
A methodology to improve the mobile diffusion forecasting: the case of Greece ¹

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Abstract: Accurate forecasting is extremely important for managers and technology planners in a rapidly evolving global environment. In this paper we apply the Gompertz model to Telecommunications growth in different countries. We conclude that although most of the European countries converge to approximately the same saturation level, using traditional diffusion models could artificially force convergence based on the historical data leading to over estimate or under-estimate of saturation level. The question for planners is how to improve these forecasts. One approach is to select the saturation level carefully based on other information available to the planner. We will show that analogy and interpolation using observed trends from other countries with similar characteristics could also produce good forecasts. The paper uses Greece and Italy to illustrate this approach.

Keywords: Technological innovations diffusion; Gompertz model; short term forecast; Mobile telephony; synthesised forecasting

1 Introduction

Forecasts are necessary for planning, decision-making, and review and understanding of prospective choices. Planning as a profession focuses specifically on trying to deal constructively with possible futures. Decision-makers need a clear perspective on the likely consequences of their options. Unfortunately most of the forecasts are inevitably inaccurate and debatable. Technological forecasting is premised on a certain orderliness of the innovation process. Managers in today's global market need to understand the speed and the direction of the innovation progress and the signals of technological change, in order to act effectively to benefit from the economic potentials that new technologies are offering. Also, the decision making process is improved after identifying the future technological opportunities and threats. *Technology forecasting* is the

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systematic process of describing the emergence, performance, features, and impacts of a technology at some time in the future [1]. Yet most technological forecasts rely on limited empirical data quite divorced from the underlying innovation process models. Dynamics of the economic and social/political contexts fundamentally affect the development of a technology. Reliable technology forecasts should consider forecasts in economic, social/political and other areas as well as taking advantage of all the available historical and current information and knowledge. Usually the limitations of all these based-on-historical-data forecasts are that they do not account for any cataclysms or other critical causal events in the future that will have a tremendous impact on the technological growth

There are many attributes that affect technological forecasts. For some attributes, opinion of experts could be good source of input. Bright technologists could not always be good technical forecasters, since they could miss the social and economic impact of the growth. All the technical assumptions should be carefully examined to eliminate oversights [2]. There are many of technology forecasting methods that are classified in different ways according to the understanding and the definition of each. They can be classified into 3 groups [3]:

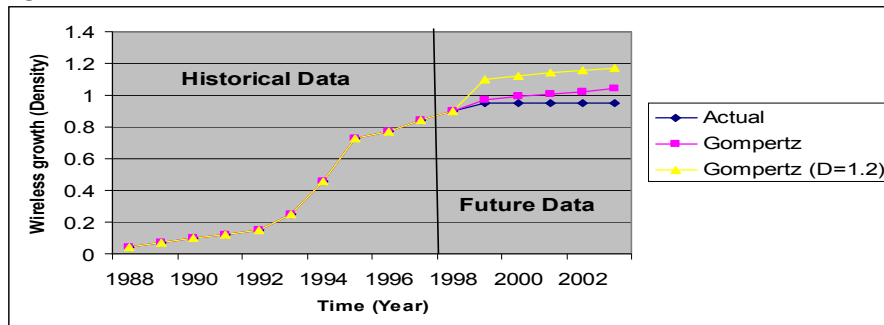
- Directive, containing among others, Delphi, surveys and growth curves
- Correlative, including scenarios, cross-impact and analogy
- Structural, described by simulation models, regression analysis and relevance trees.

The S-shape curves describe many natural phenomena and also used for technological forecasting known as growth curves. There are more than 100 logistic curves usually based on the logistic function [4]. They start slowly, followed by a steep growth, and then slowing down approaching asymptotically the limit. The most studied are the Fisher-Pry and the Gompertz. Each model represents different dynamics. The Fisher-Pry is a growth model that depends on the level of the technology adoption already achieved and the fraction that remains to be penetrated. The model has slower diffusion speed compared to the Gompertz and is largely used when the technology is unknown and unproven. The Gompertz model is more applied in cases when the new technology offers no clear cut advantages over the older and purchases seem simply replacing equipment that has worn out or has been technologically inefficient due to social changes and trends. This theory is closer to investigate the mobile diffusion with the Gompertz model instead of the Fisher-Pry. The dynamics of the Gompertz model are appropriate to cases driven by a technology or product replacement. Indeed, during the mobile revolution new infrastructure, investments and technology planning emerged to respond to the mobile user needs and the current technological convergence.

