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Diffusion Patterns of Mobile Telecommunications Services in the European Countries

이동통신서비스 확산패턴 - 유럽국가 자료를 중심으로

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목 차

국 문 요 약

이동통신시장은 지난 10년 동안 괄목할 만한 가입자 증가로 인해 급격하게 성장했다. 서비스의 확산패턴은 그러한 새로운 서비스를 준비하는 이동통신사에게 주요 관심사이다. 우리는 이러한 서비스의 확산패턴이 이전의 모바일 서비스와 유사할 것으로 가정하며, 이러한 서비스의 확산패턴을 확인하는 것은 차세대 모바일 서비스를 위한 이동통신사에게 필수적이다. 본 연구에서는 이동통신서비스의 유사한 확산패턴을 보여 주는 국가를 분류하였다. 전통적인 확산모델을 사용하여, 25개의 서유럽 국가들의 이동통신 확산패턴을 추정한다. 1993년부터 2004년까지 이들 국가들의 월 보급률 자료를 기초로 하였다. 클러스터 분석을 통해 이동통신 확산패턴측면에서 상위 모방국가와 하위 모방국가의 두 그룹을 분류하였다. 이 연구의 결과는 이동통신서비스의 상이한 확산패턴을 설명하기 위한 인과모형을 개발하거나 차세대 이동통신서비스를 위한 새로운 네트워크를 계획할 때 그 기초를 제공한다.

핵심어 : 확산모형, 이동통신서비스, 혁신효과, 모방효과, 밴드웨곤효과, 네트워크외부효과, 클러스터분석

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ABSTRACT

Mobile telecom markets have dramatically increased in the last decade due to a remarkable subscriber base growth. The diffusion patterns of the services are a major concern for mobile carriers preparing those new services. We assume that the diffusion patterns of those services will be similar to those of previous mobile services, and discovering the diffusion patterns of those services is an essential task of mobile carriers for preparing the next mobile services. This study attempts to classify some groups which show similar diffusion patterns of mobile services. Using a traditional diffusion model, this study estimates diffusion patterns of twenty five western European countries. The estimation is based on the monthly penetration ratio of those countries from 1993 to 2004. Based on the estimation, the cluster analysis discovers that there are two different countries groups in terms of mobile diffusion pattern: high imitation countries and low imitation countries. The critical point for classifying the two groups in terms of imitation effect was 0.90. The results provide the basis for developing a causal relationship model which explains the different diffusion pattern of mobile services and planning new networks for the advanced mobile services.

Key Words : Diffusion Model, Mobile telecommunication Services, Innovation effect, Imitation Effect, Bandwagon Effect, Network Externality, Cluster Analysis

I. Introduction

The telecommunications industry has grown continuously due to the rapid development of telecommunications technology, the increase of deregulation on telecommunications market, and fierce competition among market players. Those changes led to broad proliferation of telecommunications services and various types of telecommunications services that satisfy the demand of users. Mobile telecom services played a significant role in these changes. Continuous development of mobile technologies makes it possible to expect more advanced mobile telecom services in future.

