

**The Deployment of Third-Generation Mobile Services:
A Multinational Analysis of Contributing Factors**

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Abstract

Successful diffusion of 3G mobile is necessary for the provision of many advanced applications via the mobile platform such as mobile broadband Internet and video. The current deployment of 3G services is significantly more developed in some countries than others. Through a regression analysis of 106 observations, this study examines the factors affecting such differences. It was found that multiple standardization policy, lower level of 1G and 2G penetration, and a higher level of income contribute to the diffusion of 3G mobile.

The world of telecommunications has changed rapidly as we enter the era of convergence between wireless networks, broadband communication, and the content sector. Demands for advanced services such as mobile broadband Internet and mobile video have increased tremendously in recent years and been touted as the driver for the continuous growth of the telecommunications industry (Tellabs, 2009). In fact, such bandwidth consuming mobile ventures are often regarded as a means of paying off the hefty license fees for many third generation (3G) mobile service providers (Ponsford, 2006). In essence, as the mobile voice services become commoditized with increasing price competition, new data services made possible by the 3G networks are critical in generating profit and growth. Mobile network or service based on the International Mobile Telecommunication-2000 (IMT-2000) family of global standards is commonly referred to as “3G mobile” (ITU, 2003b). These mobile systems provide higher transmission rates than possible in second generation wireless technologies, supporting data transport rates of at least 144 kbit/s for all radio environments and 2 Mbit/s in low-mobility and indoor environments (ITU, 2003b; Shelanski, 2003). The 3G mobile systems enable many advanced applications such as mobile videoconferencing, video phone/mail, mobile TV/Video player, and digital audio/video delivery (Xavier, 2001; ITU, 2001). Thus, the true provision of video communication, information, and entertainment via the mobile platform will be impossible without the successful diffusion of 3G services. In addition, industry analysts have increasingly concluded that mobile broadband will soon become the standard of accessing the Internet in most countries (3g.co.uk, 2008). Nevertheless, without established 3G networks, the anticipated growth in mobile broadband data services would be unattainable.

From a global perspective, the deployment of 3G mobile services is significantly more advanced in some countries than others. At the end of 2007, there were 3.35 billion mobile subscribers throughout the world (ITU, 2008). It was estimated that mobile broadband handset users will grow from 158 million in 2008 to over 1.8 billion in 2014, with most increase coming from emerging countries such as China and India (Cellular-News, 2009). In spite of the rapid growth of 3G and even 4G services in a select number of countries, many countries are still in the early stages of 3G mobile deployment. According to the latest International Telecommunication Union (ITU) penetration data (December 2006), Korea, Italy, and Japan are the leading 3G mobile economies among ITU member countries (ITU, 2006).

What factors contribute to the differential deployment rates of 3G mobile services among countries? As important as these factors are in affecting the next phase of mobile technology development, consumer access to advanced mobile broadband and video services, and the eventual convergence between the mobile platform and other mass media content distribution systems, little empirical studies have addressed the political, economic, market, and consumer issues that might play a role in the diffusion of 3G mobile services. Through a statistical analysis of approximately 106 observations, this study attempts to explore the influential factors of global 3G mobile deployment, examining various policy, industry, consumer, and technology issues for their contribution to 3G mobile deployment.

Literature Review

Diversity in Global 3G Mobile Deployment

There has been a steady growth in worldwide 3G mobile adoption. However, there also exists a wide range of 3G diffusion levels across countries. For example, the region of Asia trumped all others in 3G adoption with close to 52 percent of the world 3G market share as early as in 2006 (ITU, 2006). More recently, Asia-Pacific was home to an estimated 158 million 3G subscribers in 2008 and is expected to reach 564 million subscribers by 2013 (Suppiah, 2009). Historically, Korea, Italy, Japan, Portugal and Hong Kong were the top five 3G mobile economies in terms of 3G mobile penetration rate (ITU, 2006). According to the official ITU report, while the number one 3G nation, Korea, had a penetration rate as high as 25.95 percent, the number five country, Hong Kong, reached only about one third of Korea's rate (8.19 percent). It is evident that there are significant regional differences in the number of 3G subscribers. While close to half of the 3G subscribers are located in the region of Asia, less than thirteen percent of them are in Europe.

Adding to (and contributing to) the complexity of regional and national mobile deployment differences is the diversity in wireless technologies adopted by different countries. WCDMA and CDMA 2000 are the two main standards for 3G wireless technologies (Gandal, Salant, & Waverman, 2003). Most of the European Community adopted WCDMA for 3G wireless services. By November 2005, almost 92 percent of the European 3G mobile customers subscribed to WCDMA technology-based services (ITU, 2005). On the other hand, many countries in the Americas, Asia, and Africa adopted CDMA 2000 or both CDMA 2000 and WCDMA in their 3G markets. By November 2005, there were approximately 115 million CDMA 2000 global subscribers, which accounted for around 86 percent of all 3G mobile subscribers (ITU, 2005). Opting for a

different path from its European counterpart, the United States actually had four digital 2G standards in its attempt to allow the market to choose its standards and avoid risks during the uncertain period when various wireless technologies were emerging (Sugrue, 2003).