The Gompertz curve was named after Benjamin Gompertz, with the following equation:

$$y = Le^{-e^{-bt}} \quad (1)$$

where L is the upper limit of the variable represented by y , b , the variable is a parameter for the speed of diffusion, coefficient estimated through regression analysis. The model is asymmetric and the inflection point is usually around 37% of the saturation level. The speed of adoption is larger in the later stages of the diffusion process.

Figure 1 The short term forecast for the UK mobile market

The purpose of this paper is to investigate mobile evolution with an edge in the demand for wireless services which are growing rapidly; i.e in some countries, such as the UK the penetration rate has already exceeded 100%, (Figure1). The transition to digital technology leading to increased spectrum capacity, may thus explain these global increases in the number of subscribers, common to all countries. In this study we focus on forecasts of the mobile diffusion comparing Gompertz with a synthesised forecasting method and taking Greece as a mobile market under investigation.

Applying the Gompertz model and other forecasting methods in several countries as explained in the rest of the paper we are seeking to evaluate the accuracy of the forecasts over the next 5 years (2006-2010). We will illustrate that the Gompertz model alone is not sufficient to provide accurate forecasts by using the growth of mobile services in several countries, such as UK, Italy, and Greece. Typical example, for UK, Figure 1 illustrates that neither of the two applied Gompertz models were able to capture and forecast the actual growth between the years 1998 and 2003. In the case of Greece, the application of the Gompertz model leads to a wireless density of 191% that is far beyond what can be expected and no rational way to explain. Thus we suggest that the forecasts need to utilize all available information and insight from other relevant countries. We argue that analogy and interpolation from countries with similar demographic, economic and technological metrics could improve the forecasting results. We introduce a “back to the future” approach defining the future in the past to evaluate the validity of the traditional diffusion model. All of our estimates are based on the actual trends and growth of national Telecommunications markets. Finally we show that analogy can lead to more robust forecast when used with good judgment in similar environments. The paper illustrates application of the model to Greece and Italy.

The rest of the paper is organized as follows: In Section 2 we will provide a brief review of literature related to the application of Gompertz to Telecommunications market; then in Section 3 we propose our “back to the future” and compare the modified models. In Section 4 we discuss the proposed approach and we close the paper with a discussion and future research.

2 Brief literature review

A number of papers in recent literature apply the Gompertz model to forecast short term national mobile diffusions. Usually the logistic growth model is modified and enhanced with new parameters. The flexible logistic growth model (FLOG) was one of the models

introduced, trying to define a “national saturation level” that was far below the today’s estimates since the upper bound was around 0.75 [5]. The purpose was to create a model that could “accommodate different patterns of diffusion by allowing the point of inflection and the degree of symmetry to be data-determined”. However, the data projections were not related to the mobile diffusion and the saturation levels are bounded between zero and one.