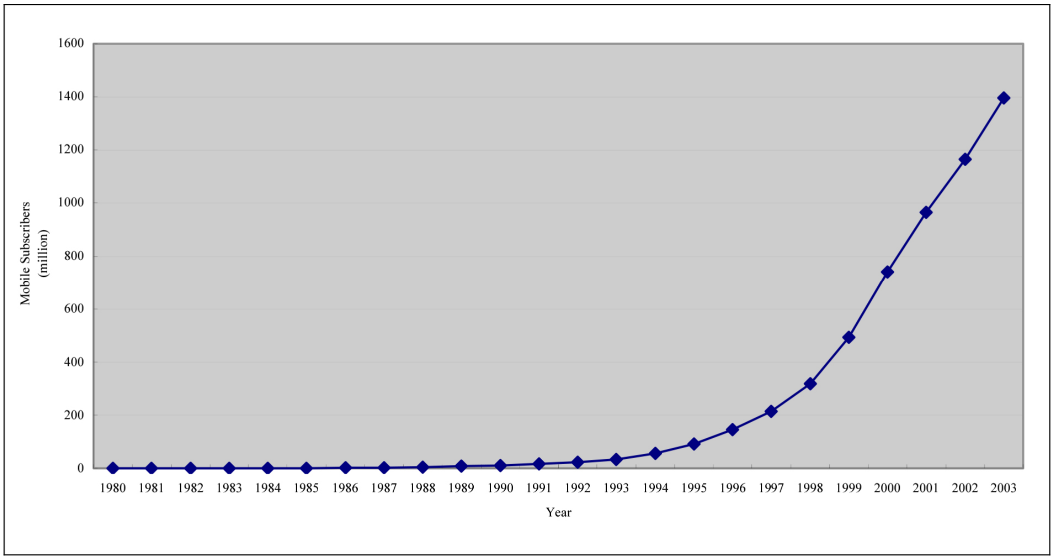
New advanced mobile services require mobile carriers to invest a massive amount of capital on their networks. The network investment starts with accurate demand forecasting. The demand forecasting is the first step for network planning as well as business investment. Mobile carriers are concerned with accurate demand forecasting for new telecommunication services. This is why it is so important to recognize the diffusion pattern of mobile service leads to higher accurate demand forecasting.

Traditionally, diffusion patterns of mobile telecom services have been shown to follow an S-curve. However, the shape of the S-curve differs from each market because the influential factors of mobile diffusion in each market differ. Previous research has been carried out through three different research streams. The first stream is an effort to develop the general diffusion model, which usually uses an auto-regressive model and focuses on the model-fitting (Bohlin et al., 2010; Wu and Chu, 2010). The second stream is to show a causal relationship model, which adopts a cross-sectional and country-level of analysis (Kongaut and Bohlin, 2016; Shieh et al., 2014). The purpose of this stream is to study country-specific factors. This study is based on the premise that cultural factors can affect the diffusion patterns of mobile telecom services.

This study aims in developing a comprehensive diffusion model of mobile telecom services. In order to develop the model, this study first attempts to show that there is a difference in the diffusion of mobile services among countries. By analyzing different diffusion patterns, this study attempts to discover whether certain countries follow a homogeneous diffusion pattern of mobile telecom services. The objective of this study is to develop a model which explains the different diffusion patterns of mobile telecom services at the country level.

II. Mobile Telecom Market and Systems

Since mobile telecom services launched in 1979, the mobile telecom market has increased dramatically. The number of subscribers increased from 11 million in 1990 to 1,395 million in 2003 (see Figure 1). The compound annual growth rate from 1990 to 2003 is 44.93 percent.



Source: (ITU, 2004).

(Fig. 1) Mobile Subscribers in the world

Mobile services started out using analog signal technology. This so-called the first generation of mobile services had serious limitations, including poor quality of service and a small capacity to cover subscribers' demand. The first generation analog service could also not provide roaming services between countries because standards across countries which were not compatible. Beginning in the early 1990s, a conversion from analog to digital was carried out. European countries, attempting to develop a common standard for their digital mobile services, adopted the Global Systems for Mobile Communications (GSM). Nevertheless, there were still different standards throughout the world. The third generation (3G) services like the International Mobile Telecommunications for the 2000 (IMT-2000) attempted to develop a single global standard. However, the International Telecommunications Union (ITU) approved two different standards for the 3G services, the W-CDMA (Wide-band Code Division Multiple Access) and CDMA-2000. China also proposed its own standard, TD-SCDMA (Time Division Synchronous Code Division Multiple Access). Table 1 provides an overview of the characteristics of the various generations of mobile technologies.

