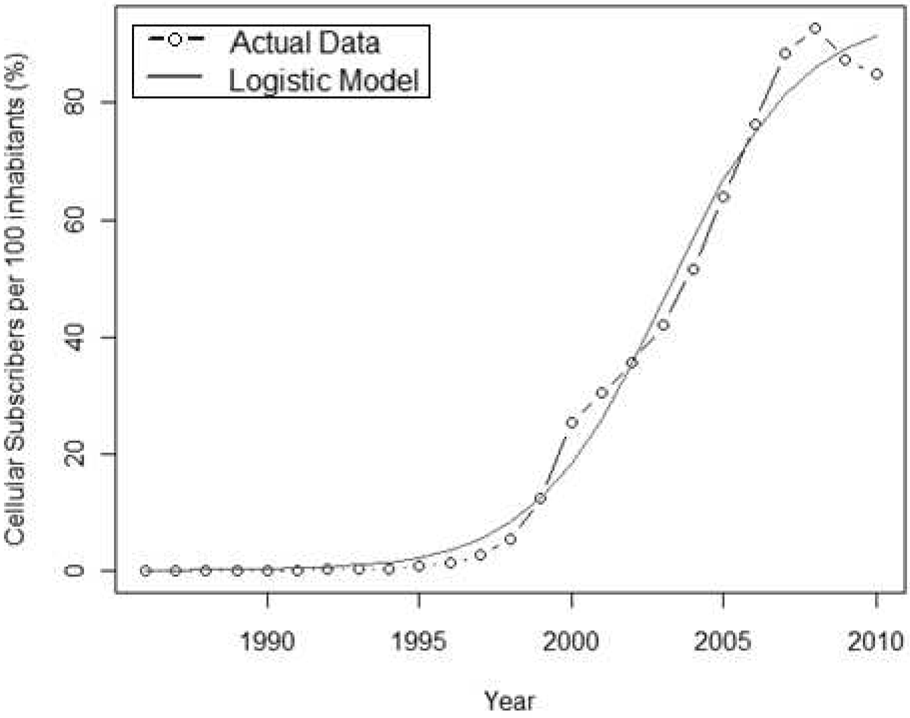


Figure 11: Cellular Subscribers per 100 inhabitants (%): Logistic Model vs. Actual Values

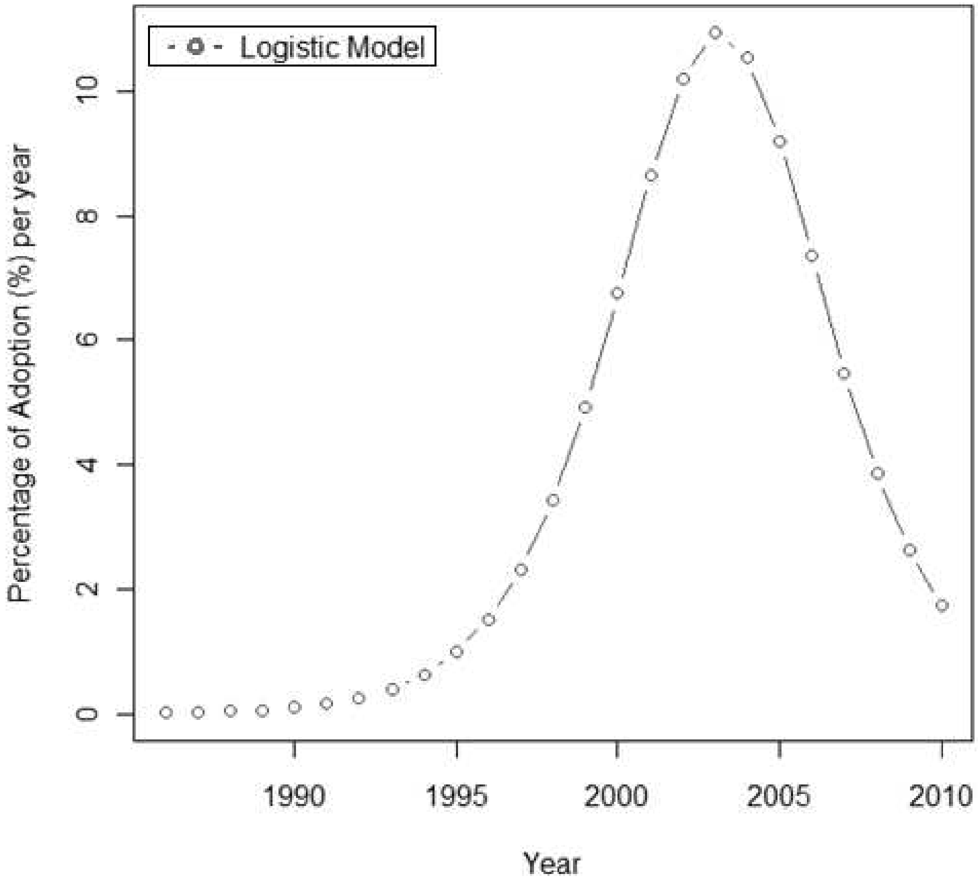


Figure 12: Percentage of Adoption (%) per Year in the Logistic Model

Figure 12 shows that the peak demand occurred in 2003 with 10.92% of adoption. Considering the population of Turkey, which was 65.4 million in 2003, new mobile subscription is estimated to be near 7.14 million in 2003. Based on the results of the logistic model, adoption rate decreased after 2003.

The results of Gompertz, Bass, and logistic curve supports that peak demand occurred between 2002 and 2003. The results suggest that while different models are used for the Turkish mobile penetration, the results are close to each other in terms of the peak demand year.

5.4. Evaluation of the Models

Residual analysis is an important part of the model assessment process. By residual analysis the adequacy of the model itself relative to the data and any assumptions can be evaluated and usefulness of the model can be determined. The presence of measurement errors results in inconsistent and biased parameter estimates and leads to erroneous conclusions to various degrees. In order to evaluate the models, the model diagnostics procedure defined by Ritz and Streibig (2008) is followed.

Model assumptions are defined as:

(1) Correct mean function f

(2) Variance homogeneity (homoscedasticity)

(3) Normally distributed measurements errors

(4) Mutually independent measurement errors ε_i

Correct mean function assumption requires that the plot of the residuals versus fitted values should show no pattern or trend. Variance homogeneity assumption means that the variance around the fitted line is the same for all values. Normality assumption necessitates the normal distribution of errors and finally mutually independent measurement errors

Bass, Gompertz, and logistic models are developed in the statistical programming language of R using nonlinear regression model. Before selecting the appropriate model, the assumptions made in the nonlinear regression model should be validated. For the evaluation of assumptions, Ritz and Streibig (2008) stated that “graphical procedures will often be sufficient for validating model assumptions, but they may be supplemented by statistical tests”.

5.4.1. Checking the Mean Structure

In order to check the mean structure in the Bass, Gompertz, and logistic model, the data together with the model results are plotted. Figure 13 shows the graphical representation of the actual data together with the model estimations. Note that the estimations of Bass model and logistic model are overlapping. The graph reveals that the arrangement between the actual data and the estimations of models are quite good and we can conclude that the models are appropriately describes the systematic part of the data.

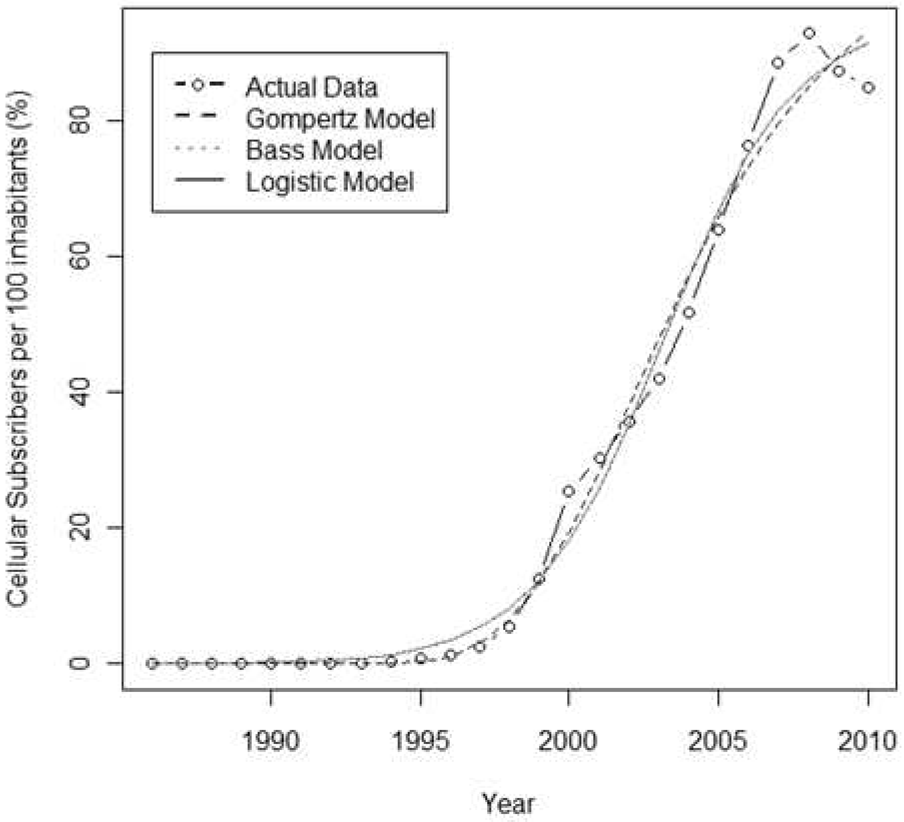


Figure 13: Plot of the Bass, Gompertz and Logistic models with Actual Data

Residual is equal to the difference between the observed value of Y and the predicted value of Y:

$$r_i = Y_i - \hat{Y}_i \tag{16}$$

Residual plots are used to assess the deviation of the model fit from a horizontal line. Figure 14, 15, and 16 shows the residual plot of the model fit for Bass, Gompertz, and logistic respectively. The figures reveal that there is no apparent pattern in the residual plots.

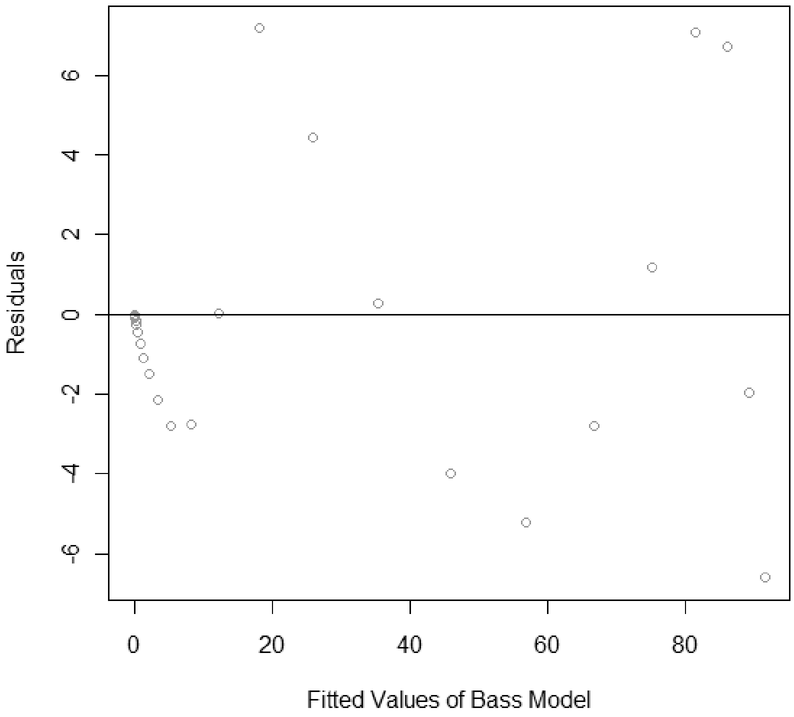


Figure 14: Residual Plot based on the Bass Model Fit

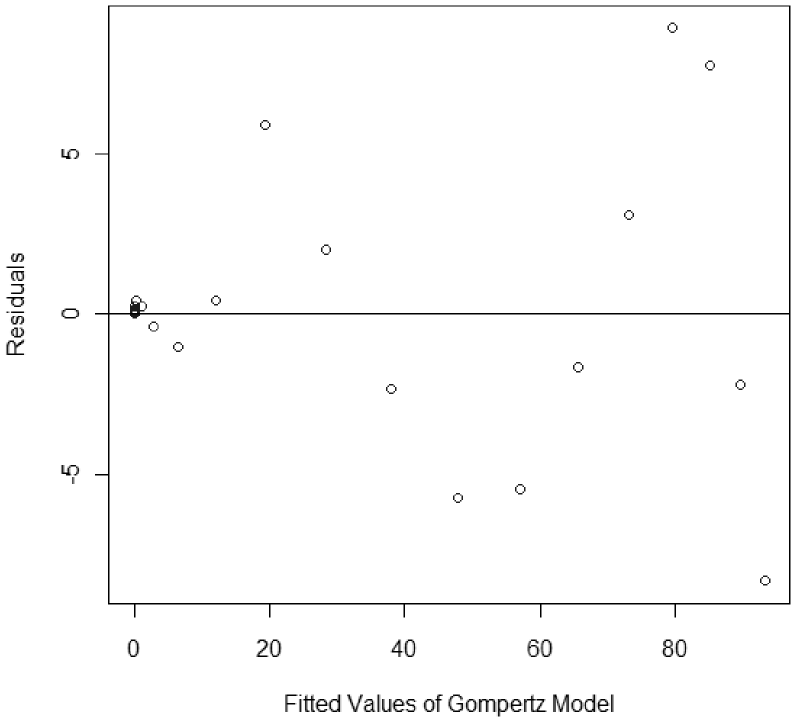


Figure 15: Residual Plot based on the Gompertz Model Fit

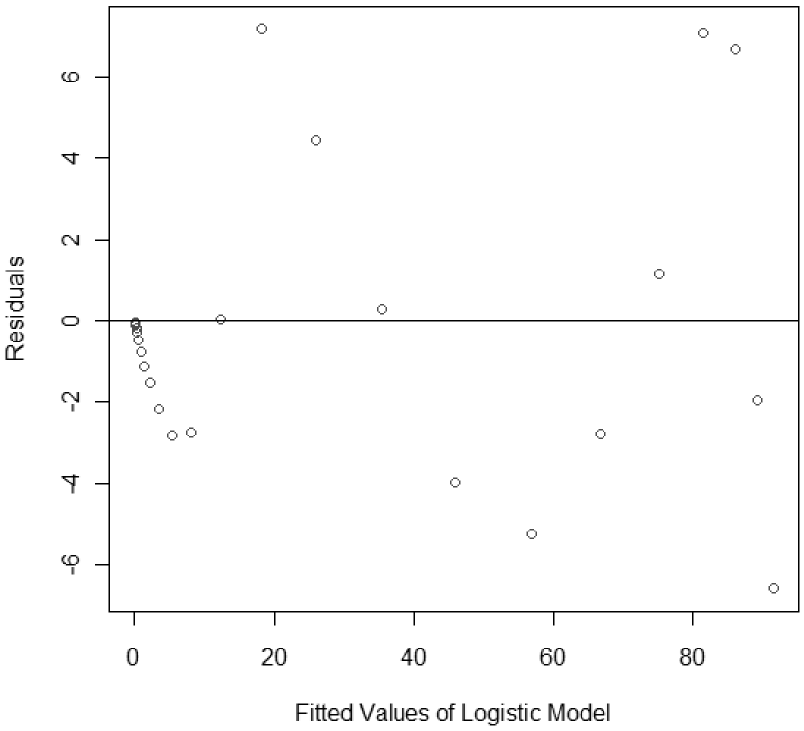


Figure 16: Residual Plot based on the Logistic model fit

5.4.2. Variance Homogeneity

In order to detect variance inhomogeneity, plot of the fitted values versus the absolute residuals is evaluated. Absolute residuals are defined as follows:

$$|\hat{r}_i| = \begin{cases} \hat{r}_i & \hat{r}_i \geq 0 \\ -\hat{r}_i & \hat{r}_i < 0 \end{cases} \tag{17}$$

The resulting plots for Bass, Gompertz, and logistic models are shown in Figure 17, 18, and 19 respectively. The figures hint an increasing trend with increasing fitted values of the models.