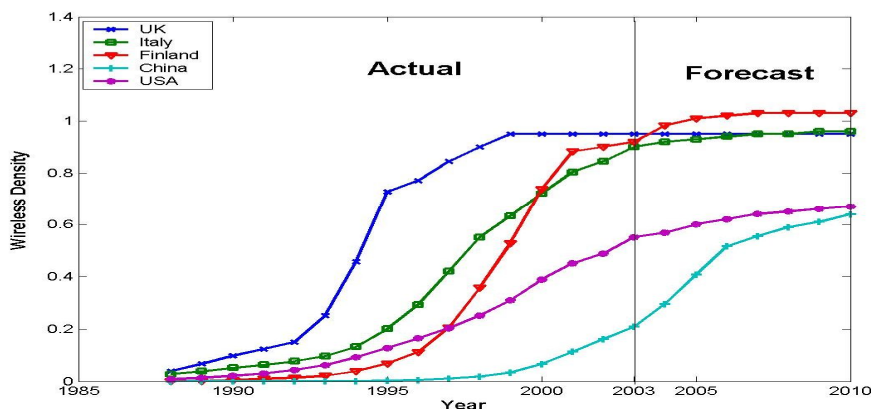
In [6] the mobile diffusion of the European Union was studied and the effect of delays in granting the first mobile licenses, where the countries present a slow catch-up. Additionally the impact of introducing competition was significant in both digital and analogue period. Another study investigated the mobile diffusion in Italy and the UK comparing the logistic and the Gompertz models [7]. They found that the new digital technology in both Italy and UK has made the process faster and increased the saturation level in Italy, but not in the UK; in Italy only the decreasing price of the handset has affected the diffusion process. The decreasing tariffs and increasing consumption expenditures have been significant in shaping the diffusion process of mobile telephony in the UK. The models were modified in the linear form, adding other variables such as the number of subscribers, number of potential adopters, and relevant economic factors: the price of the handset, the tariff, and consumption expenditures covering roughly the First and Second Generations of mobile telephony in the two countries. It seems that Italy has reached the saturation or near saturation level, and could be a good prototype or pattern to estimate the mobile diffusion of the neighbour countries or countries with similarities. The mobile diffusion was also studied in the Central and Eastern Europe [8]. They applied a logistic diffusion model concluding that in countries that have adopted mobile telecommunications late, the diffusion speed is faster, implying a pattern of convergence in technology and services. The speed of diffusion increases with the number of service providers. Simultaneous entry is more effective in accelerating the diffusion speed than is sequential entry. Diffusion is quicker the larger the fixed telecommunications penetration rate and the longer the waiting list.

Additionally in [9] a recent study was conducted on the diffusion of digital mobile telephony across developed and developing countries with the aid of a Gompertz model. The conclusions were various with more important the case of a developing country context: having a large potential user base, accumulating network effects, being open, commanding a high (non-telecom) technological level, and introducing innovation(s) complementing mobile telephony. Then, the late entrants experience faster diffusion promoting cross-country convergence. In another cross-country study [10] four models for pooling the cross-sectional data are described and two diffusion models are discussed but only the Gompertz model is used throughout the three data sets that include digital cellular telephones. The study concludes regarding the mobile wireless data set that the saturation levels in each country are to some extent determined by national wealth and cellular telephone connection charges. The fixed effect model is of particular interest, since it can be estimated if there is just one observation for a country. However, after 3 years, the forecasts over longer horizons have similar accuracy to those of the fixed effect model using Gompertz. The cross-sectionally varying, CSV, model works well; the estimates of saturation levels are plausible and the forecasts are most accurate according to the median absolute error and percentage better measures used.

There are several methods proposed to estimate the parameters of the Gompertz model, with the simplest, constructing three data points by taking some average of the first, middle, and the last observations. The result is to obtain three equations with three

unknown [11]. In our analysis we use a nonlinear least square regression method to estimate the parameters with the help of the Mathematica software package.

Figure 2 The short term mobile diffusion forecasts with Gompertz



In Figure 2 the wireless density curve for each country shown, is composed of two segments. The curve from 1988 to 2003 is the actual plot of wireless density from our database. The extension of the curve from 2003 to 2010 is the forecast using the Gompertz model as we discussed earlier without restricting the saturation level.

Most of the illustrated countries converge to around the same saturation level. We will investigate Greece further in the following section. However, from a social aspect Greeks updated their handsets in 2005 more than three times of the European average [12] pointing out that the Greek mobile users present a very strong growth in the wireless services. On the other hand the chart shows that US is significantly behind these other countries in terms of wireless density and the growth is much slower. This estimate is below other industry numbers i.e the “Diffusion Group”, claims that by 2010 mobile phone subscribers will climb to approximately 236 million users or about 75% of the US population [13].

3 Modified Gompertz models and discussion

Data description

The study is based on annual national data. The data on the number of subscribers at the end of each year and is from Mobile Communications for the period 1988-2003 is from International Telecommunications Union (World Telecommunications Indicators) for the period 1984-2003. Then for the period 2004-2005 the data is from the NetSizeGuide 2006. Data on GDP/capita is from the OECD. The S-shaped growth curves are frequently used with small data sets since it is difficult to create a large dataset of a new technology or product that was introduced in the past few years. A subscriber is a user usually on a contractual relationship with a wireless service provider, namely in the form of a subscription plan or an active prepaid card. Hence a subscriber is an account. A usual phenomenon is residents having a personal and business account with different providers

or a foreigner could maintain an account without being a resident. The ITU dataset may be counting them twice, leading in some cases into higher penetration than the real one.