〈Table 1〉 Evolution of Mobile Telecom Services

Generation	1G	2G	3G	4G	5G
Features	Analog	Digital	Global standard	Improved data transmission rate (100Mbps-1Gbps)	Improved data transmission rate (1Gbps)
Applications	Voice only	Voice and data	Voice, data, and video	Voice, data, and real-time video	Voice, data, and real-time video
Spectrum	800MHz	800MHz, 1.8GHz	1.8-2.2GHz	1.8-2.2GHz	Undecided
Time to launch	1979	1992	2001	2010	2018
Standards	AMPS, TACS, NMT	GSM, TDMA, CDMA	UMTS(W-CDMA), CDMA-2000, TD-SCDMA	LTE-A WiBro-A	Undecided

AMPS: Advanced Mobile Phone Services; TACS: Total Access Communications System; NMT: Nordic Mobile Telecommunications; GSM: Global Systems for Mobile Communications; TDMA: Time Division Multiple Access; CDMA: Code Division Multiple Access; UMTS: Universal Mobile Telecommunications System; WCDMA: Wide-band CDMA; TD-SCDMA: Time Division Synchronous Code; HSDPA: High-Speed Downlink Packet Access; MBS: Mobile Broadband System; LTE-A: Long Term Evolution – Advanced; WiBro-A: Wireless Broadband – Advanced

We are now on the threshold of entering the next generation of mobile services. The market forecasts for those services are essential for implementing mobile commerce applications.

III. Prior Research

The importance of recognizing the diffusion pattern of telecommunications services is crucial to upgrading existing and future telecommunications networks. Upgrading telecom infrastructures demands huge capital expenditure. Large fixed costs expenditures are typically, because of consumer demand, followed by very small variable costs after launching the services. Such a cost structure classifies the telecommunications service as a quasi-public good, because its marginal cost is almost zero (Laffont and Tirole, 2002).

The second characteristic of investments in telecommunications networks is obsolescence of network technology. Telecommunications technology evolves continuously. If a telecommunications company incurs a large amount of investment in the existing network at a certain time, it can lose the opportunity to invest in a more advanced and potentially more appropriate network in the future. The cost of a telecommunications network can drop rapidly. Capacity, therefore, becomes a critical decision driving network enhancements. Diffusion and the resultant demand for capacity drive the investment process.

Technology diffusion is also an important area of academic research. Diffusion studies are valuable of finding factors for success and provide learning points for businesses seeking to launch products or services into an uncertain market. Thus, if each market has different characteristic of diffusion pattern of mobile services, those characteristics are crucial and have strategic implications for both mobile carriers and academicians in this area.

The pattern of diffusion in most countries is generally characterized by an S-shaped curve. Nevertheless, significant differences among countries exist in the spread of the S curve. These differences could result from various policy issues, such as the number of carriers, regulation of dominant carriers, types or periods of competition, market characteristics, and the economic level of each country.

1. Diffusion models

There are many types of long-term growth models, such as exponential model and

Gompertz model. The Bass model (1969) consists of a simple differential equation that describes the process of how new products get adopted in a population. The model presents a rationale of how current adopters and potential adopters of a new product interact. The basic premise of the model is that adopters can be classified as innovators or as imitators and the speed and timing of adoption depends on their degree of innovativeness and the degree of imitation among adopters (Bass, 1969). The Bass model has been widely used in forecasting, especially new products' sales forecasting and technology forecasting.

There are three kinds of research steams in terms of diffusion models. The first one develops a forecasting model, usually auto-regressive model, such as Bass (1969), or variations of that model. The second stream attempts to discover a causal relationship models. Typically cross-sectional country-level data and econometric methods are used. The last stream is the case study, which focuses on a certain country or a certain region and explains some factors that influence mobile diffusion.

Efforts to develop a new forecasting model, which explains the technology diffusion, have shown various research tools. The innovation diffusion model proposed by Bass (1969) is one of the most frequently used models. In addition, there is plenty of research being done on diffusion of the demand for mobile services. Grantham and Tsekouras (2005) review the recent diffusion literature and highlight the limitations associated with retrospective population models of diffusion that tend to emphasize success and innovation while ignoring diffusion failure or re-invention. They argue that the focus on single artifacts or products rather than on bundles of technologies or services is unhelpful, particularly concerning complex products and services. Ilonen et al. (2006) present an automated framework for forecasting the diffusion of innovations, utilizing existing diffusion information from market areas, and examining similar products previously introduced into the market.