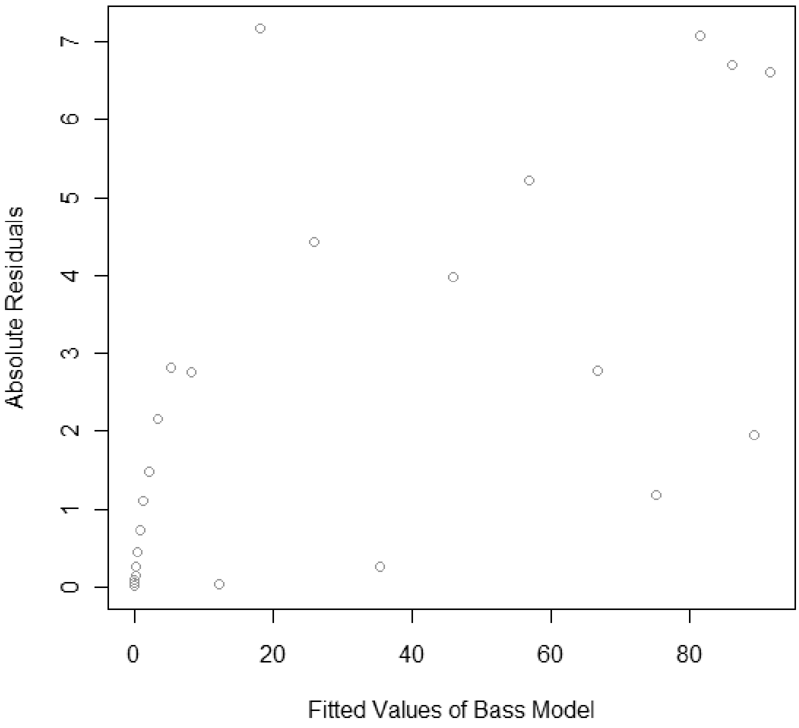


Figure 17: Absolute Residual Plot based on the Bass Model Fit

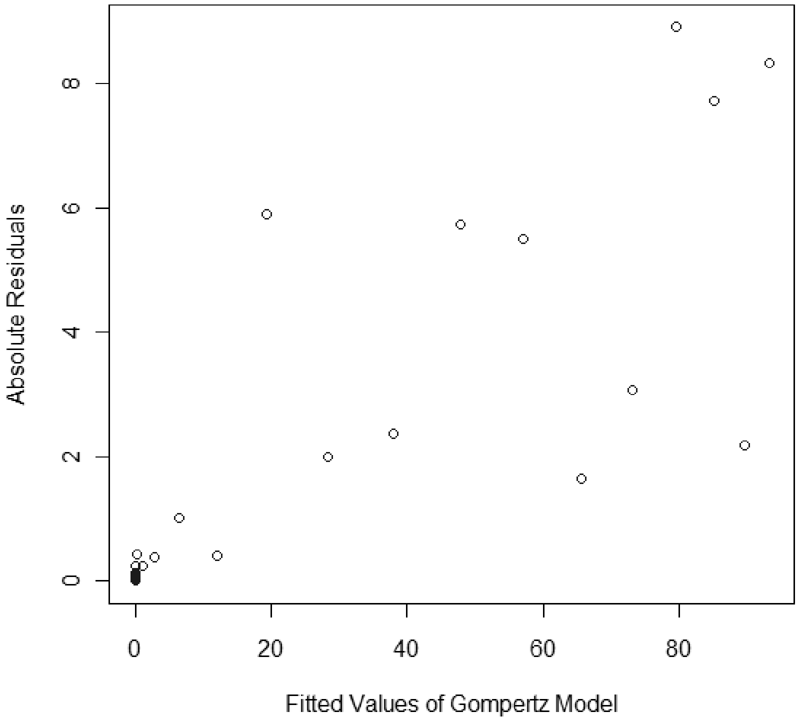


Figure 18: Absolute Residual Plot based on the Gompertz model fit

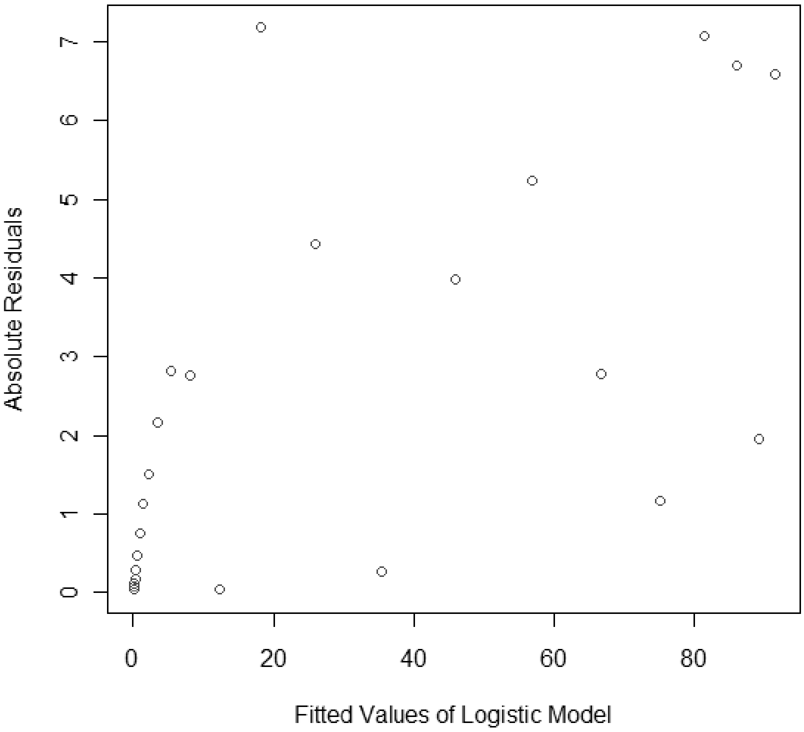


Figure 19: Absolute Residual Plot based on the Logistic model fit

5.4.3. Normal Distribution

Skewness, one or few outliers or too many extreme values can make the distribution of the measurement errors deviate from the normality assumption. Standardized residuals are used to assess the deviation in normality assumption and they are defined as the raw residuals divided by the square root of the estimated residual variance:

$$\hat{e}_i = {}^{\hat{r}_i}/_{S} \qquad (18)$$

In order to satisfy the normality assumption, the standardized residuals should be approximately standard normally distributed with expectation 0 and deviation 1. QQ Plot is also informative in comparing the distribution of the standard residuals to a standard normal distribution. Following a straight line with a slope of 1 and passing through point of (0,0) is expected in the QQ Plot. Figure 20, 21, and 22 shows the distribution of the standardized residuals and QQ Plot for Bass, Gompertz, and logistic model respectively.

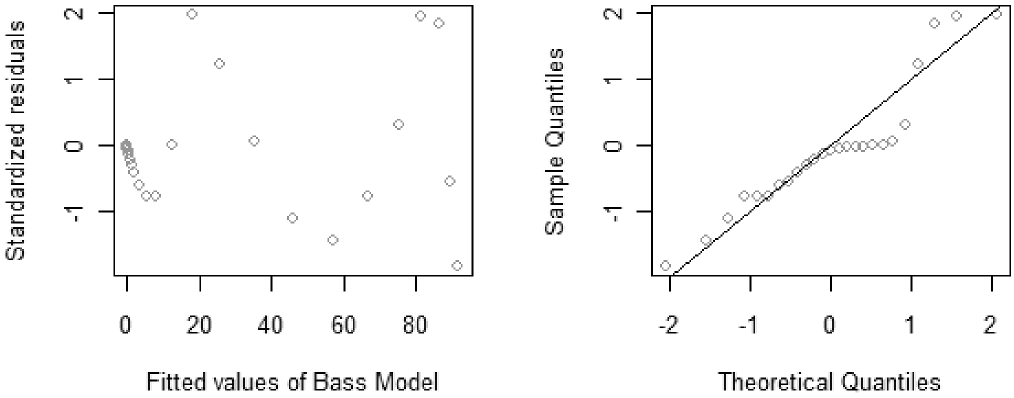


Figure 20: Plot of the fitted values versus the standardized residuals and Normal QQ Plot for the Bass Model

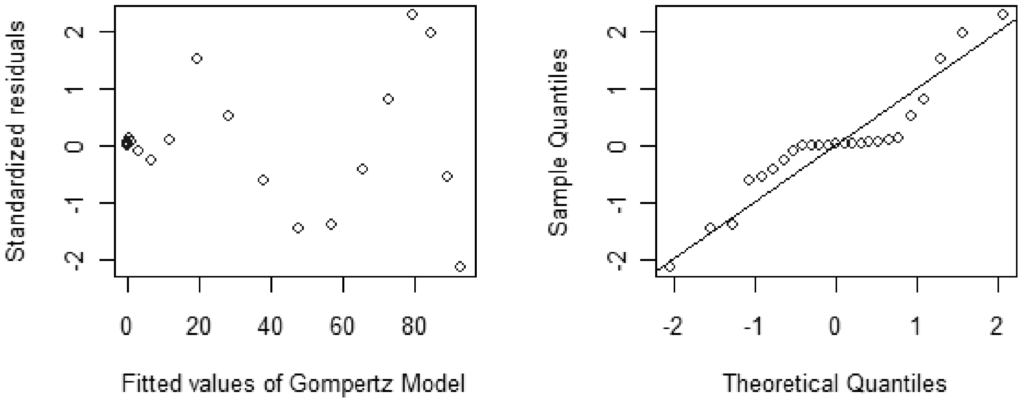


Figure 21: Plot of the fitted values versus the standardized residuals and Normal QQ Plot for the Gompertz Model

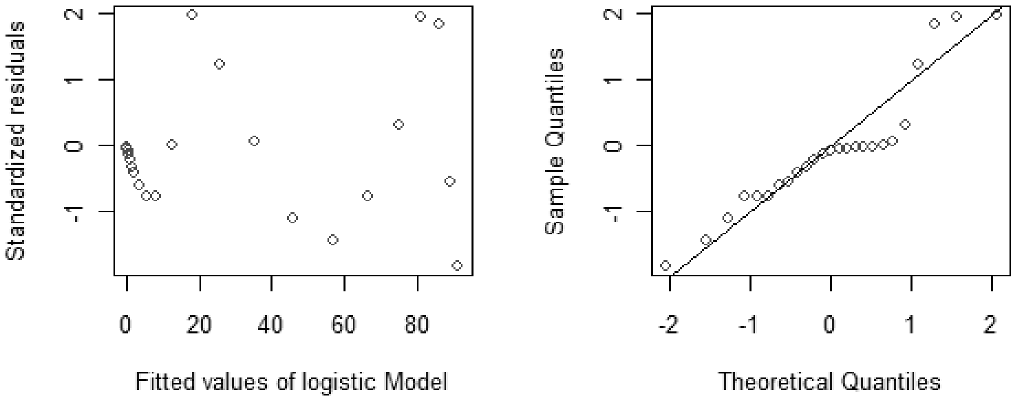


Figure 22: Plot of the fitted values versus the standardized residuals and Normal QQ Plot for the logistic Model

5.4.4. Independence

Lag plot where raw residuals versus the previous residual (lag-one residual) is used to assess whether the errors are mutually independent. The lag plots of Bass, Gompertz, and logistic model are given in Figures 23, 24, and 25 respectively.

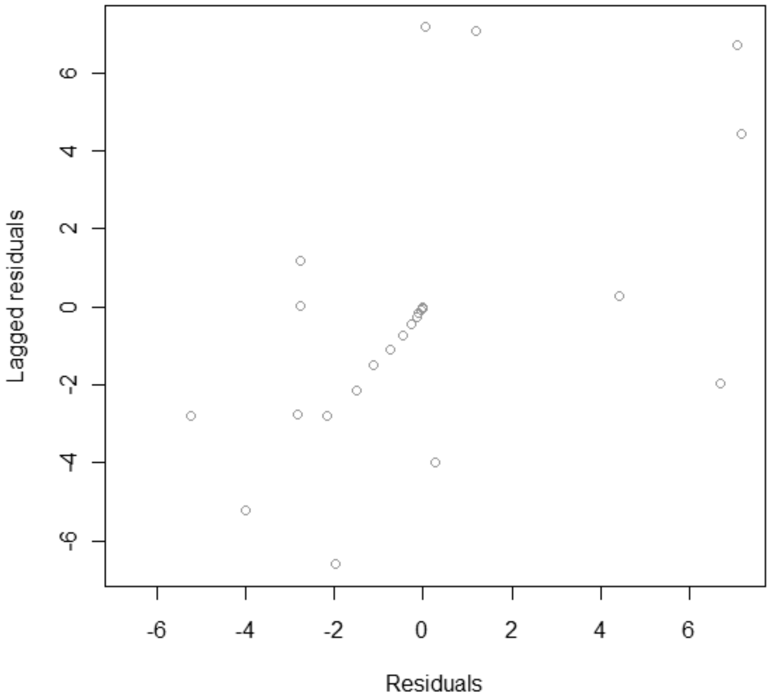


Figure 23: Lag Plot of the Bass Model Fit

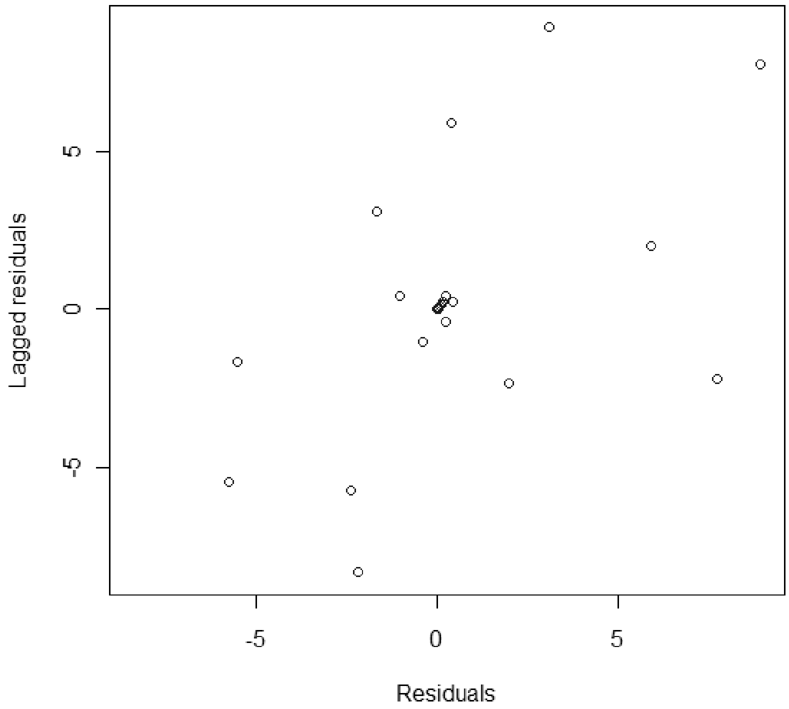


Figure 24: Lag Plot of the Gompertz Model Fit

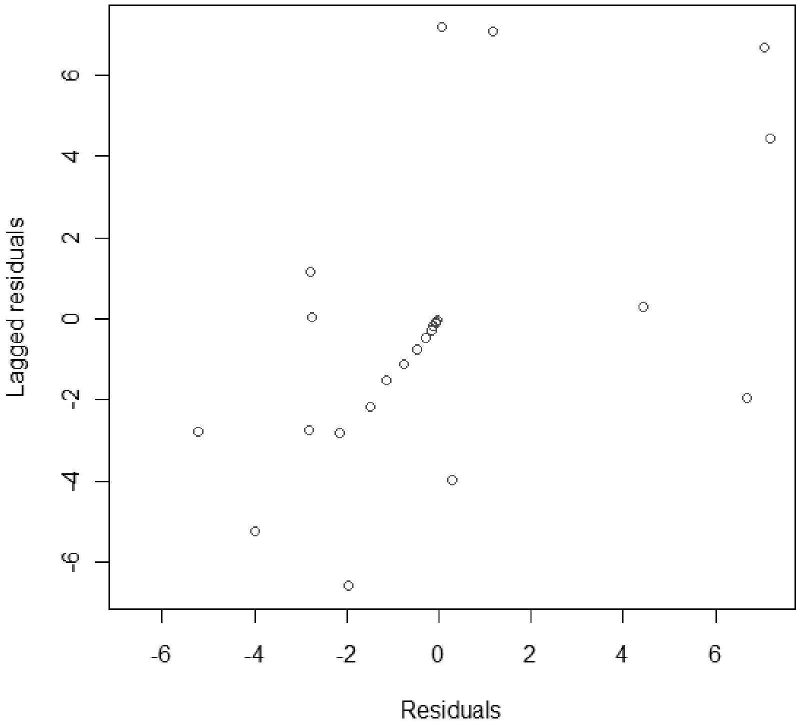


Figure 25: Lag Plot of the Logistic Model Fit

The graphs hint a positive linear relationship between residual and lag-one residual for each models. However, since the plots are quite scattered, one cannot be certain about this trend.

5.5. Forecasting the Future of the Turkish Mobile Market

Figure 26 shows the forecast results of the three models for the period between 2011 and 2025. Based on the results it is observed that the cellular phone penetration is expected to be between 96% and 108%. However, the graphs together with evaluation of the models indicate that the models overestimate and underestimate the cellular penetration rate in Turkey for certain periods of time. Structure of the competition in the market, economic and social dynamics of the country, evolution of new mobile technologies are some of the factors that are expected to affect the future of mobile market in Turkey.