Methodology and results

Estimating the upper limit in the Gompertz model is very important, because if it is under or overestimated leads to inaccurate forecasts. Usually the upper limit is estimated as the natural limit requiring a detailed knowledge of the technical approach by the forecaster in conjunction with a specialist with good knowledge of the field. As shown in Figure 2 for most countries the upper limit could be around 1.2 ($L=1.2$). This is based on the argument that the target population for mobile wireless phones are those older than 10 years. Among those only a fraction will have more than one phone or SIM card at any time. Furthermore the actual penetration curves for some of the lead markets in Europe are flattening slightly above one. In the rest of this section we will use Gompertz model with and without upper bound to and compare the resulting forecasts with the actual growth for Greece, Italy and UK. According to our methodology called it “back to the future”, we assume that the current year is 1998. Thus we fit in the model the past 10 year historical data (1988-1998). We already have the actual values for the years 1999-2003, but for our models that 5 years period is the “future”. This way we compare the results of both models and their behaviours.

Table 1 presents the estimates of the model parameters using nonlinear regression analysis for both models:

Table 1 Parameter estimates for Gompertz

<i>Gompertz</i>	<i>Parameters</i>	<i>Greece</i>	<i>Italy</i>	<i>UK</i>
Upper bound=1.2	b^1	0.29	0.29	0.34
No upper bound	b^2	0.42	0.45	0.42
	L	1.91	1.06	1.06

Note: b^1 , is the diffusion speed for the bounded model

b^2 , is the diffusion speed for the non-bounded model

The UK and Italy converge at the same upper bound, whereas Greece is presenting a tremendous growth with a very high value compared to the other countries, but in the short term forecast presents a similar behaviour. The extrapolation analysis for Greece was conducted using less than 10 points as the initial dataset, since Greece was a late adapter of the wireless service starting in 1994. Potentially this has an impact on the L value that is estimated extremely high in the regression model. This is one of the weaknesses of the extrapolation analysis, since Greece is presenting normal behaviour until 2003, which does not suspect the forecaster to expect this penetration boost. Also the actual data of Greece until 2005 do not seem to excuse the 191% penetration.

In Figure 4 and 5 we draw short term forecasts for these 3 countries comparing with the actual data graph of Figure 3. To compute the forecasts we substitute the estimates from Table 1 into Gompertz equation as described earlier. The future values of t were substituted into the formula to obtain forecasts of the variable y [14].