The second research stream related to technology diffusion is development of a causal relationship model, which usually uses econometric models and economic theories. Jang et al.(2005) show that the critical factors affecting mobile telecom diffusion are the differences in the magnitude of the network externality coefficient, the importance of the switch to digital technology, market competition, and fee payment. Wareham et al.(2004) investigated what socio-economic factors are determinant for the diffusion of mobile telecom services, how these findings can be extended to help close the digital divide, and how these findings can inform policy making concerning the digital divide. Kiiski and Pohjola (2002) showed the factors which determine the diffusion of the Internet across countries using the Gompertz model of technology diffusion. They found that GDP per capita and Internet access costs best explain the observed growth in computer hosts per capita, using data from OECD countries on Internet hosts per capita for the years 1995-2000.

Much research focuses on case studies to explain the specific factors on a certain market which were not usually explained by econometrics models and country-level data. Gruber and Verboven(2001) study the technological and regulatory determinants of the diffusion of mobile telecom services in European Union and use a logistic model of diffusion. Gruber(2001) unravels the determinants of the diffusion of mobile telecom services in Central and Eastern Europe. The diffusion speed is faster in countries that have adopted mobile telecom services late, implying that a pattern of convergence in the diffusion levels. The speed of diffusion increases with the number of firms. Simultaneous entry is more effective than sequential entry in accelerating the diffusion speed. Diffusion speed increases with the size of the fixed telecommunications network and the length of the waiting list. Beise(2004) used a detailed case study to evaluate the mobile telecom industry using the concept of lead market factors.

Botelho and Pinto(2004) analyzed the pattern and rate of adoption of mobile telecom services by the Portuguese population. They found that the pattern of diffusion is S-shaped and is consistent with a logistic function, which describes a symmetrical growth process. Frank(2004) found that the economic environment affected the relative growth rate and that the mobile network coverage affected the number of potential adopters. By extrapolating the logistic model, a forecast with a confidence interval of mobile telecom subscriber rates in Finland was developed. Iimi(2005) analyzed the demand for mobile telecom services using data on the Japanese mobile market in the late 1990s. Iimi(2005) found that the market is highly product-differentiated and conventional network externalities are no longer decisive factors in choosing a mobile phone carrier. Park and Yoon(2005) examine a key static determinants and dynamic diffusion processes to develop a diffusion model of network products from the case of rapid growth of broadband internet in Korea.

Appropriate diffusion model for mobile telephony is stage-dependent, complementing the case dependency of the appropriate diffusion model demonstrated by cross-sectional studies (Wu and Chu, 2010). For mobile broadband services, multiple standardization policy and population density are the main factors affecting their initial diffusion (Lee et al., 2011). Gaps of mobile phone penetration among different groups of income level countries have decreased. Average income, legacy phone system, population density, and education level, are to have influence on mobile phone penetration (Zhang, 2017). Despite the fact that in recent years the rate of growth of mobile phone subscribers has started to slow down, there still appears to be room for further expansion as the saturation level is expected to be reached in 2013 (Gamboa and Otero, 2009). There is an evidence of network externalities in Mobile Social Networking(MSN) adoption for all of these countries, captured by the left skew of the cumulative adoption curves. It is confirmed even after taking into account the contrasting effect of heterogeneity in the propensity to adopt (Scaglione et al., 2015).

Endeavors to develop a new model explaining model diffusion produced various alternative models. However, those models do not exhibit why those diffusion patterns differ. Research on casual relationship model devoted to show general economic implications. Those are not considered country-specific factors. Case studies overcame the shortcomings of causal relationship models. However, those have limitations to generalize the diffusion phenomena across country.

2. Imitation effects

Adopters are classified as innovators, early adopters, early majority, late majority, and laggards. This classification is based upon the timing of adoption by the various groups. Innovators, who decide to adopt an innovation independently of the decisions of other individuals in a social system, are expected to be the first adopters. Other groups, except for innovators are defined as imitators who are influenced in the timing of adoption by the decisions of other members of the social system (Bass, 1969).