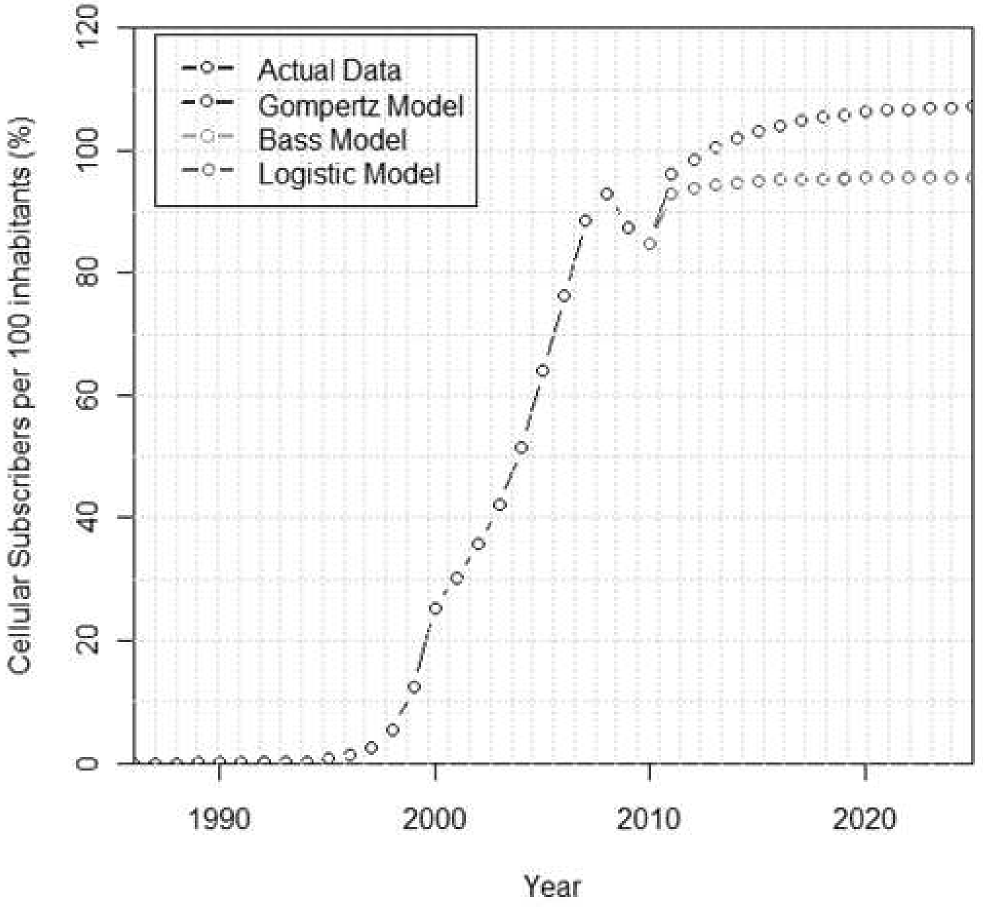


Figure 26: Forecast Result of Gompertz, Logistic and Bass Models (2011-2025)

CHAPTER 6

CROSS-COUNTRY ANALYSIS

6.1. Motivation

In the previous chapter, diffusion of cellular penetration is analyzed for Turkey. The results show that S-shaped curves are quite capable in explaining the diffusion process. In order to address the uncertainty in optimal model selection and reach generalized conclusions, a cross-country analysis covering 20 countries is performed using the data obtained from the International Telecommunication Union. The same calculation methodology used for analysis in Chapter 5 is applied to different countries. Below, we provide the results for two countries in order to highlight some issues. Results for the other countries are provided in the Appendix arranged in order of mobile telecommunication services launch year.

6.2. Results of Canada

The results of Canada show that Bass, Gompertz, and logistic models are quite successful in defining the diffusion of mobile telecommunication services in Canada. The accuracy of the models is also supported by the low value of RMSE in comparison with other countries.

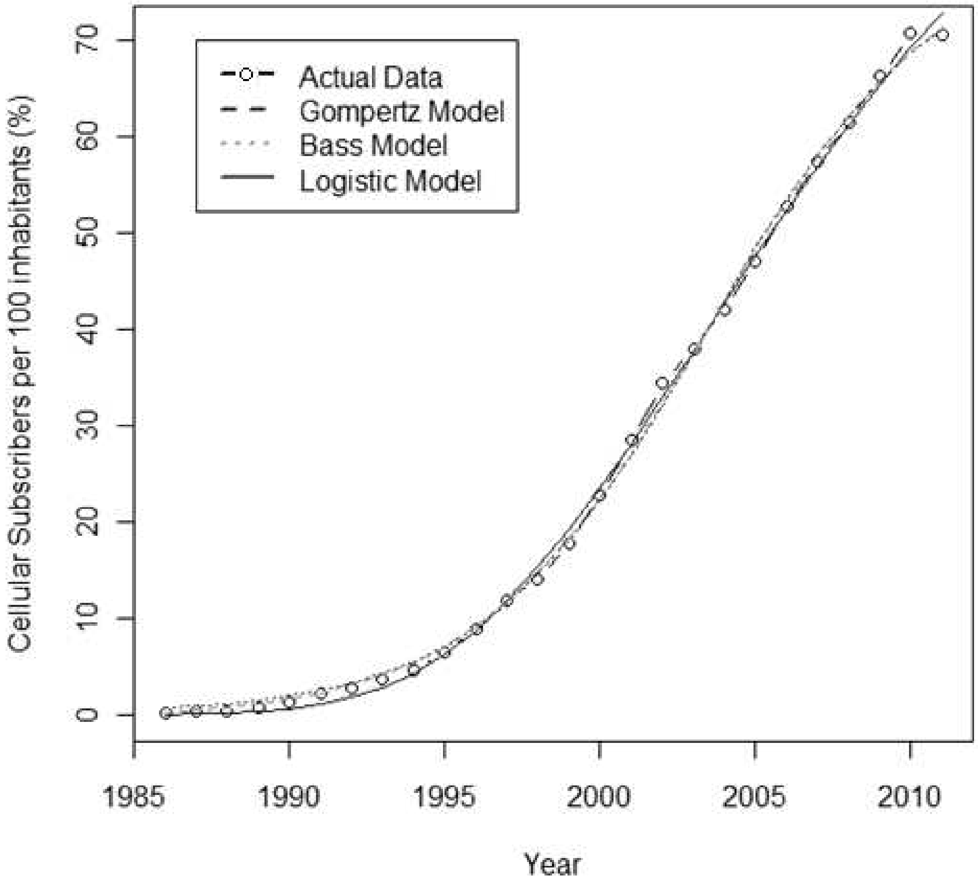


Figure 27: Model Fit of Canada

Table 10: Estimation Results of Bass Model for Canada

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	8.11E+01	1.50E+00	54.150	< 2e-16	***
p	1.89E-03	1.47E-04	12.870	5.38E-12	***
q	2.65E-01	7.75E-03	34.220	< 2e-16	***

RMSE: 0.8214977

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.8734 on 23 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 5.172e-06

Table 11: Estimation Results of Gompertz Model for Canada

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.06E+02	4.11E+00	25.890	<2e-16	***
q	1.26E-01	5.48E-03	23.040	<2e-16	***
m	1.83E+01	3.57E-01	51.110	<2e-16	***

RMSE: 0.8700643

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.9251 on 23 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 4.957e-06

Table 12: Estimation Results of Logistic Model for Canada

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	7.99E+01	1.46E+00	54.540	<2e-16	***
q	2.77E-01	7.67E-03	36.130	<2e-16	***
m	1.84E+01	1.82E-01	101.420	<2e-16	***

RMSE: 0.9102148

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.9678 on 23 degrees of freedom

Number of iterations to convergence: 6

Achieved convergence tolerance: 7.452e-06

6.3. Results of Greece

The results of Greece indicate distortions in certain periods of time. As a result of this, RMSE is higher in comparison with other countries. The case of Greece suggests the importance of local conditions in the diffusion process. The change in the market structure together with the country dynamics should be taken into account during the analysis of the results.

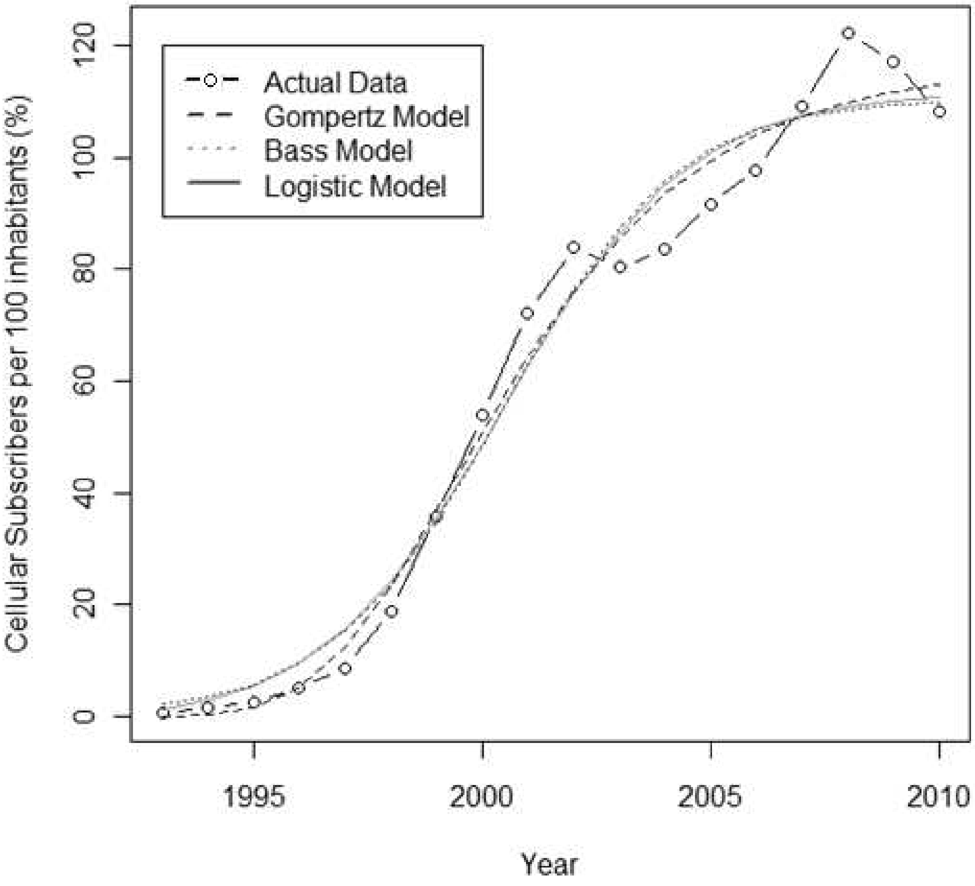


Figure 28: Model Fit of Greece

Table 13: Estimation Results of Bass Model for Greece

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.12E+02	4.41E+00	25.386	9.73E-14	***
p	7.42E-03	3.36E-03	2.209	0.0432	*
q	4.87E-01	7.80E-02	6.243	1.57E-05	***

RMSE: 6.816704

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 7.467 on 15 degrees of freedom

Number of iterations to convergence: 33

Achieved convergence tolerance: 7.462e-06

Table 14: Estimation Results of Gompertz Model for Greece

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.16E+02	4.91E+00	23.728	2.62E-13	***
q	3.32E-01	4.41E-02	7.542	1.76E-06	***
m	7.44E+00	2.54E-01	29.269	1.20E-14	***

RMSE: 5.815622

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.371 on 15 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 5.466e-06

Table 15: Estimation Results of Logistic Model for Greece

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.11E+02	4.14E+00	26.757	4.49E-14	***
q	5.28E-01	7.21E-02	7.326	2.50E-06	***
m	8.48E+00	3.13E-01	27.063	3.80E-14	***

RMSE: 6.973115

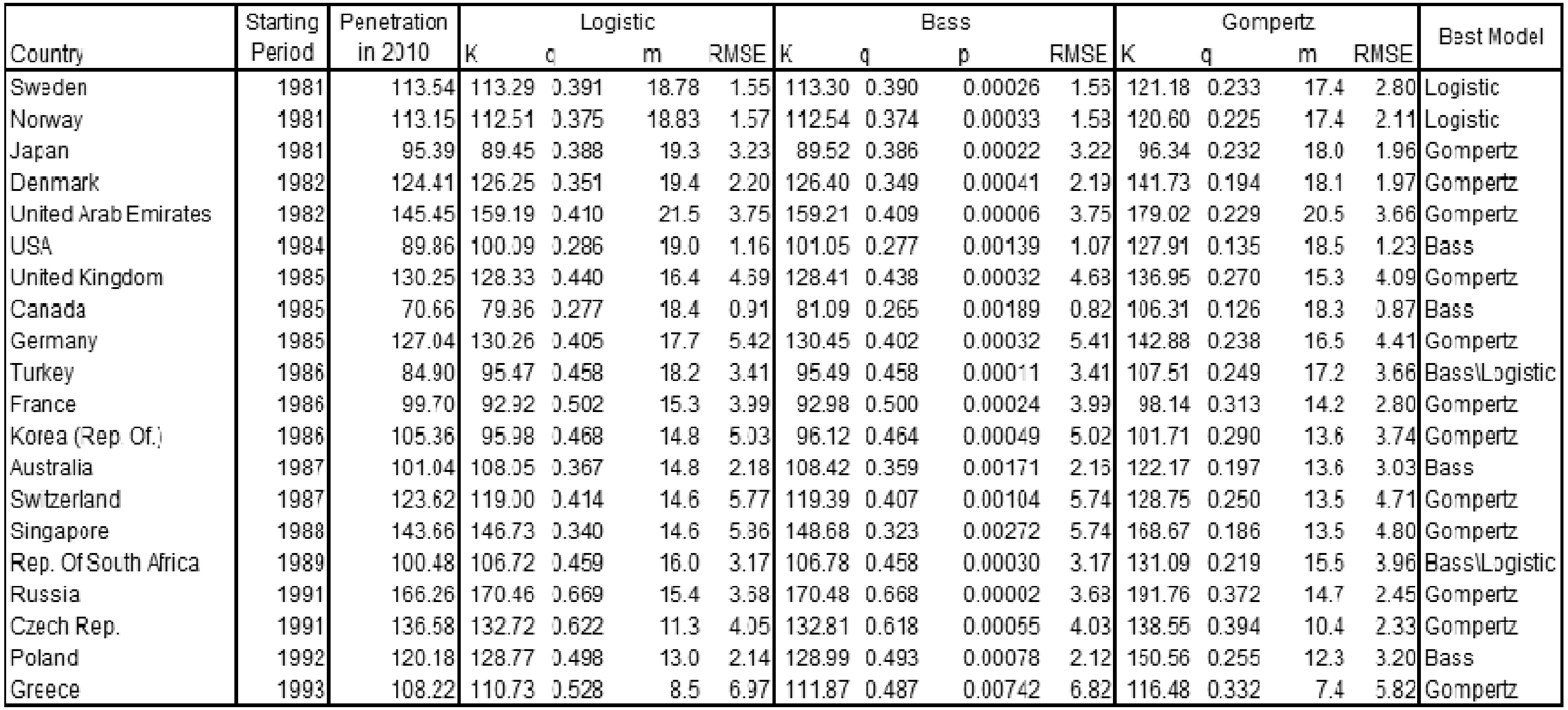
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

```
Residual standard error: 7.639 on 15 degrees of freedom
Number of iterations to convergence: 13
Achieved convergence tolerance: 6.236e-06
```

6.4. Results of Cross-Country Analysis

Table 16 presents the estimation results of the three models for each country together with the RMSE (root mean square error). Best model is selected based on the RMSE for each model. K parameter gives the potential market. In other terms it indicates saturation level for mobile telephone penetration for each country.

Table 16: Country-specific Performance Comparison among Three Models



Country	Starting Period	Penetration in 2010	Logistic K	Logistic q	Logistic m	Logistic RMSE	Bass K	Bass q	Bass p	Bass RMSE	Gompertz K	Gompertz q	Gompertz m	Gompertz RMSE	Best Model
Sweden	1981	113.54	113.29	0.391	18.78	1.55	113.30	0.390	0.00026	1.55	121.18	0.233	17.4	2.80	Logistic
Norway	1981	113.15	112.51	0.375	18.83	1.57	112.54	0.374	0.00033	1.53	120.60	0.225	17.4	2.11	Logistic
Japan	1981	95.39	89.45	0.388	19.3	3.23	89.52	0.386	0.00022	3.22	96.34	0.232	18.0	1.96	Gompertz
Denmark	1982	124.41	126.25	0.351	19.4	2.20	126.40	0.349	0.00041	2.19	141.73	0.194	18.1	1.97	Gompertz
United Arab Emirates	1982	145.45	159.19	0.410	21.5	3.75	159.21	0.409	0.00006	3.75	179.02	0.229	20.5	3.66	Gompertz
USA	1984	89.86	100.09	0.286	19.0	1.16	101.05	0.277	0.00139	1.07	127.91	0.135	18.5	1.23	Bass
United Kingdom	1985	130.25	128.33	0.440	16.4	4.59	128.41	0.438	0.00032	4.63	136.95	0.270	15.3	4.09	Gompertz
Canada	1985	70.66	79.36	0.277	18.4	0.91	81.09	0.265	0.00189	0.82	106.31	0.126	18.3	0.87	Bass
Germany	1985	127.04	130.26	0.405	17.7	5.42	130.45	0.402	0.00032	5.41	142.88	0.238	16.5	4.41	Gompertz
Turkey	1986	84.90	95.47	0.458	18.2	3.41	95.49	0.458	0.00011	3.41	107.51	0.249	17.2	3.66	Bass\Logistic
France	1986	99.70	92.92	0.502	15.3	3.99	92.98	0.500	0.00024	3.99	98.14	0.313	14.2	2.80	Gompertz
Korea (Rep. Of.)	1986	105.36	95.98	0.468	14.8	5.03	96.12	0.464	0.00049	5.02	101.71	0.290	13.6	3.74	Gompertz
Australia	1987	101.04	108.05	0.367	14.8	2.18	108.42	0.359	0.00171	2.15	122.17	0.197	13.6	3.03	Bass
Switzerland	1987	123.62	119.00	0.414	14.6	5.77	119.39	0.407	0.00104	5.74	128.75	0.250	13.5	4.71	Gompertz
Singapore	1988	143.66	146.73	0.340	14.6	5.36	148.68	0.323	0.00272	5.74	168.67	0.186	13.5	4.80	Gompertz
Rep. Of South Africa	1989	100.48	106.72	0.459	16.0	3.17	106.78	0.458	0.00030	3.17	131.09	0.219	15.5	3.96	Bass\Logistic
Russia	1991	166.26	170.46	0.669	15.4	3.58	170.48	0.668	0.00002	3.63	191.76	0.372	14.7	2.45	Gompertz
Czech Rep.	1991	136.58	132.72	0.622	11.3	4.05	132.81	0.618	0.00055	4.03	138.55	0.394	10.4	2.33	Gompertz
Poland	1992	120.18	128.77	0.498	13.0	2.14	128.99	0.493	0.00078	2.12	150.56	0.255	12.3	3.20	Bass
Greece	1993	108.22	110.73	0.528	8.5	6.97	111.87	0.487	0.00742	6.82	116.48	0.332	7.4	5.82	Gompertz

The results show that the estimated parameters of the Bass model and the Logistic model are almost equivalent. The underlying reason behind this result is the small value of p coefficient in the Bass model. In the Bass model equation, as p approaches to 0, Eq (19) transforms to Eq (20) which is equal to the equation of the Logistic model given in Eq (6)

$$\frac{d[A(t)]}{dt} = Kp + (q - p)A(t) - \frac{q}{K}A(t)^2 \tag{19}$$

$$\frac{d[A(t)]}{dt} = qA(t) - \frac{q}{K}A(t)^2 \tag{20}$$

Liu, Wu and Chu (2010) and Chu, Wu, Kao and Yen (2009) provide similar findings for China and Taiwan respectively. Our cross-country analysis together with these researches reveals that this situation is not a country-specific issue and is valid for many countries.