Figure 3 The Actual Growth for Italy Greece and the UK

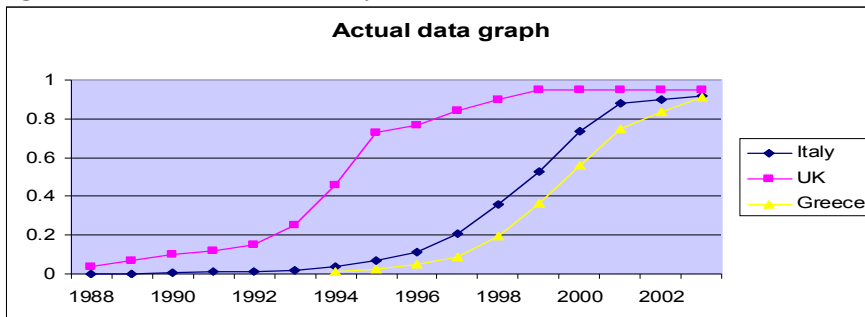


Figure 4 Short term forecasts with an upper limit

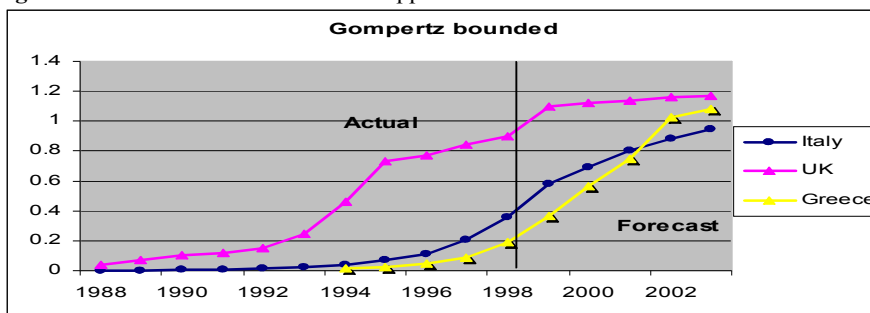
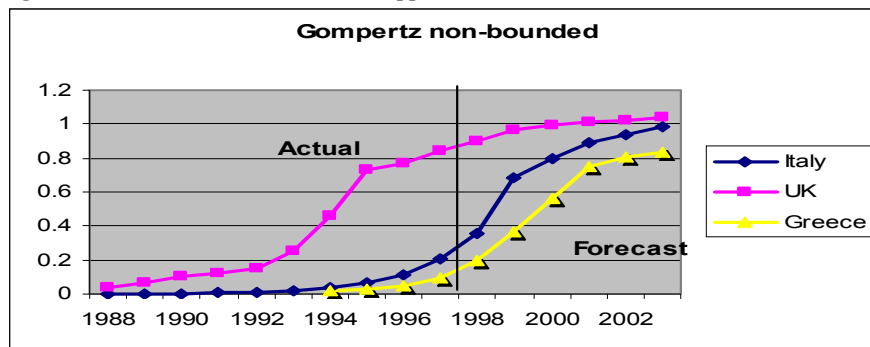


Figure 5 Short term forecasts with no upper limit



According to the above Figures, we conclude that the non-bounded Gompertz is closer to the actual growth performing similar predictions. On the other hand the upper-bounded model although it produced close estimates for the countries was not able to meet the actual values in the short term. One of the reasons might be that our fraction value of 1.2 might be more appropriate for the next short term period concerning years 2005-2010, when the convergence was closer to the 1.2. Greece and the UK climbed over 1, when Italy was closer to the actual value. We believe that although the countries seem to have similar saturation levels, the upper bound may be different for each case. In the next section we apply a different methodology that improves dramatically the prediction for the Greek mobile market.

4 Improving short term forecasting: case study, Greek and Italian mobile markets

The regulatory framework

The Telecom regulators in Italy and Greece shaped quite different market structures at the launch of mobile telephony. In Italy the fixed line telephony was a government monopoly. Telecom Italia (then SIP) was the only licensee for mobile telephony from 1985 till 1994 when a second license was granted by Omnitel, which recently become Vodafone Omnitel. Following EU indications, to increase competition a third operator, Wind, was introduced in 1998, and a fourth, Blu, in 1999, both basing their services on micro cellular technology. [15]

In Greece mobile telephony became the first type of telecommunications not monopolized by the OTE when two private consortia introduced it in 1993. In 1994 the government attempted partial privatization of the OTE by selling a minority part of the company's equity capital to the Greek and foreign stock exchanges, but the plan died amid interministerial wrangling and insufficient planning when market prices for the shares appeared much lower than expected. Instead, the government extended the OTE's monopoly over the national telecommunications infrastructure and cable networks until 2003. In January 2001 the Greek telecommunication market was fully liberalised and OTE 's (the incumbent) explicit right for the provision of voice telephony was removed. Currently, there are four main operators in Greece; Cosmote and Vodafone are dominating the market, TIM Hellas, formerly known as Stet Hellas Telecommunications and Q-Telecom, which is a virtual mobile operator using the Vodafone network [16]. Both countries issued UMTS licences in 2004, including all the existing operators.