The mobile diffusion phenomena can be also explained by the concept of the bandwagon effect. The bandwagon effect is a positive network externality in which a consumer's demand for a good increases with the number of other consumers who have purchased the good. The dominant design decreases the uncertainty associated with a technological discontinuity by serving to lock-in a product design supported by a bandwagon of firms, customers, and suppliers (Wade, 1995). Therefore, firms are highly motivated to jump on the right bandwagon. Under these technological bandwagon conditions (Wade, 1995), the strength of the support for a design should affect firm success. The bandwagon effect can be examined by the imitation effect in the diffusion model presented by Bass(1969).

Each research steam contributes its own research area. The area of the theoretical model building shows many models we can use. Econometric models also discovered a lot of influential factors on mobile diffusion. Case studies showed country-specific factors. However, there was little research on causal relationship models that explain the factors of country level study from a comprehensive view.

We believe that it is necessary to develop a new, more robust, model to explain mobile diffusion. The model detailed in this paper draws on economic theories, time-series analysis, and country-level data and also considers country-specific factors. This approach is unique, and as illustrated in subsequent section, a very powerful predictor of the adoption process of mobile users.

IV. Research Model

This study consists of two steps. The first step is to estimate innovation effect and imitation effect for each of the 25 European countries using the Bass(1969) model with the ordinary least squares(OLS). The next step is to group 25 western European countries into homogeneous groups using cluster analysis of innovation coefficients and imitation coefficients.

The reference model in this study is the traditional Bass(1969) model because the objective of this study is to compare the diffusion patterns of mobile services among countries.