Figure 29 shows the relationship between the timing of the peak demand (m) and the launch time of mobile telephones for each country. Correlation between these two parameters is calculated to be -0.8387, which indicates that follower countries catch up pioneer countries rather rapidly. Based on Figure 30, peak demands are observed between 1999 and 2006. Possible reasons behind this finding might be related to multinational learning effect and the impact of digital technology in comparison with analog technology in mobile telecommunications services. First generation systems were analog systems and different standards were used such as NMT (Nordic Mobile Phone) in Sweden, Norway and Denmark, TACS (Total Access Communication System) in United Kingdom, and Japan and lastly AMPS (Advance Mobile Phone System) in North America and Australia. Second generation systems were digital and resolved the quality, capability and reliability problems of the first generation. Additional services like SMS, GPRS and EDGE in second generation also played a catalyst role in the expansion of the number of subscribers.

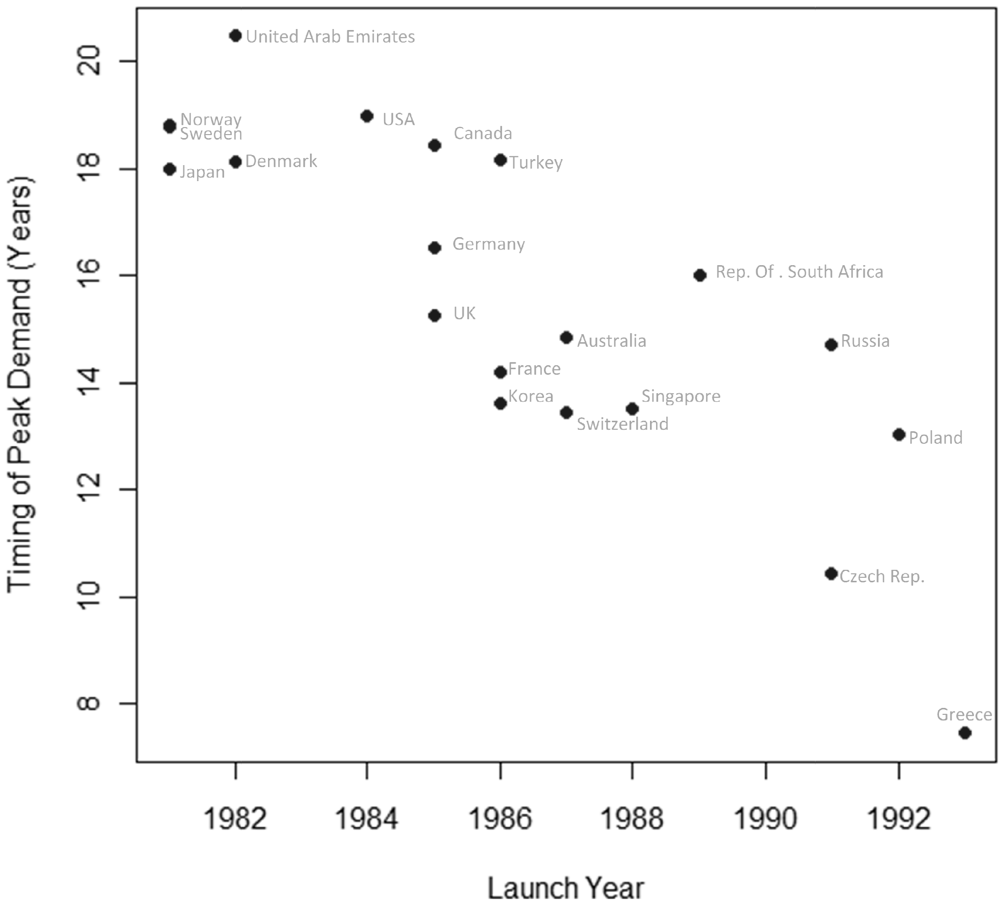


Figure 29: Comparison of the Peak Demand Timing for the Countries

Mahajan, Srinivasan and Mason (1986) state that “studies suggest that stable robust parameter estimates for the Bass model are obtained only if the data under consideration include the peak of the noncumulative adoption curve." Accordingly, the years of peak demand for countries in Figure 30 can form a basis for the country-specific analyses. In our analysis, data up to 2010 are used for each country and the peak year is included within the analyzed time interval for each country.

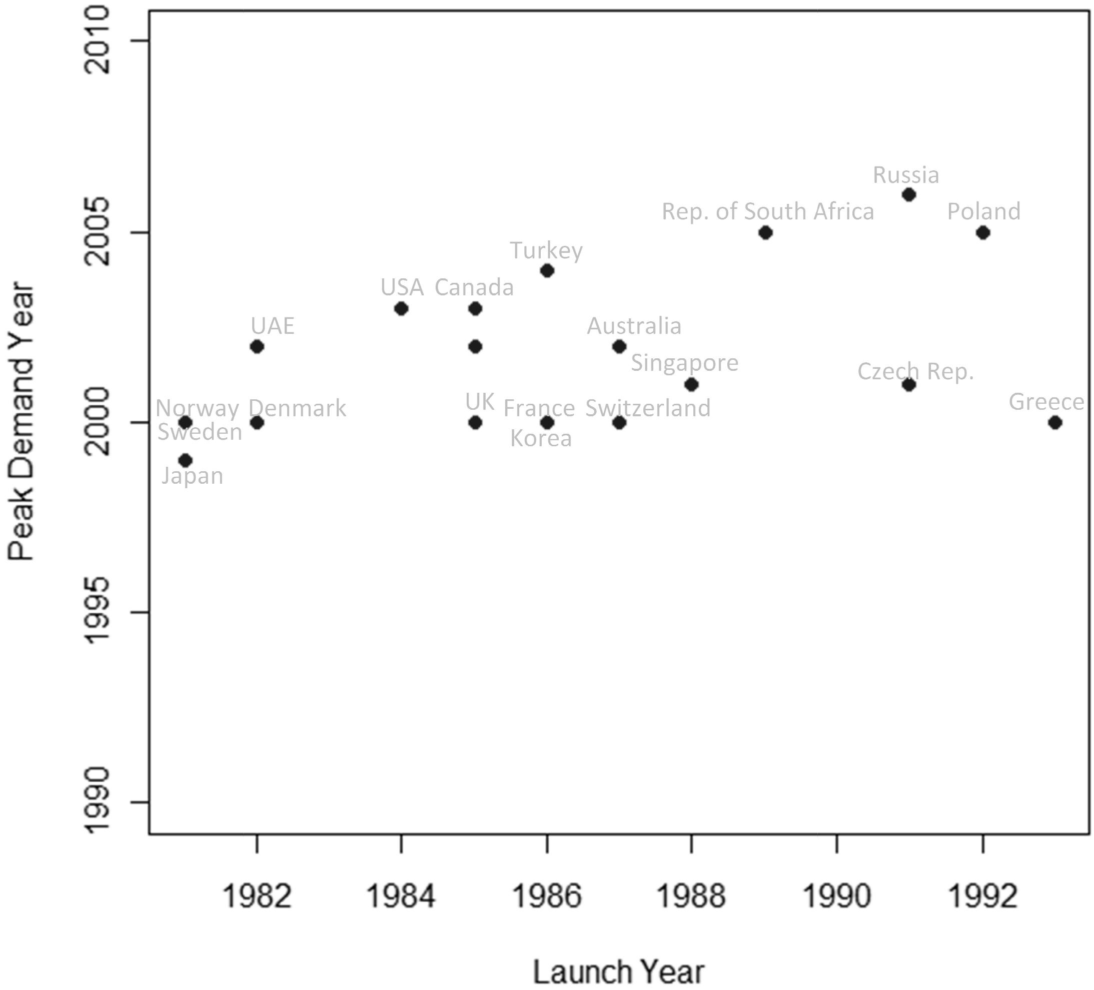


Figure 30: Peak Demand Year vs. Launch Year for Each Country

CHAPTER 7

DISCUSSION

Cross-country analysis provides a forward-looking assessment for the diffusion of mobile telecommunications services for different countries around the world. Comparing the results of our cross-country analysis with the previous studies, Lee and Cho estimate final penetration rate as 71.3 percent for Korea. In our analysis, the saturation level of Korea is forecasted to be 101.71 percent. Penetration in 2010 was given as 105.95 percent for Korea by the ITU. Both our analysis and Lee and Cho's analysis underestimate the saturation level of Korea. The graphical representation of the diffusion in Korea in Appendix reveals a change in the upward direction in the diffusion of cellular phones after 2008. As a result of this, internal and external factor that affect the diffusion process together with the quality of data should be analyzed carefully in order to reach a conclusion. In our analysis, the data of cellular subscribers per 100 inhabitants for ITU was used. While it eliminates the population growth effects, errors in population data will certainly affect the results of the models.

Michalakelis, Varoutas, and Sphicopoulos estimate the saturation level in Greece between 111 and 126 percent based on the results of the eight different models. In our analysis we use only Bass, Gompertz and logistic models. Though, our cross-country analysis also reveals similar range between 111 and 117 percent for Greece.

Analyzing the diffusion of mobile telephony in China, Liu, Wu, and Chu (2010) find that the coefficient of innovation (p) parameter in the Bass model is small and Bass model is degenerated into logistic model. Chu, Wu, Kao and Yen (2009) show that the fitness of logistic and Bass models are indistinguishable due to the relatively small value of p value in the Bass model for the case of Taiwan. In our study, the results of Bass models and logistic model are also in parallel with the analysis results of China and Taiwan. As innovation coefficient approaches to 0, it is mathematically proved that Bass model transforms into logistic model. The findings suggest that the transformation of Bass model into logistic model is a general phenomenon in the diffusion of mobile telecommunications services across the world.

Based on the results of our cross-country analysis, estimated saturation levels of Gompertz model are higher than estimated saturation levels of Bass and logistic models for all countries without an exception. Botelho and Pinto (2004) analyze the diffusion of cellular phone subscribers in Portugal and they compare the results of Gompertz and logistic model. Logistic model predicts a saturation level of 67.4 percent and Gompertz model forecasts a saturation level of 125.5 percent. Chu, Wu, Kao and Yen (2009) forecasted the number of adopters in equilibrium in Taiwan as 24.0, 23.7 and 23.8 million for Gompertz, logistic and Bass models respectively. Michalakelis, Varoutas, and Sphicopoulos (2008) examine the diffusion rate of mobile telephony subscriptions in Greece. The predicted the saturation level for Greece is predicted as 111 percent, 123 percent, and 111 percent for Bass general, Gompertz, and linear logistic models respectively. The results together with our cross-country analysis reveal that Gompertz model’s prediction of saturation level is higher than logistic and Bass models for the experimented countries up to now. It is known that different from Bass and logistic models, Gompertz model is asymmetric and derived from a skewed frequency distribution. However, to the extent of our knowledge; no detailed explanation has been done about the observation of higher saturation levels in the Gompertz model.

The results of cross-country analysis don’t indicate a strong support for a specific model in diffusion of mobile phones. Out of 20 countries, 12 countries are described best by Gompertz model and the remaining 8 by Bass and Logistic models in our analysis. Liu, Wu, and Chu (2010) analyze eight countries and no model outperforms the others in fitted performance in their study.

Considering the evolution of mobile telecommunications services in Turkey, while the models are quite capable in describing the diffusion of cellular phones in Turkey, they fail to show the period-specific affects. The models are unable to detect the decrease after year 2008. After November 2008, with the legal regulation allowing number portability, decrease in penetration is observed due to the cancellation of SIM cards by people having more than one SIM card. Based on the quarterly reports of Turkey’s Telecommunication Authority, number of mobile subscribers decreased from 65.8 million in 2008 to 61.8 million in 2010. Nevertheless, based on the forecasts, there is still room for expansion in the penetration of mobile telecommunication services. However, as the penetration rate approaches saturation level, marketing focus is expected to shift away from subscriber driven mode to average revenue per user (ARPU) driven mode.

After the launch of 3G services by June 2009, Turkish market has observed a rapid uptake of 3G services in a relatively short period of time. Considering the expansion of mobile broadband, Turkish mobile market can preserve its momentum in the following years.

It can be observed that the launch time of mobile telephones plays an important role in the timing of peak demand. While it takes more than 18 years to reach the peak demand for the pioneer countries, the period gradually decreases for the follower countries over the time. This result suggests a multinational learning effect and the superiority of digital technology in comparison with analog technology in the diffusion of mobile telephones. Additionally peak years are observed to be between 1999 and 2006 and this period is the mature time of the second generation systems. The major distinction between second generation systems and first generation systems is that second generation systems are digital and this result suggests the impact of digital technology in comparison with analog technology. Additional services like SMS, GPRS and EDGE in second generation may also play a catalyst role in the expansion of the number of subscribers.

CHAPTER 7

CONCLUSION

In this thesis, diffusion of mobile telecommunication services in countries from different regions of the world is analyzed with an emphasis on Turkey. Bass model, Gompertz model and logistic model are fitted to the observed data of mobile phone penetration starting from 1981 to 2010. In order to provide the unity of the data for each country, the database of International Telecommunications Union is used. Best model is selected based on the root mean square error (RMSE) of each model.

Empirical results demonstrate that Gompertz, logistic, and Bass models are quite capable of describing the diffusion of mobile phone penetration in different countries. The results of the cross-country analysis presented in this thesis show that due to the negligibly low value of the coefficient of innovation parameter (p) in Bass model, Bass model transformed into the logistics model. Additionally, the estimated saturation levels forecasted by Gompertz models are higher than logistic and Bass model calculations.

We observed that while saturation level in Turkey is calculated as 95.5% in Bass model and Logistic model, 108% is calculated in Gompertz model. Based on RMSE (root mean squared error), Bass and logistic models outperform Gompertz model in characterizing the situation in Turkey. According to the Bass and Logistic model 95% of cellular penetration will be reached in 2015.

Estimated parameters in the analyses can be used to forecast the future of the diffusion of mobile telecommunications services in different countries. Additionally, the difference between the current penetration and saturation level can provide valuable insight for the global investors in the telecommunications domain. Additionally, as Bass, logistic, and Gompertz models estimate different saturation level of mobile communication services, they provide valuable intelligence related to the lower and upper bounds of saturation level.

This thesis provides strong support for the hypothesis that the adoption of mobile telecommunications services follows an S-shaped curve. While empirical results show that S-shaped growth models are capable of explaining the diffusion of mobile telecommunications services, the models are not capable enough to explain the distortions in the diffusion period for certain periods of time in different countries. Accordingly future work of including the internal and external effects into the models is beneficial. Additional studies covering the influence of regulatory environment, state of competition, economic situation, level of technology, fixed-line telephone penetration, existence and level of pre-paid services.

Each country consists of different regions and each region may have unique economic and socio-demographic characteristics. A region-based analysis can improve the accuracy in forecasting the market demand. Additionally, best fitting model does not mean the best forecasting model. As a result of this, in addition to fitting performances, in-sample forecasting performances of the models can also be analyzed.

The history of mobile telecommunications services contains incremental and radical innovations. Up to 2010, the real effects of 3G and 4G services have not been observed yet. These technologies may grow so high that it starts to dominate the total behavior in the telecommunications market. Together with the emergence of machine to machine applications, the term “subscriber” is not enough to explain usage of mobile services; machines may also become “subscriber” and enjoy the benefit of cellular data services. In conclusion, diffusion of mobile telecommunications services should be analyzed in a wider perspective containing the evolution in the market.