Methodology and results

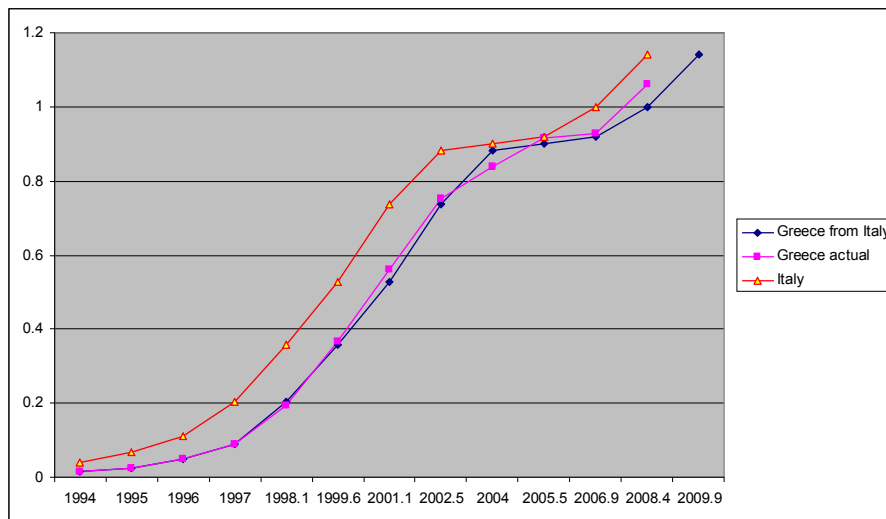
We are applying different metrics to compare Italy and Greece considering wealth as GDP/capita, population, considering the population as the group that ranges from 14-67 years old, arguing that the majority of the wireless users that drive the mobile diffusion reside in that group. Additionally we found the APRU's to be comparable. Furthermore, in both countries the UMTS services were introduced in the same year, 2004. Both countries are in European Union following the same Telecom regulations and currency. Greece was the last country in 2006 that have transposed into the EU telecom regulatory framework. The main similarities of both countries are summarized and highlighted in Table 2.

Table 2: Similarities of Greece and Italy

<i>Metrics</i>	<i>Greece</i>	<i>Italy</i>
GDP/capita	\$23,000	\$28,000
ARPU	\$27	\$30.2
UMTS services launch	2004	2004
Population group	15-64 years: 66.7%	15-64 years: 66.8%
Total median age	40.5	41.7

Our metrics (Table 2) cover a range of different national indicators suggesting a good technological interaction among the two neighbour countries. Applying historical analogy and interpolation method using Italy's mobile density growth as a model for Greece we estimated the Greek mobile diffusion based on the Italian. This methodology was successfully applied in the case of China and Korea [17]. According to our estimate, Greece will reach the 114% penetration around the September of 2010 (Figure 6).

Figure 6 : Greek Mobile diffusion forecast based on Italy



From the same Figure we can see that Greece is still in a growth phase even in September of 2010, since the curve does not seem to flatten yet. Additionally the estimated curve is covering the actual one very closely, suggesting a good fit and good prediction accuracy of the methodology.

5 Conclusions and future research

Accurate technology diffusion forecasting is extremely important for today's managers and technology planners. In this paper we applied the Gompertz model to the mobile wireless services industry in different countries. We showed that although most of the European countries converge approximately around the same level, when upper-bounding the model into the same saturation level we experienced different model behaviours. The short term forecasts except for Italy were different from the actual suggesting the inaccuracies of the forecasts. We concluded that one may have to come up with a very accurate upper bound for each country. Also when we tried to estimate Greece with Gompertz model the upper limit was overestimated much higher than expected, concluding that the extrapolation trend analysis is not the appropriate forecasting method for late adapters. Also using few data points in the early stage of the S curve could easily diverge the curve. That might be one of the problems among others for the inaccuracies in the national forecasts. To improve upon these estimates, we used a synthesised method, including historical analogy and interpolation, applied into patterns of growth in

relevant neighbour countries with similar mobile markets characteristics. In the case of Greece, prediction based on the Italian mobile market came very close to the actual market growth. We estimated that Greece will reach the 114% of penetration around the September of 2010. It turns out that historical analogy can lead to more robust forecasts when used with judgment and insight to the growth in similar environments

This study is a work in progress. We need to test the approach in other countries and with other technologies and develop application and goodness of fit criteria. Furthermore, our goal is to continue this area of research and explore ways of integrating analogy with the traditional forecasting models. Finally we are interested in comparing the Gompertz predictions to the other kind of models exploring advantages and limitations and also comparing with other kind of diffusion curve for similar technologies i.e. broadband to confirm that the methodology's validity.

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