$$n(t) = \frac{dN(t)}{dt} = p[m - N(t)] + \frac{q}{m}N(t)[m - N(t)] \tag{1}$$

where $N(t)$: the cumulative number of adopters at time t

$n(t)$: the number of adopters at time t

m : the potential maximum number of adopters

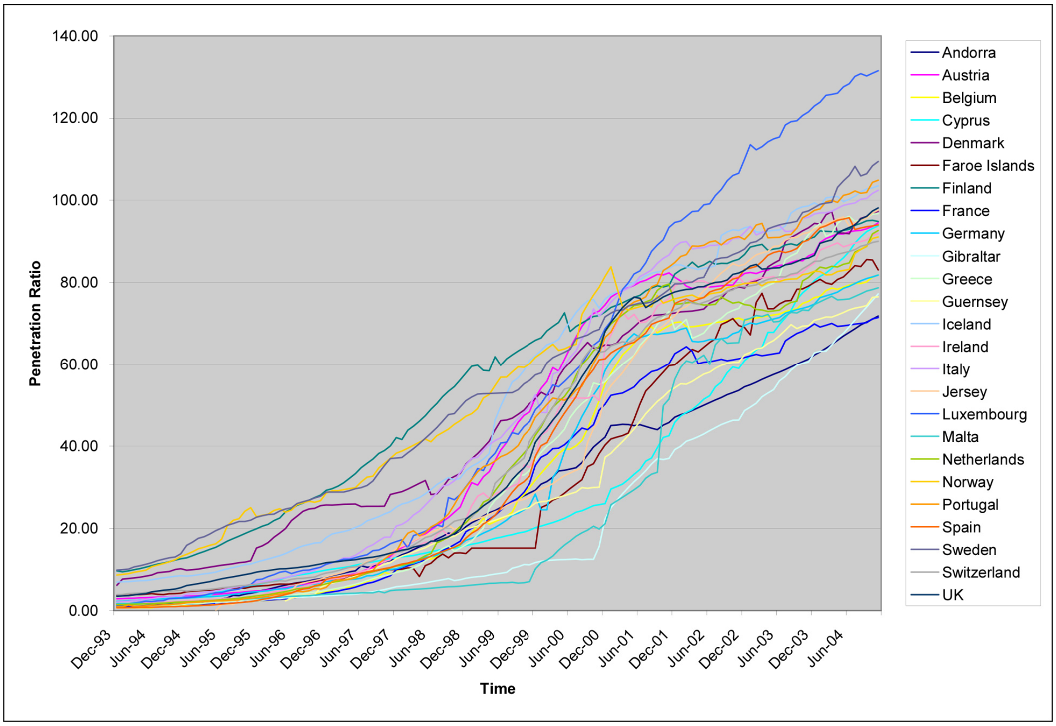
p : the coefficient of innovation

q : the coefficient of imitation

In equation (1) $p[m - N(t)]$ represents adoptions due to buyers who are not influenced in the timing of their adoption by the number of people who already have bought the product. $\frac{q}{m}N(t)[m - N(t)]$ represents adoptions due to buyers who are influenced by the number of previous buyers (Mahajan et al., 1990). If no data is available, parameter estimates can be obtained by using either management judgments or the diffusion history of analogous products (Mahajan et al., 1990).

We used the monthly penetration ratio data of the 25 European countries from December 1993 to November 2004. The data was collected from a newsletter in the mobile industry, *Mobile Communications* (issue no. 141-391). In a diffusion curve, the beginning and the growing parts are considered relatively critical in order to identify the whole diffusion pattern. This study focuses on the beginning and the growing parts of mobile telecommunication services, which are 1990s and early 2000s.

The penetration ratio is usually measured by dividing the numbers of subscribers by the population of a country. The number of mobile subscribers and the population of each country are also needed in this study. However, *Mobile Communications* provides only the monthly penetration ratio of countries. Therefore, this study uses the data from *Mobile Communications* directly instead of calculating the penetration ratio by using the number of subscribers and population.



Source: (MobileCommunications) (Dec. 1993 – Nov. 2004).

(Fig. 2) Penetration rates of mobile services in European countries

This data coupled with the Bass model was used to identify the diffusion patterns for each country. We then went on to classify those 25 European countries into groups in terms of diffusion patterns of mobile services, doing so by using the cluster analysis.

Cluster analysis is used to identify homogenous subgroups of cases in a population. The analysis is used to identify a set of groups that both minimize within-group variation and maximize between-group variation. The method classifies objects so that each object is very similar to others in the cluster with respect to some predetermined selection criterion. The resulting clusters of objects should then exhibit high internal homogeneity and high external heterogeneity (Hair et al., 1998).

K-means is one of methods for cluster analysis. *K*-means clustering is popular for cluster analysis in data mining. *K*-means clustering aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with nearest mean, serving as a prototype of the cluster (Hair et al., 1998).

V. Results

Table 2 shows the results of estimation of innovation effects and imitation effects by using the traditional model (Bass, 1969). Twenty-four countries out of twenty-five show significant results in terms of the imitation effect.