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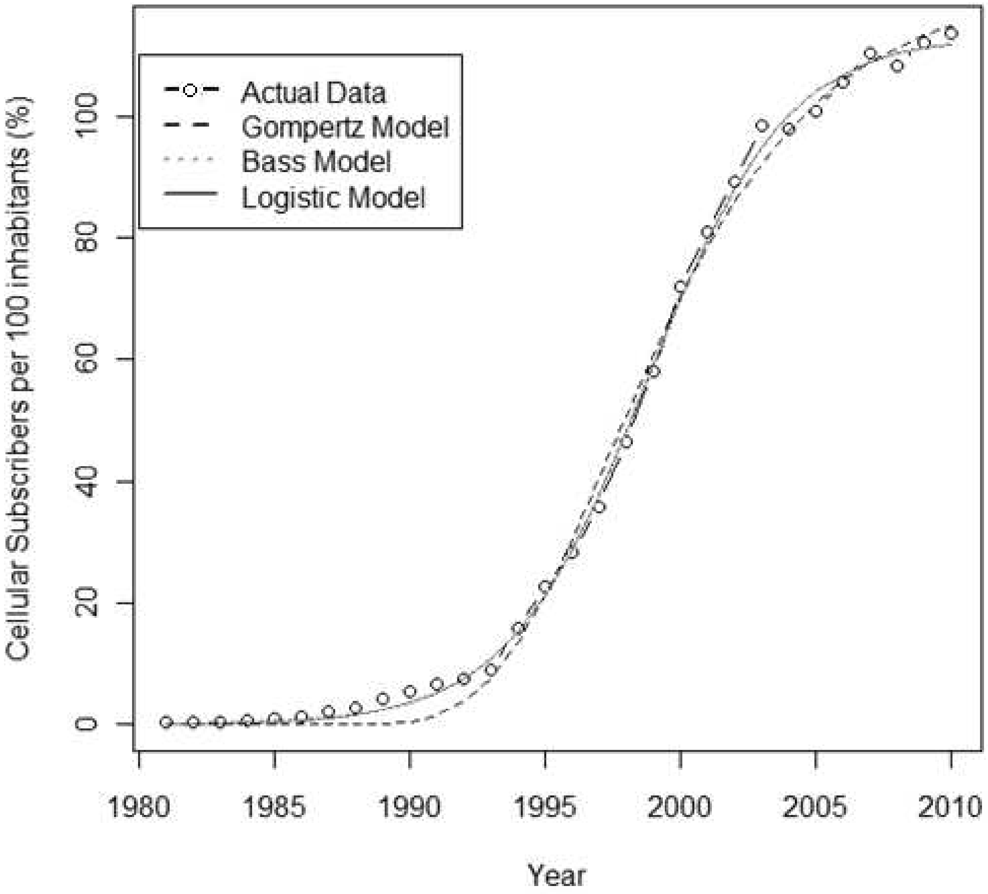
APPENDICES

APPENDIX A – ANALYSIS RESULTS OF SWEDEN



Estimation Results of Bass Model for Sweden

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.13E+02	9.28E-01	122.089	< 2e-16	***
p	2.57E-04	3.94E-05	6.527	5.34E-07	***
q	3.90E-01	1.03E-02	37.901	< 2e-16	***

RMSE: 1.557031

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.641 on 27 degrees of freedom

Number of iterations to convergence: 4

Achieved convergence tolerance: 7.24e-07

Estimation Results of Gompertz Model for Sweden

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.21E+02	2.63E+00	46.100	< 2e-16	***
q	2.33E-01	1.33E-02	17.470	3.06E-16	***
m	1.74E+01	1.58E-01	110.240	< 2e-16	***

RMSE: 2.795464

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.947 on 27 degrees of freedom

Number of iterations to convergence: 10

Achieved convergence tolerance: 6.119e-06

Estimation Results of Logistic Model for Sweden

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.13E+02	9.17E-01	123.570	<2e-16	***
q	3.91E-01	1.00E-02	38.890	<2e-16	***
m	1.88E+01	8.31E-02	226.110	<2e-16	***

RMSE: 1.545159

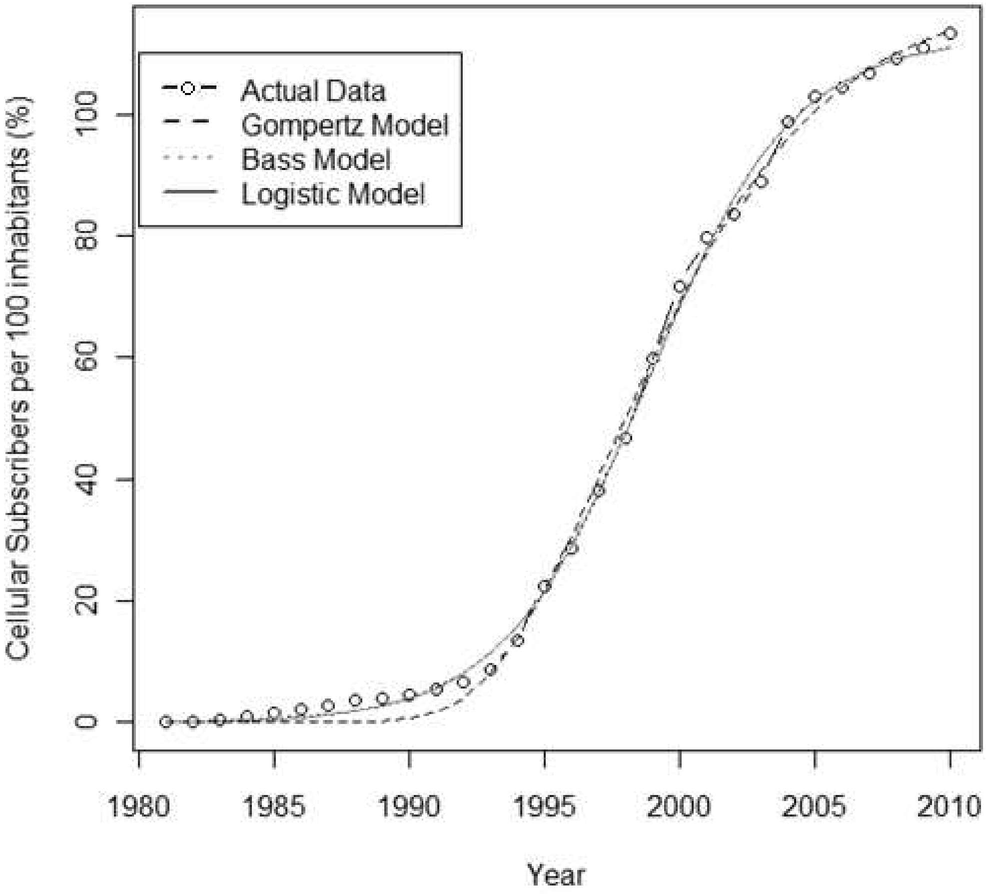
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.629 on 27 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 5.036e-06

APPENDIX B – ANALYSIS RESULTS OF NORWAY



Estimation Results of Bass Model for Norway

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.13E+02	9.86E-01	114.170	< 2e-16	***
p	3.27E-04	4.87E-05	6.730	3.17E-07	***
q	3.74E-01	1.01E-02	36.920	< 2e-16	***

RMSE: 1.580379

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.666 on 27 degrees of freedom

Number of iterations to convergence: 6

Achieved convergence tolerance: 1.363e-06

Estimation Results of Gompertz Model for Norway

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.21E+02	2.08E+00	58.030	<2e-16	***
q	2.25E-01	9.90E-03	22.750	<2e-16	***
m	1.74E+01	1.26E-01	137.970	<2e-16	***

RMSE: 2.107087

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.221 on 27 degrees of freedom

Number of iterations to convergence: 9

Achieved convergence tolerance: 4.186e-06

Estimation Results of Logistic Model for Norway

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.13E+02	9.74E-01	115.510	<2e-16	***
q	3.75E-01	9.87E-03	37.980	<2e-16	***
m	1.88E+01	8.98E-02	209.700	<2e-16	***

RMSE: 1.572176

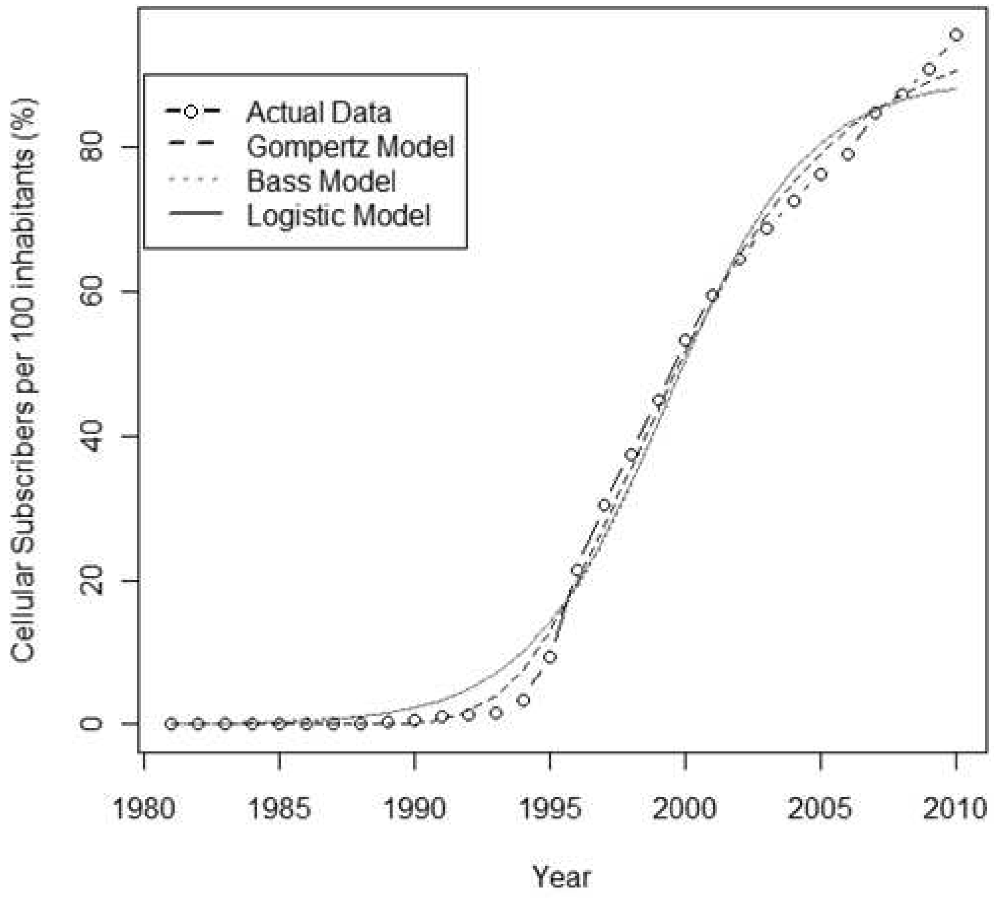
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.657 on 27 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 1.484e-06

APPENDIX C – ANALYSIS RESULTS OF JAPAN



Estimation Results of Bass Model for Japan

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	8.95E+01	2.07E+00	43.219	< 2e-16	***
p	2.19E-04	9.09E-05	2.406	0.0233	*
q	3.87E-01	2.72E-02	14.214	4.70E-14	***

RMSE: 3.216974

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.391 on 27 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 3.895e-06

Estimation Results of Gompertz Model for Japan

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	9.63E+01	2.02E+00	47.630	<2e-16	***
q	2.32E-01	1.22E-02	18.950	<2e-16	***
m	1.80E+01	1.48E-01	121.900	<2e-16	***

RMSE: 1.963017

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.069 on 27 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 9.842e-06

Estimation Results of Logistic Model for Japan

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	8.94E+01	2.06E+00	43.410	< 2e-16	***
q	3.88E-01	2.70E-02	14.400	3.46E-14	***
m	1.93E+01	2.29E-01	84.340	< 2e-16	***

RMSE: 3.225811

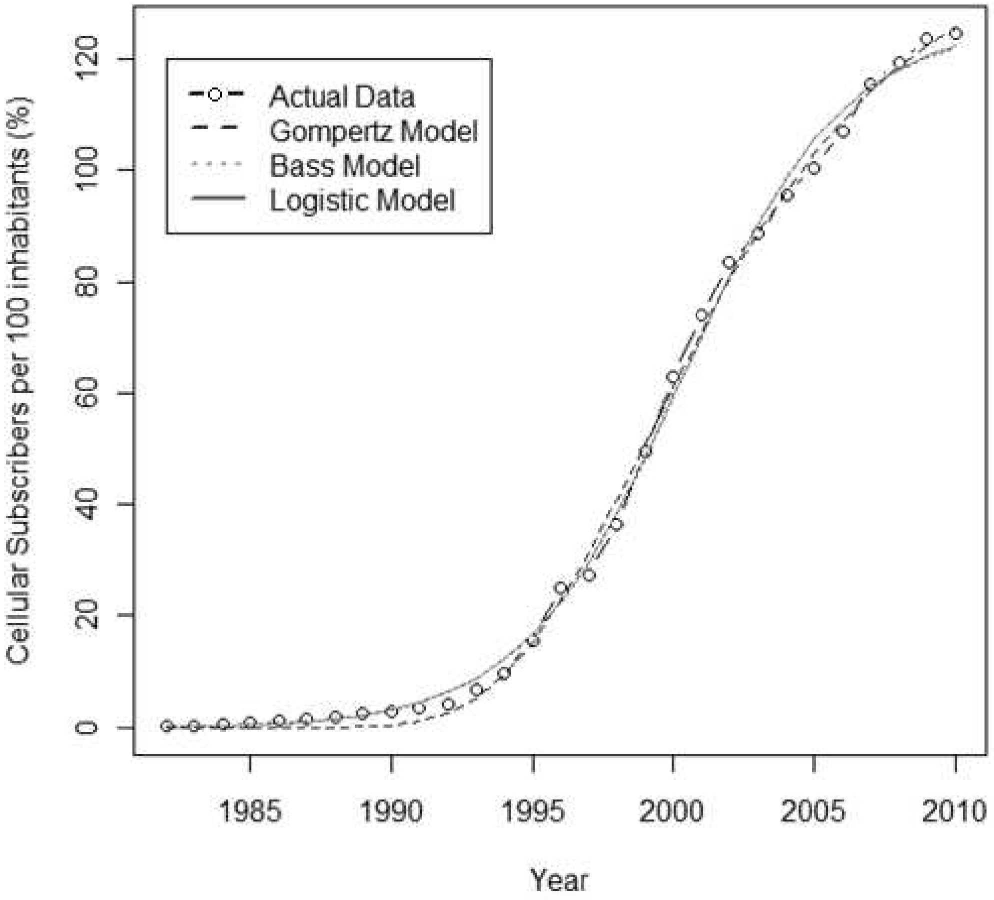
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.4 on 27 degrees of freedom

Number of iterations to convergence: 9

Achieved convergence tolerance: 4.448e-06

APPENDIX D – ANALYSIS RESULTS OF DENMARK



Estimation Results of Bass Model for Denmark

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.26E+02	1.83E+00	69.090	< 2e-16	***
p	4.06E-04	7.36E-05	5.510	8.80E-06	***
q	3.49E-01	1.27E-02	27.530	< 2e-16	***

RMSE: 2.192074

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.315 on 26 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 3.422e-06

Estimation Results of Gompertz Model for Denmark

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.42E+02	3.09E+00	45.880	<2e-16	***
q	1.94E-01	8.30E-03	23.430	<2e-16	***
m	1.81E+01	1.57E-01	115.270	<2e-16	***

RMSE: 1.972840

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.084 on 26 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 8.153e-06

Estimation Results of Logistic Model for Denmark

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.26E+02	1.81E+00	69.720	<2e-16	***
q	3.51E-01	1.24E-02	28.280	<2e-16	***
m	1.94E+01	1.40E-01	138.680	<2e-16	***

RMSE: 2.201938

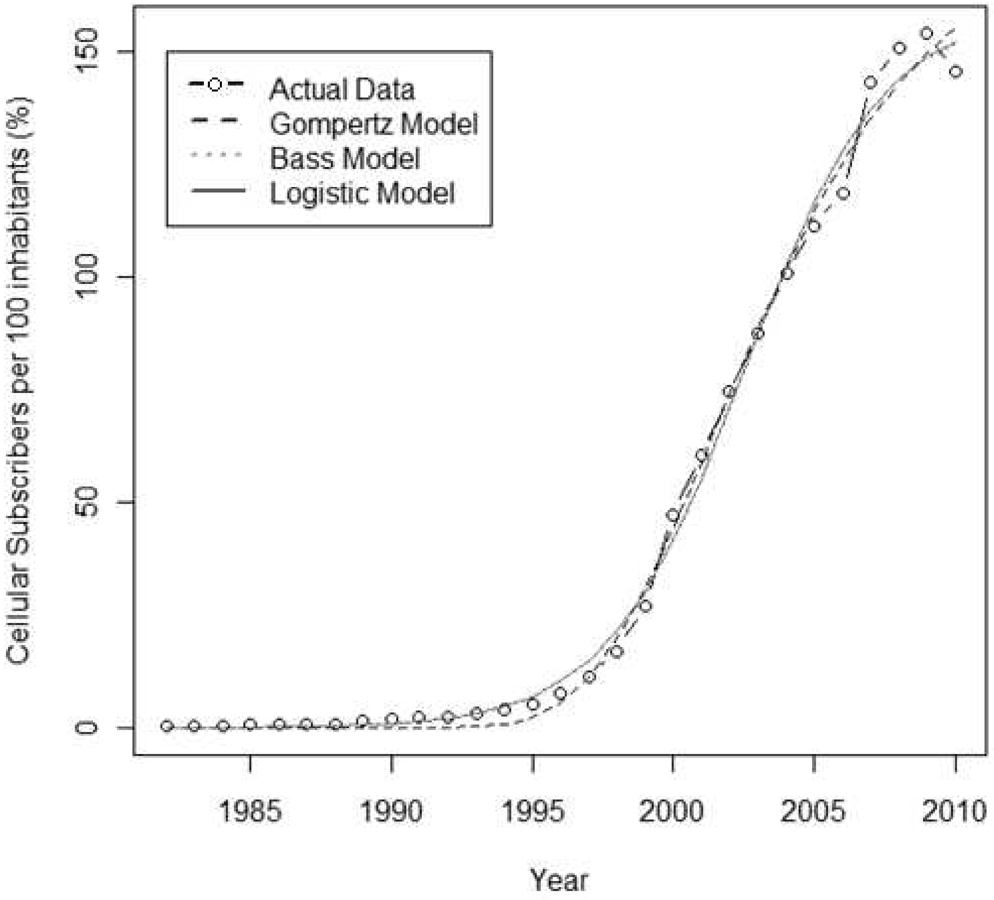
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.326 on 26 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 2.421e-06