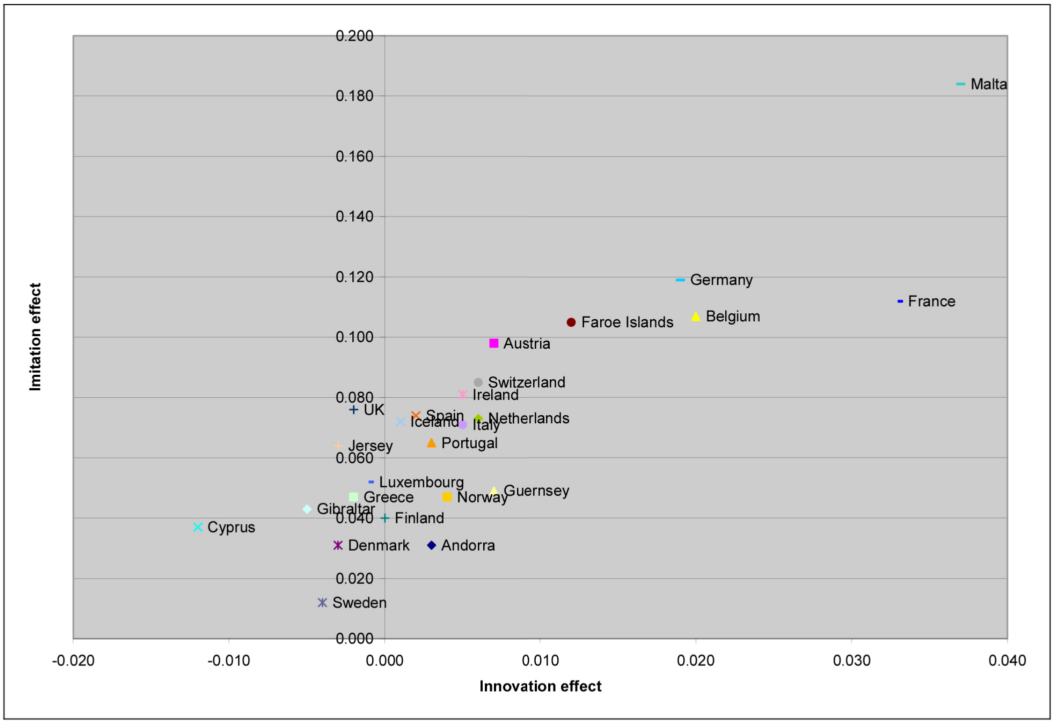
〈Table 2〉 Results of coefficients estimation for innovation effect and imitation effect

Country	Innovation effect	Imitation effect	Country	Innovation effect	Imitation effect
Andorra	0.003	0.031***	Ireland	0.005	0.081***
Austria	0.007***	0.098***	Italy	0.005	0.071***
Belgium	0.020***	0.107***	Jersey	-0.003	0.064***
Cyprus	-0.012***	0.037***	Luxembourg	-0.001	0.052***
Denmark	-0.003	0.031**	Malta	0.037***	0.184***
Faroe islands	0.012*	0.105***	Netherlands	0.006*	0.073***
Finland	0.000	0.040***	Norway	0.004	0.047**
France	0.033***	0.112***	Portugal	0.003	0.065***
Germany	0.019***	0.119***	Spain	0.002	0.074***
Gibraltar	-0.005	0.043**	Sweden	-0.004**	0.012
Greece	-0.002	0.047***	Switzerland	0.006**	0.085***
Guernsey	0.007	0.049**	UK	-0.002**	0.076***
Iceland	0.001	0.072***			

*p〈0.1, **p〈0.05, ***p〈0.01

Figure 3 plots the twenty five western European countries in terms of the innovation effect and imitation effect.

In terms of innovation effect and imitation effect, the most proper tool to classify countries is using the Euclidian distance. There are several ways to work out the distance between two points in multi-dimensional space. Usually one would choose the method which gives the best results in terms of some error function or ability to classify certain data points. The most commonly used one is the Euclidian distance measure. The Euclidian distance can be considered to be the shortest distance between two points, and is basically the same as Pythagorus' equation when considered in two dimensions. In this case, the difference of diffusion patterns can be measured by



(Fig. 3) Plotting countries by innovation and imitation effects

the distances in two dimensions which consist of innovation effect and imitation effect.

Based on the estimates of innovation coefficient and imitation coefficient, the cluster analysis is carried out to classify those countries into some groups which show the homogeneous diffusion patterns. Table 3 shows the results of the cluster analysis.

The cluster analysis using K-Means shows that two groups are classified. Custer 1 has 19 countries and cluster 2 has 6 countries. Cluster 1 has 0.001 innovation effects and 0.021 imitation effects and cluster 2 has 0.055 innovation effects and 0.121 imitation effects.