APPENDIX E – ANALYSIS RESULTS OF UAE



Estimation Results of Bass Model for United Arab Emirates

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.59E+02	3.85E+00	41.377	<2e-16	***
p	6.06E-05	2.29E-05	2.642	0.0138	*
q	4.09E-01	2.23E-02	18.328	<2e-16	***

RMSE: 3.751243

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.962 on 26 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 9.477e-07

Estimation Results of Gompertz Model for United Arab Emirates

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.79E+02	7.09E+00	25.260	< 2e-16	***
q	2.29E-01	1.67E-02	13.720	2.05E-13	***
m	2.05E+01	2.36E-01	86.660	< 2e-16	***

RMSE: 3.656738

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.862 on 26 degrees of freedom

Number of iterations to convergence: 12

Achieved convergence tolerance: 6.667e-06

Estimation Results of Logistic Model for United Arab Emirates

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.59E+02	3.84E+00	41.470	<2e-16	***
q	4.10E-01	2.22E-02	18.430	<2e-16	***
m	2.15E+01	1.91E-01	112.480	<2e-16	***

RMSE: 3.751596

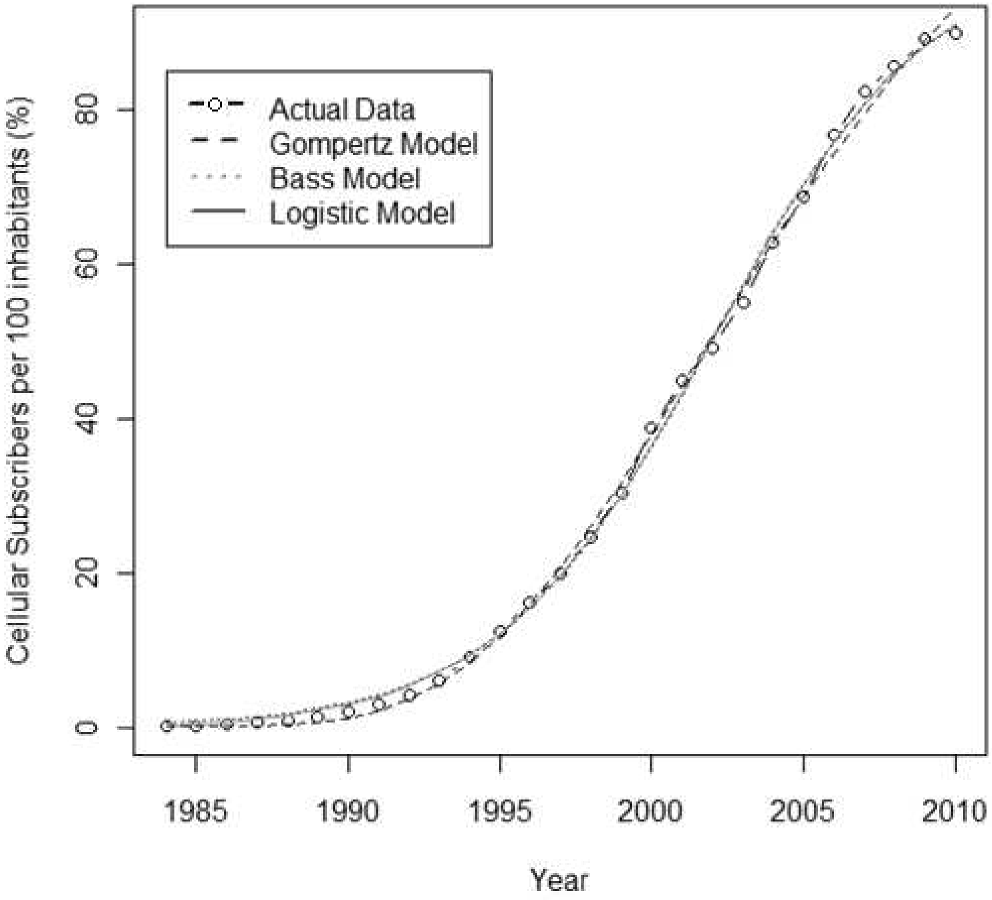
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.962 on 26 degrees of freedom

Number of iterations to convergence: 10

Achieved convergence tolerance: 1.274e-06

APPENDIX F – ANALYSIS RESULTS OF USA



Estimation Results of Bass Model for United States of America

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.01E+02	1.64E+00	61.710	< 2e-16	***
p	1.39E-03	1.20E-04	11.550	2.76E-11	***
q	2.77E-01	7.73E-03	35.880	< 2e-16	***

RMSE: 1.070322

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.135 on 24 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 8.179e-06

Estimation Results of Gompertz Model for United States of America

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.28E+02	4.66E+00	27.480	<2e-16	***
q	1.35E-01	6.08E-03	22.190	<2e-16	***
m	1.85E+01	3.24E-01	56.990	<2e-16	***

RMSE: 1.229288

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.304 on 24 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 5.695e-06

Estimation Results of Logistic Model for United States of America

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.00E+02	1.63E+00	61.270	<2e-16	***
q	2.86E-01	7.71E-03	37.100	<2e-16	***
m	1.90E+01	1.62E-01	116.960	<2e-16	***

RMSE: 290.28

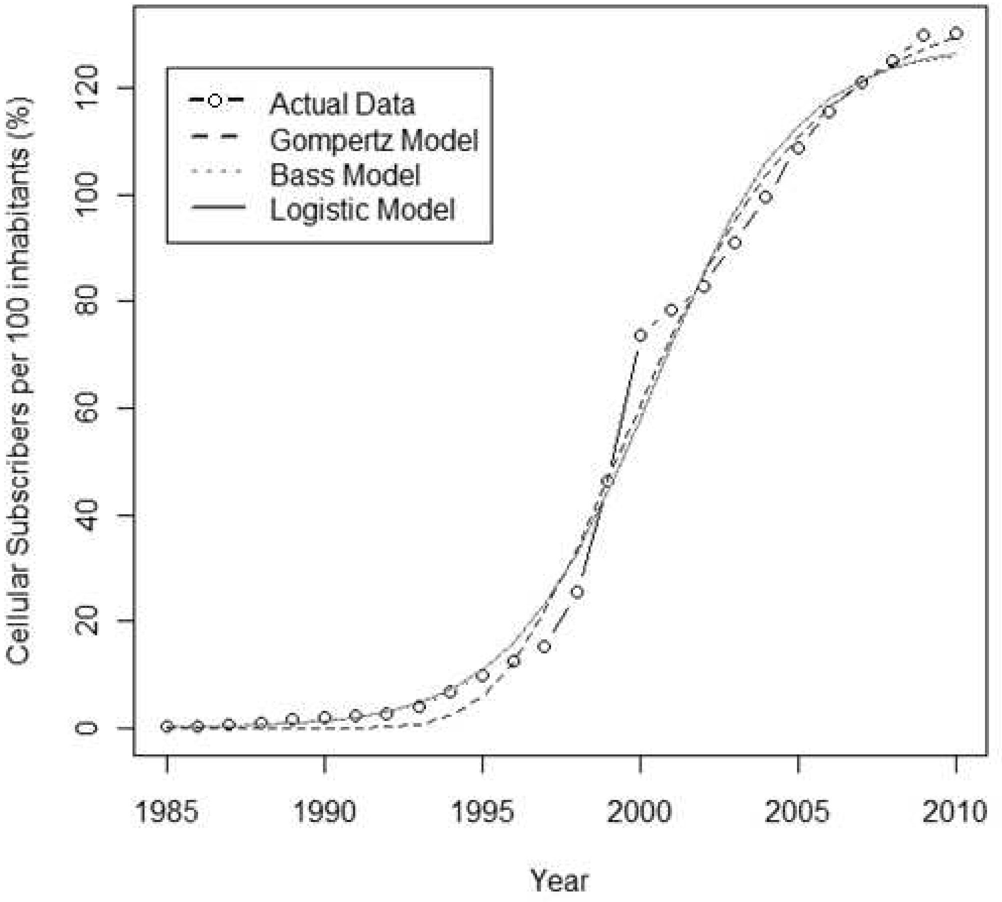
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.234 on 24 degrees of freedom

Number of iterations to convergence: 6

Achieved convergence tolerance: 3.234e-06

APPENDIX G – ANALYSIS RESULTS OF UNITED KINGDOM



Estimation Results of Bass Model for United Kingdom

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.28E+02	3.15E+00	40.783	< 2e-16	***
p	3.25E-04	1.40E-04	2.316	0.0298	*
q	4.38E-01	3.34E-02	13.107	3.73E-12	***

RMSE: 4.684305

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.98 on 23 degrees of freedom

Number of iterations to convergence: 11

Achieved convergence tolerance: 2.965e-06

Estimation Results of Gompertz Model for United Kingdom

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.37E+02	4.21E+00	32.550	< 2e-16	***
q	2.70E-01	2.19E-02	12.380	1.18E-11	***
m	1.53E+01	1.92E-01	79.510	< 2e-16	***

RMSE: 4.085426

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.344 on 23 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 3.67e-06

Estimation Results of Logistic Model for United Kigdom

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.28E+02	3.13E+00	41.020	< 2e-16	***
q	4.40E-01	3.29E-02	13.360	2.54E-12	***
m	1.64E+01	2.17E-01	75.800	< 2e-16	***

RMSE: 4.688589

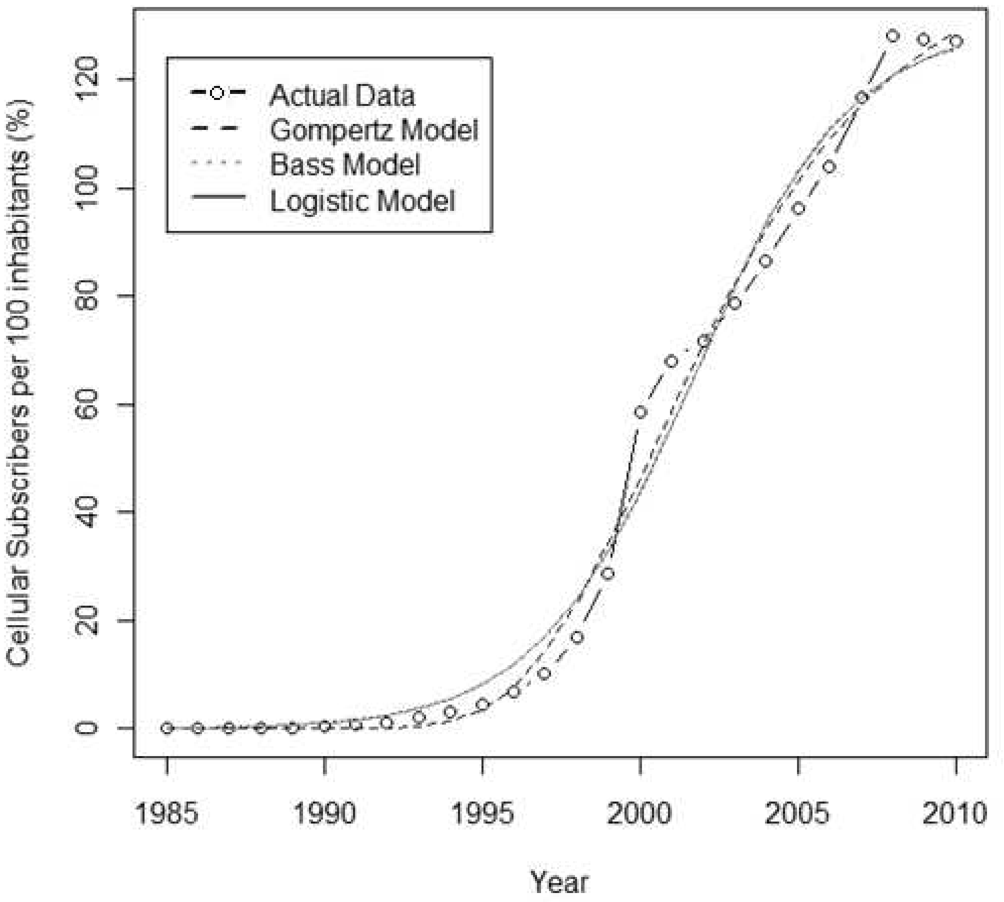
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.985 on 23 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 4.605e-06

APPENDIX H – ANALYSIS RESULTS OF GERMANY



Estimation Results of Bass Model for Germany

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.30E+02	4.87E+00	26.790	< 2e-16	***
p	3.23E-04	1.61E-04	2.003	0.0571	.
q	4.02E-01	3.75E-02	10.735	1.97E-10	***

RMSE: 5.411386

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.753 on 23 degrees of freedom

Number of iterations to convergence: 9

Achieved convergence tolerance: 8.887e-06

Estimation Results of Gompertz Model for Germany

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.43E+02	6.74E+00	21.210	< 2e-16	***
q	2.38E-01	2.34E-02	10.170	5.53E-10	***
m	1.65E+01	2.87E-01	57.560	< 2e-16	***

RMSE: 4.405699

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.684 on 23 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 2.505e-06

Estimation Results of Logistic Model for Germany

Logistic Model

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.30E+02	4.82E+00	27.050	< 2e-16	***
q	4.05E-01	3.69E-02	10.960	1.32E-10	***
m	1.77E+01	3.12E-01	56.720	< 2e-16	***

RMSE: 5.424283

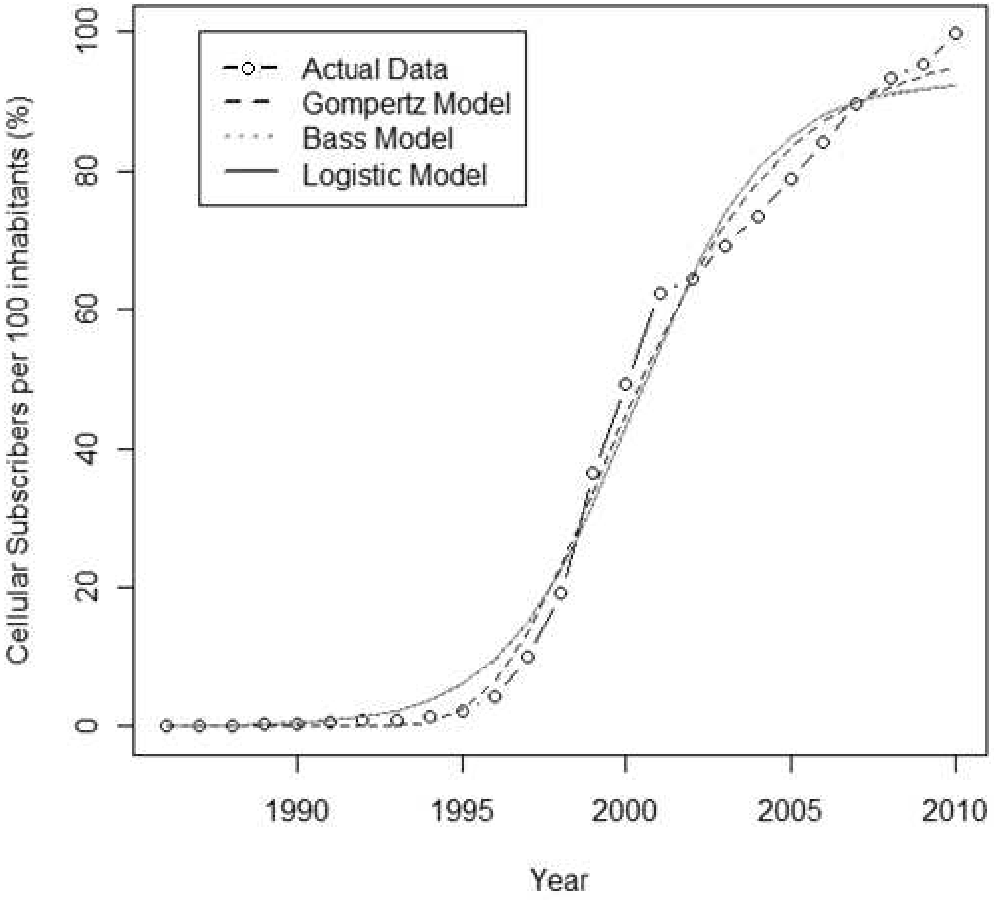
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.767 on 23 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 9.216e-06

APPENDIX I – ANALYSIS RESULTS OF FRANCE



Estimation Results of Bass Model for France

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	9.30E+01	2.35E+00	39.655	< 2e-16	***
p	2.37E-04	1.32E-04	1.789	0.0874	.
q	5.01E-01	4.49E-02	11.137	1.64E-10	***

RMSE: 3.988825

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.252 on 22 degrees of freedom

Number of iterations to convergence: 15

Achieved convergence tolerance: 9.743e-06

Estimation Results of Gompertz Model for France

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	9.81E+01	2.39E+00	41.140	< 2e-16	***
q	3.13E-01	2.30E-02	13.570	3.60E-12	***
m	1.42E+01	1.50E-01	94.810	< 2e-16	***

RMSE: 2.799198

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.984 on 22 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 2.165e-06

Estimation Results of Logistic Model for France

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	9.29E+01	2.34E+00	39.780	< 2e-16	***
q	5.02E-01	4.46E-02	11.260	1.33E-10	***
m	1.53E+01	2.17E-01	70.440	< 2e-16	***

RMSE: 3.994372

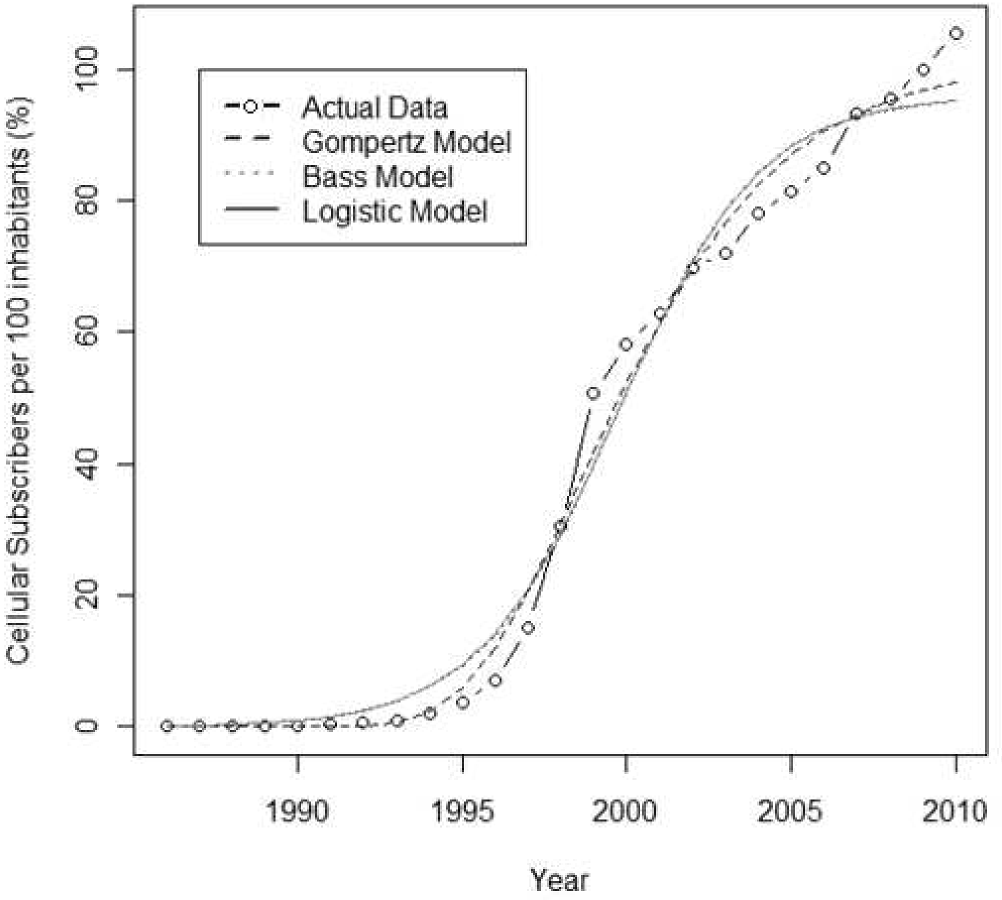
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.258 on 22 degrees of freedom

Number of iterations to convergence: 9

Achieved convergence tolerance: 5.854e-06

APPENDIX J – ANALYSIS RESULTS OF SOUTH KOREA



Estimation Results of Bass Model for Korea

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	9.61E+01	2.94E+00	32.677	< 2e-16	***
p	4.88E-04	2.84E-04	1.716	0.1	
q	4.64E-01	4.99E-02	9.291	4.52E-09	***

RMSE: 5.018073

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.349 on 22 degrees of freedom

Number of iterations to convergence: 18

Achieved convergence tolerance: 6.556e-06

Estimation Results of Gompertz Model for Korea

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.02E+02	3.20E+00	31.770	< 2e-16	***
q	2.90E-01	2.70E-02	10.730	3.31E-10	***
m	1.36E+01	2.04E-01	66.620	< 2e-16	***

RMSE: 3.739495

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.986 on 22 degrees of freedom

Number of iterations to convergence: 11

Achieved convergence tolerance: 3.974e-06

Estimation Results of Logistic Model for Korea

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	9.60E+01	2.91E+00	32.932	< 2e-16	***
q	4.68E-01	4.93E-02	9.492	3.09E-09	***
m	1.48E+01	2.77E-01	53.206	< 2e-16	***

RMSE: 5.032038

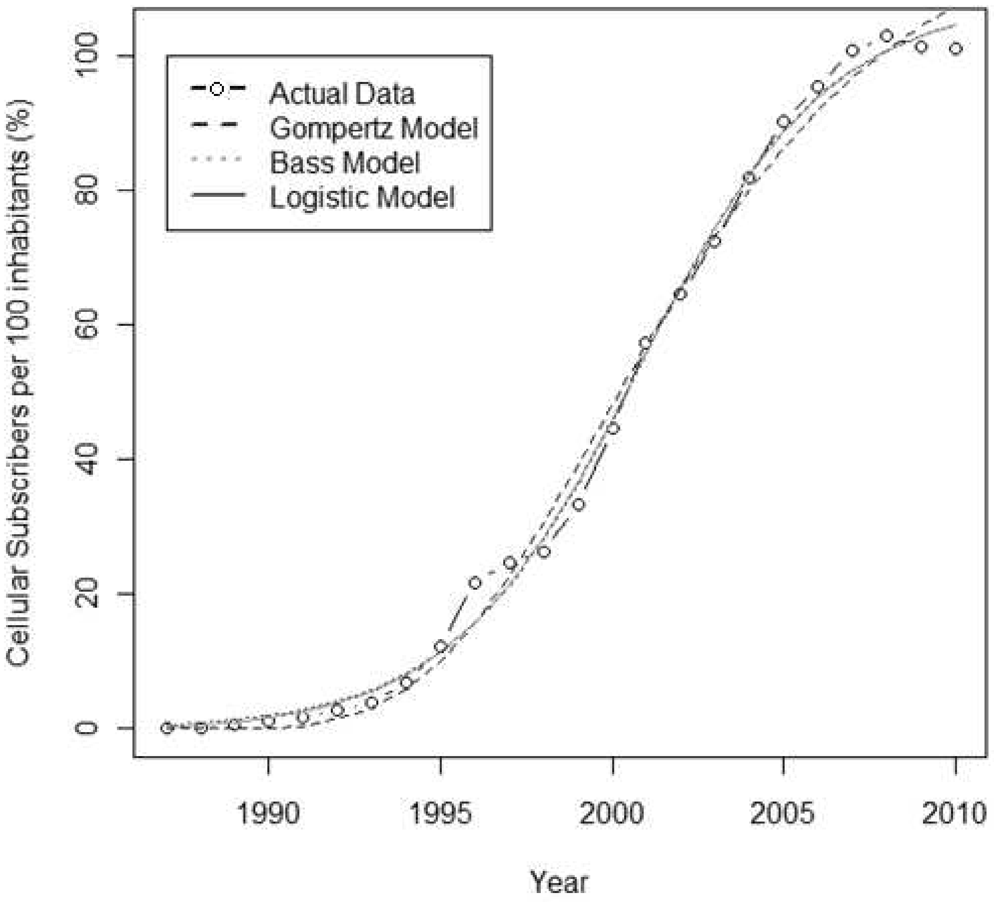
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.364 on 22 degrees of freedom

Number of iterations to convergence: 10

Achieved convergence tolerance: 3.69e-06

APPENDIX K – ANALYSIS RESULTS OF AUSTRALIA



Estimation Results of Bass Model for Australia

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.08E+02	1.93E+00	56.098	< 2e-16	***
p	1.71E-03	2.86E-04	5.988	6.07E-06	***
q	3.59E-01	1.66E-02	21.618	7.87E-16	***

RMSE: 2.159141

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.308 on 21 degrees of freedom

Number of iterations to convergence: 10

Achieved convergence tolerance: 5.201e-06

Estimation Results of Gompertz Model for Australia

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.22E+02	5.14E+00	23.770	< 2e-16	***
q	1.97E-01	1.58E-02	12.490	3.47E-11	***
m	1.36E+01	2.95E-01	46.150	< 2e-16	***

RMSE: 3.028814

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.238 on 21 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 1.768e-06

Estimation Results of Logistic Model for Australia

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.08E+02	1.87E+00	57.840	<2e-16	***
q	3.67E-01	1.56E-02	23.510	<2e-16	***
m	1.48E+01	1.61E-01	92.390	<2e-16	***

RMSE: 2.182482

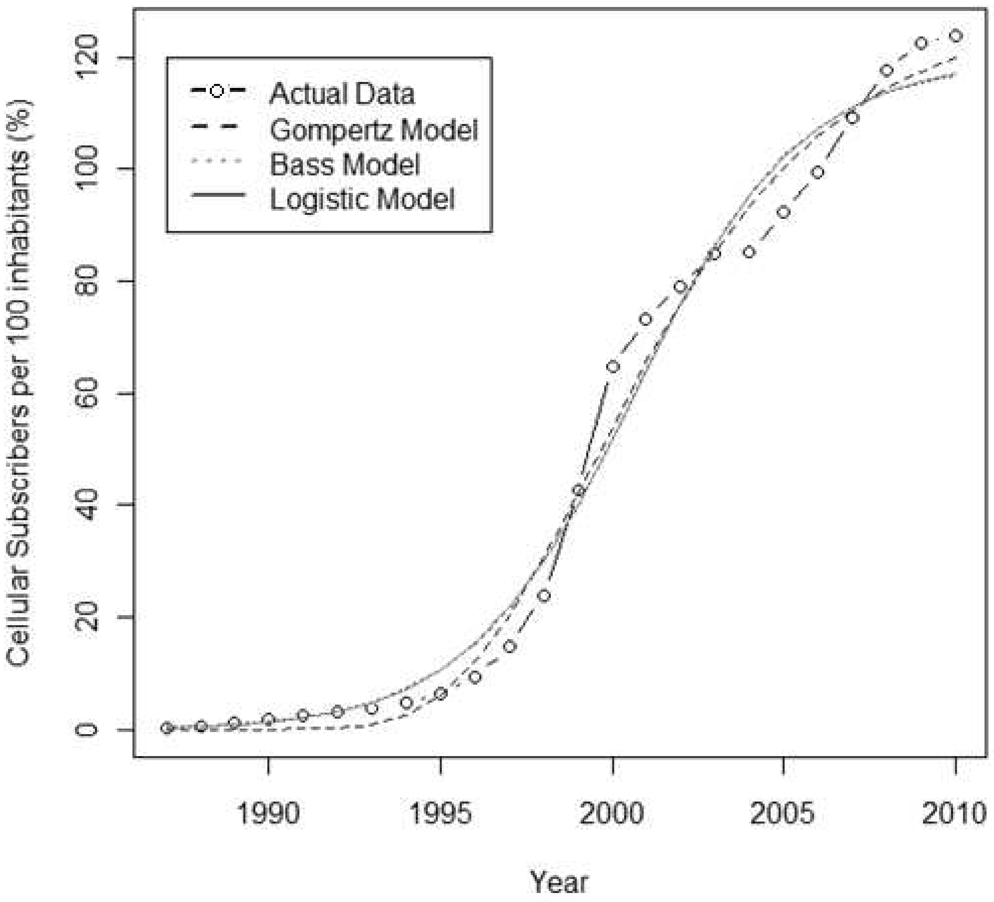
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.333 on 21 degrees of freedom

Number of iterations to convergence: 5

Achieved convergence tolerance: 5.234e-06

APPENDIX L – ANALYSIS RESULTS OF SWITZERLAND



Estimation Results of Bass Model for Switzerland

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.19E+02	4.32E+00	27.620	< 2e-16	***
p	1.04E-03	4.78E-04	2.168	0.0418	*
q	4.07E-01	4.31E-02	9.452	5.15E-09	***

RMSE: 5.742528

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.139 on 21 degrees of freedom

Number of iterations to convergence: 14

Achieved convergence tolerance: 5.763e-06

Estimation Results of Gompertz Model for Switzerland

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.29E+02	5.61E+00	22.969	2.32E-16	***
q	2.50E-01	2.60E-02	9.584	4.06E-09	***
m	1.35E+01	2.75E-01	48.968	< 2e-16	***

RMSE: 4.711522

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.037 on 21 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 9.821e-06

Estimation Results of Logistic Model for Switzerland

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.19E+02	4.22E+00	28.230	< 2e-16	***
q	4.14E-01	4.16E-02	9.939	2.16E-09	***
m	1.46E+01	3.18E-01	46.037	< 2e-16	***

RMSE: 5.766547

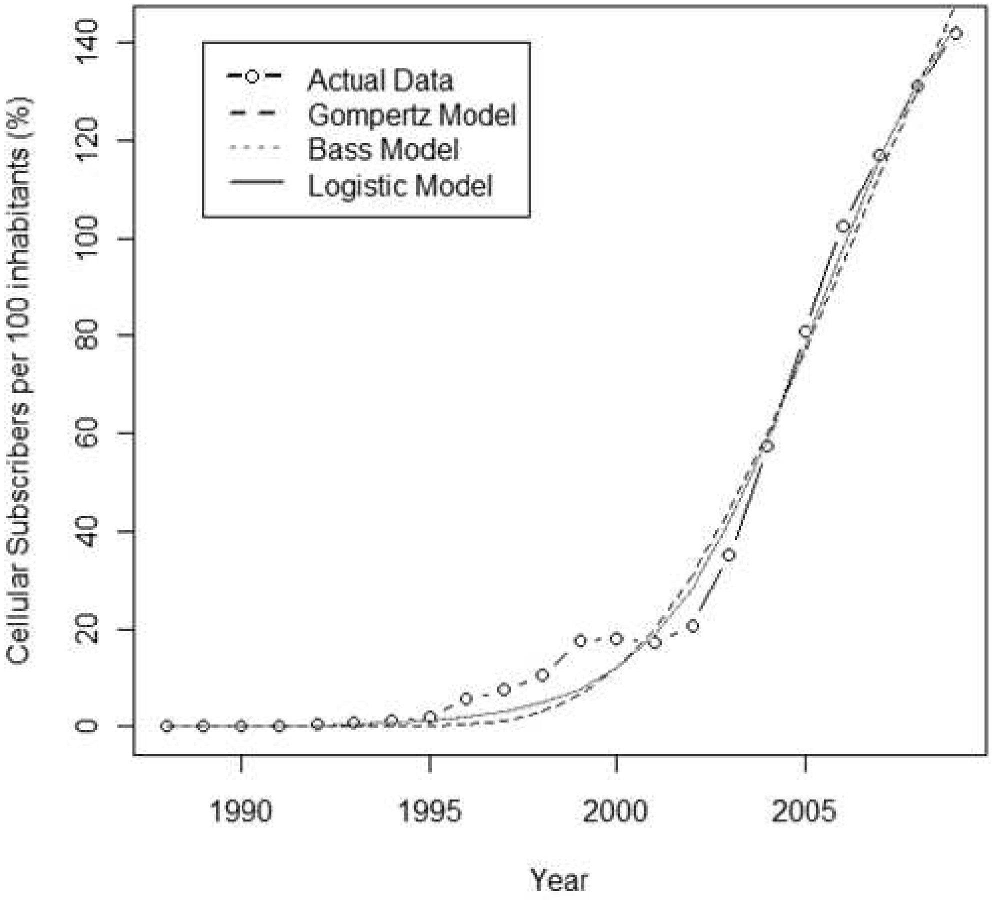
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.165 on 21 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 7.973e-06

APPENDIX M – ANALYSIS RESULTS OF SINGAPORE



Estimation Results of Bass Model for Singapore

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.68E+02	1.01E+01	16.630	8.86E-13	***
p	7.24E-05	3.71E-05	1.950	0.0661	.
q	4.81E-01	3.94E-02	12.220	1.92E-10	***

RMSE: 290.00

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.233 on 19 degrees of freedom

Number of iterations to convergence: 9

Achieved convergence tolerance: 8.59e-06

Estimation Results of Gompertz Model for Singapore

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	2.73E+02	6.50E+01	4.204	4.81E-04	***
q	1.81E-01	3.69E-02	4.898	9.98E-05	***
m	1.93E+01	1.41E+00	13.664	2.81E-11	***