From the results of cluster analysis, two different groups are shown in Table 4. The critical criterion used to classify the two sub-groups is the imitation effect. All six countries that are classified into group 2 are also the six highest countries that also exhibit imitation effects. In essence, the countries that exhibit the six highest imitation

〈Table 3〉 Results of cluster analysis

Country	Cluster	Distance	Country	Cluster	Distance
Andorra	1	0.024	Ireland	1	0.026
Austria	2	0.027	Italy	1	0.016
Belgium	2	0.014	Jersey	1	0.009
Cyprus	1	0.022	Luxembourg	1	0.004
Denmark	1	0.025	Malta	2	0.065
Faroe islands	2	0.018	Netherlands	1	0.019
Finland	1	0.015	Norway	1	0.009
France	2	0.015	Portugal	1	0.010
Germany	2	0.003	Spain	1	0.019
Gibraltar	1	0.013	Sweden	1	0.043
Greece	1	0.009	Switzerland	1	0.030
Guernsey	1	0.009	UK	1	0.021
Iceland	1	0.017			

Cluster centers	Cluster	
	1	2
Innovation effect	0.001	0.021
Imitation effect	0.055	0.121

effects are classified into group 2. Other countries that show low imitation effects are grouped into class 1. We named group 1 the “Low imitation countries” and group 2 the “High imitation countries.”

〈Table 4〉 Classification of European countries by the mobile diffusion pattern

Group	Number of countries	Countries
Group 1: **Low imitation countries**	19	Andorra, Cyprus, Denmark, Finland, Gibraltar, Greece, Guernsey, Iceland, Ireland, Italy, Jersey, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK
Group 2: **High imitation countries**	6	Austria, Belgium, Faroe Islands, France, Germany, Malta

The country that shows the lowest imitation coefficient in group 2 is Austria. It has an imitation coefficient of 0.098. The country that exhibits the highest imitation coefficient in group 1 is Switzerland. Its imitation coefficient is 0.085. By interpolating, we can see the critical point for classifying countries into the high imitation or low imitation category is approximately 0.09.

VI. Conclusions

From this analysis, we can conclude the imitation effect is the crucial criteria for classifying countries according to their diffusion patterns of mobile services. Imitation effects can be used as a measurement for classifying countries into high or low mobile diffusion countries. The critical point is around 0.09 points of imitation effect.

This study has several implications for mobile carriers and policy makers. In countries with high imitation effects, mobile carriers should prepare for high demand before the majority adopters' stage. In the process of network planning, proper investment in networks should be considered. Otherwise, carriers will miss the high demand for their new mobile services.

Other countries which have low imitation phenomena should consider gradual network expansion, as over capacity can lead to the obsolescence of network components. This leads to inefficient network operations, which also results in negative effects on business results.

The results of this analysis can also be the basis for developing a causal relationship model which explain the different diffusion pattern of mobile services and planning new mobile networks for the advanced mobile services. We expect that the results will readily explain the different patterns of diffusion of mobile services.

This study also has several limitations. In the process of parameter estimation, the OLS procedure may yield parameter estimates that are unstable or have the wrong signs because of the presence of mulicollinearity between independent variables (Mahajan et al., 1990). In this study, some of the innovation coefficients have negative signs, which result from the multicollinearity with the imitation coefficients.

VII. Future Research

From results of this study, there are several opportunities for future research. Difference on diffusion patterns might come from the difference on cultures. Research on the reason why the diffusion patterns are different is open in future(Kongaut and Bohlin, 2016; Shieh et al., 2014).

First and foremost is the development of a causal relationship model to explain mobile diffusion of countries. The model should cover some critical factors. We can consider national income as an economic factor. For regulation on telecommunications industry, market entry policy and market structure can be important factors. Price regulation and interconnection policy are also potential factors for the model. Additional factors to include are market factors such as fee payment mechanism, duration of the services as well as several cultural factors which can be used to understand the dynamics of the diffusion process.

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김진기

한국항공대학교 경영학부 부교수로, 한양대학교 경영학과에서 학사와 석사 학위를, 미국 뉴욕주립대학교(버팔로)에서 경영학 박사를 취득하였다. 정보통신정책연구원(KISDI)에서 책임연구원으로 재직하였다. 연구관심분야로는 ICT 전략 및 정책정책, 디지털융합과 생태계, 미디어전략, 재난방재시스템 등이다.