RMSE: 5.284452

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.686 on 19 degrees of freedom

Number of iterations to convergence: 21

Achieved convergence tolerance: 8.642e-06

Estimation Results of Logistic Model for Singapore

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.68E+02	1.01E+01	16.680	8.37E-13	***
q	4.81E-01	3.90E-02	12.320	1.65E-10	***
m	1.83E+01	3.30E-01	55.370	< 2e-16	***

RMSE: 3.928502

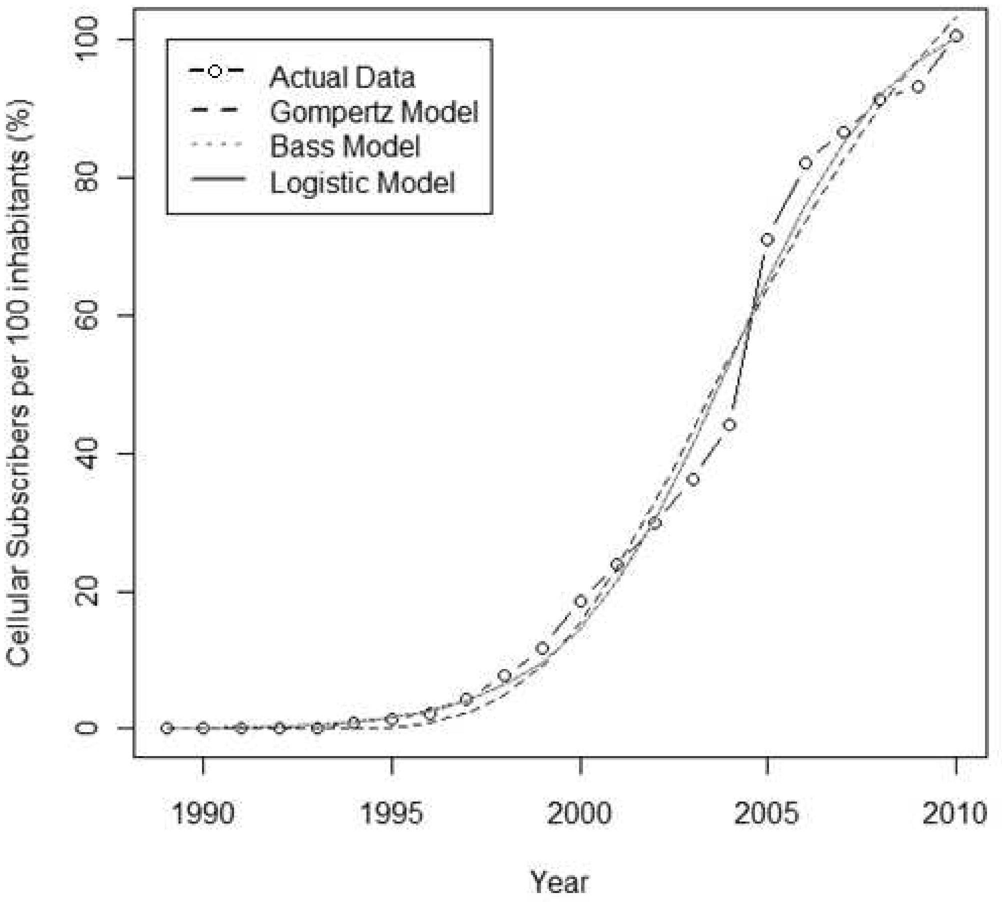
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.227 on 19 degrees of freedom

Number of iterations to convergence: 12

Achieved convergence tolerance: 9.605e-06

APPENDIX N – ANALYSIS RESULTS OF SOUTH AFRICA



Estimation Results of Bass Model for South Africa

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.07E+02	4.12E+00	25.902	2.77E-16	***
p	2.99E-04	1.27E-04	2.344	0.0301	*
q	4.58E-01	3.65E-02	12.553	1.21E-10	***

RMSE: 3.170211

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.411 on 19 degrees of freedom

Number of iterations to convergence: 9

Achieved convergence tolerance: 1.567e-06

Estimation Results of Gompertz Model for South Africa

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.31E+02	1.31E+01	9.984	5.40E-09	***
q	2.19E-01	3.19E-02	6.877	1.47E-06	***
m	1.55E+01	5.75E-01	26.927	< 2e-16	***

RMSE: 3.958867

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.26 on 19 degrees of freedom

Number of iterations to convergence: 19

Achieved convergence tolerance: 9.027e-06

Estimation Results of Logistic Model for South Africa

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.07E+02	4.08E+00	26.170	2.29E-16	***
q	4.59E-01	3.58E-02	12.830	8.28E-11	***
m	1.60E+01	2.58E-01	61.990	< 2e-16	***

RMSE: 3.167888

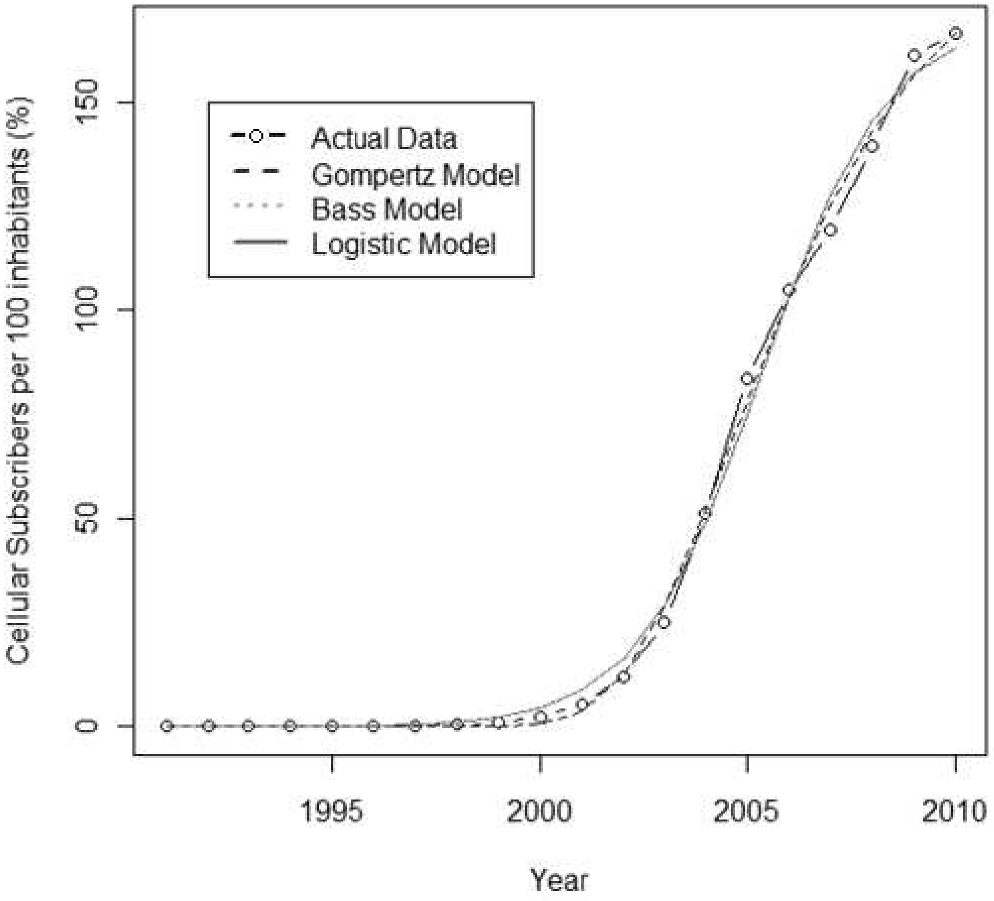
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.409 on 19 degrees of freedom

Number of iterations to convergence: 7

Achieved convergence tolerance: 1.741e-06

APPENDIX O – ANALYSIS RESULTS OF RUSSIA



Estimation Results of Bass Model for Russia

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.71E+02	4.56E+00	37.355	< 2e-16	***
p	2.32E-05	1.24E-05	1.866	0.0794	.
q	6.68E-01	4.25E-02	15.740	1.44E-11	***

RMSE: 3.677875

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.989 on 17 degrees of freedom

Number of iterations to convergence: 11

Achieved convergence tolerance: 5.167e-06

Estimation Results of Gompertz Model for Russia

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.92E+02	5.80E+00	33.040	< 2e-16	***
q	3.72E-01	2.15E-02	17.340	3.05E-12	***
m	1.47E+01	1.13E-01	130.770	< 2e-16	***

RMSE: 2.453939

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.662 on 17 degrees of freedom

Number of iterations to convergence: 6

Achieved convergence tolerance: 6.345e-06

Estimation Results of Logistic Model for Russia

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.70E+02	4.56E+00	37.380	< 2e-16	***
q	6.69E-01	4.24E-02	15.760	1.41E-11	***
m	1.54E+01	1.34E-01	114.870	< 2e-16	***

RMSE: 3.678744

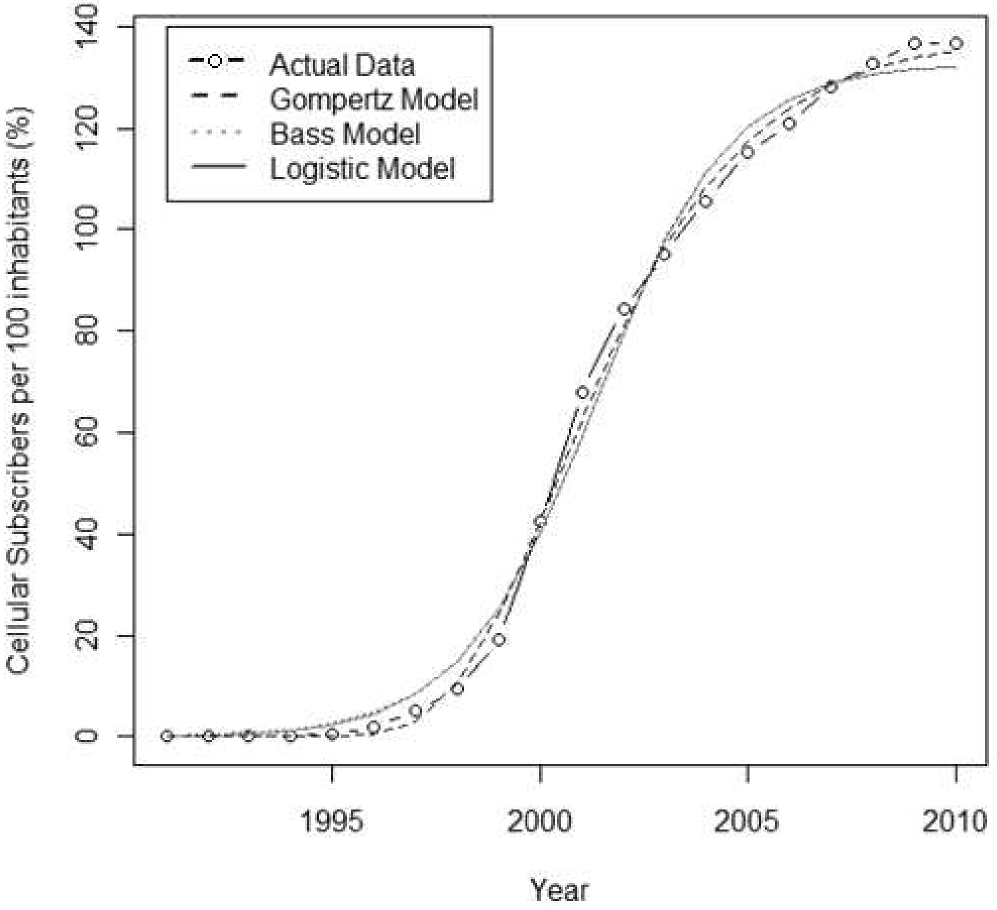
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.99 on 17 degrees of freedom

Number of iterations to convergence: 9

Achieved convergence tolerance: 1.699e-06

APPENDIX P – ANALYSIS RESULTS OF CZECH REPUBLIC



Estimation Results of Bass Model for Czech Republic

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.33E+02	2.37E+00	56.166	< 2e-16	***
p	5.54E-04	2.20E-04	2.522	0.022	*
q	6.18E-01	4.33E-02	14.286	6.70E-11	***

RMSE: 4.034735

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.376 on 17 degrees of freedom

Number of iterations to convergence: 19

Achieved convergence tolerance: 4.828e-06

Estimation Results of Gompertz Model for Czech Republic

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.39E+02	1.87E+00	74.230	< 2e-16	***
q	3.94E-01	1.80E-02	21.950	6.52E-14	***
m	1.04E+01	7.44E-02	140.120	< 2e-16	***

RMSE: 2.331305

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 32.529 on 17 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 3.297e-06

Estimation Results of Logistic Model for Czech Republic

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.33E+02	2.36E+00	56.240	< 2e-16	***
q	6.22E-01	4.29E-02	14.510	5.21E-11	***
m	1.13E+01	1.34E-01	84.880	< 2e-16	***

RMSE: 4.054246

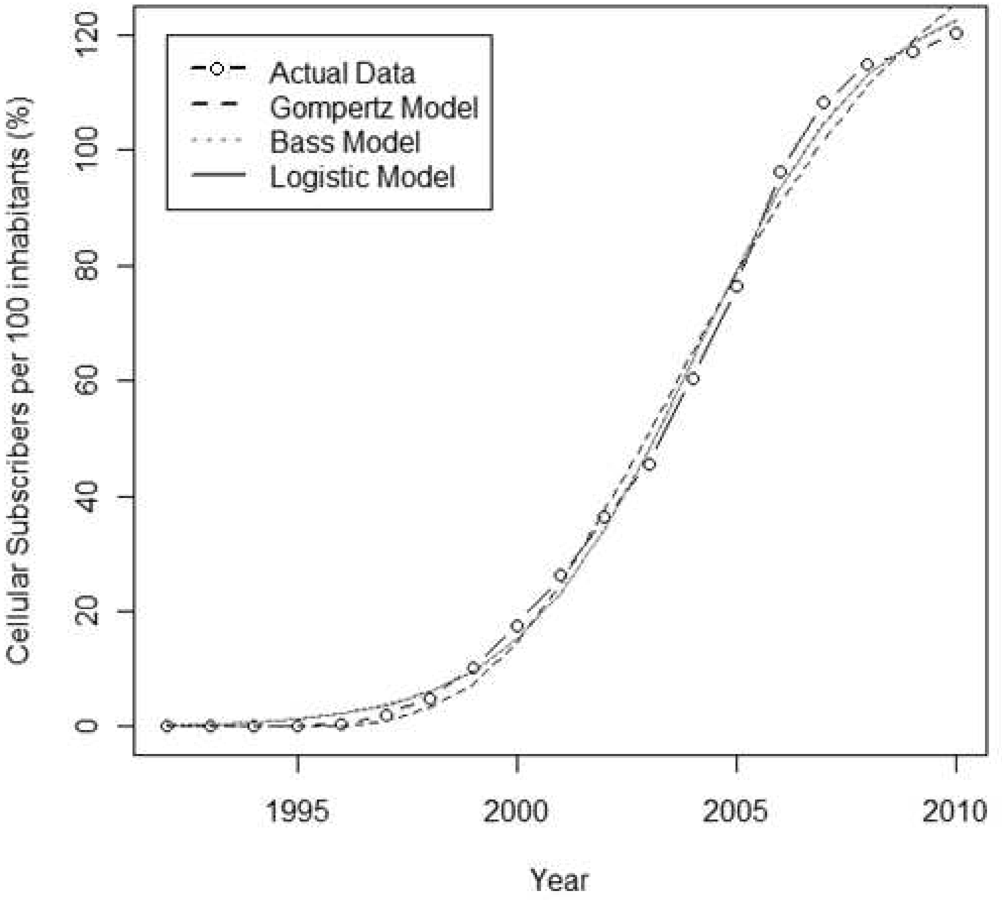
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.397 on 17 degrees of freedom

Number of iterations to convergence: 10

Achieved convergence tolerance: 3.111e-06

APPENDIX Q – ANALYSIS RESULTS OF POLAND



Estimation Results of Bass Model for Poland

Parameters:					
	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.29E+02	2.59E+00	49.781	< 2e-16	***
p	7.84E-04	1.63E-04	4.815	0.00019	***
q	4.93E-01	2.24E-02	22.005	2.18E-13	***

RMSE: 2.121038

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.311 on 16 degrees of freedom

Number of iterations to convergence: 12

Achieved convergence tolerance: 1.993e-06

Estimation Results of Gompertz Model for Poland

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.51E+02	8.47E+00	17.780	5.84E-12	***
q	2.55E-01	2.38E-02	10.690	1.08E-08	***
m	1.23E+01	2.90E-01	42.430	< 2e-16	***

RMSE: 3.204130

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.492 on 16 degrees of freedom

Number of iterations to convergence: 10

Achieved convergence tolerance: 4.354e-06

Estimation Results of Logistic Model for Poland

Parameters:	Estimate	Std. Error	t value	Pr(>|t|)	Signif. Codes
K	1.29E+02	2.55E+00	50.440	< 2e-16	***
q	4.98E-01	2.18E-02	22.800	1.26E-13	***
m	1.30E+01	1.29E-01	101.480	< 2e-16	***

RMSE: 2.135589

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.327 on 16 degrees of freedom

Number of iterations to convergence: 8

Achieved convergence tolerance: 3.732e-06