Diffusion of Innovations

At the micro level, socio-psychological factors may influence new media technology adoption. Rogers theorized that innovations would spread through society in an S-curve, as the early adopters select the technology first, followed by the majority, until a technology or innovation is common (Rogers, 2003). In explaining the diffusion of innovation, Rogers (2003) identified five perceived characteristics of an innovation such as relative advantage, compatibility, complexity, trialability and observability. These five perceived characteristics may influence the 3G mobile adoption in the individual level. Among these five perceived characteristics, we mainly have interest in relative advantage- the degree to which an innovation is perceived as being better than the idea it supersedes and this construct is one of the best predictors of the adoption of an innovation (Rogers, 2003). In other words, relative advantage may mean the amount of improvement the new technology offers compared to the old, which may suggest that 2G and 1G penetration could be correlated to the 3G penetration.

Path Dependence

Path dependence theory can be related to the policy choice for 3G mobile diffusion. In general, path dependence refers to the “dependence of a system or network on past decisions of producers and consumers” (Liebowitz & Margolis, 1995). The case of the QWERTY keyboard (David, 1985) is a well-known example of path-dependence theory.

The current dominance of the QWERTY keyboard today is not thought to be due to its superiority for typing but because it was invented earlier than the Dvorak keyboard (David, 1985; Katz & Shapiro, 1994; Shapiro, & Varian, 1999). Path dependence may suggest that inferior standards can persist simply because of the legacy they have built up (David, 2000). Relating to the mobile communications standardization policy, in spite of EU's success story of mandated standard (GSM) in initial stage of 2G, if market-mediated standard policy leads to faster adoption of 3G mobile in the markets, it may imply that the EU 3G standard policy that may have assumed WCDMA or locked operators into WCDMA might be a very costly public policy decision (Gandal et al., 2003). Path dependence induces an inefficiency arising from small differences in initial public policy-making, which lead to outcomes that are likely to be costly to change (Liebowitz & Margolis, 1995).

Policy Factors: Standardization and Institutional Environment

Many stakeholders in the mobile industry such as policymakers, mobile service operators, content providers, and end-users play an influential role in shaping 3G deployments at different phases. Saugstrup and Henten (2004) propose that regulation and market competition are important factors affecting the deployment of the new 3G technology. Specifically, Gans, King, and Wright (2004) suggest that "standardization" policy plays a significant role in the success of wireless communication. From a historical perspective, regulations such as standardization with the intent to safeguard consumers have sometimes confined the development of new telecommunications services. Maeda, Amar, and Gibson (2006) argue that because of the typical progression of a new media technology market from the initial monopoly dominance of a large firm,

to the addition of many smaller competitors in the growth stage, to the few, surviving strong competitors after a phase of consolidation, inflexible regulation such as mandated standardization may not actually benefit the consumers.

Many studies in the economics of standards have focused on the private and social incentives for standardization (Gandal, 2002; David & Greenstein, 1990). Most of the literature suggests that compatibility and standardization may lead to efficient outcomes in the market. Theoretically, a single standard tends to deliver better economies of scale and network externalities. Nevertheless, Gandal et al. (2003) claim that the aforementioned benefits of standardization are unclear in the mobile market. It was argued that as long as the mobile networks are interconnected and coverage is effective, there is little need for compatibility (Gandal et al., 2003). Roaming (i.e., using one's cellular phone outside the provider's coverage area) is a main network benefit for mobile communication. Thus, there are few network externalities that may justify a government mandated standard in the mobile market (Gans et al., 2004). In essence, there are both advantages and disadvantages in market mediated multiple standards and government mandated single standard. Though market mediated standards might lead to limited network externalities and economies of scale, multiple wireless standards and different types of services across technologies enable the existence of diverse competing systems which may lead to more and better mobile services (Gruber & Verboven, 2001).

There are a few empirical studies addressing the standardization policy in the mobile industry. Gruber and Verboven (2001) find that the early diffusion of digital technologies in mobile markets was faster in Europe where most countries had adopted a single standard. Kioski and Kretschmer (2002) empirically estimate the effects of

standardization through two alternative approaches. They conclude that standardization has a positive but insignificant effect on the timing of initial entry of 2G services but can also lead to higher prices as it dampens competition. It seems that while a government mandated standard was useful in stimulating mobile adoption in the initial stage (e.g., first generation mobile), as the mobile technology becomes more advanced, standardization policies become less relevant and even limiting (Cabral & Kretschmer, 2004). Cabral and Kretschmer (2004) examine the effectiveness of public policy in the context of competing standards with network externalities and discovered that current mobile diffusion levels are quite similar between the United States (multiple standards) and Europe (mostly single standards). Recently Kauffman and Techatassanasoontorn (2005) found that market-mediated standardization policy is a contributing factor of international diffusion of digital mobile technology. More recently, Rouvinen (2006) investigate the factors affecting the diffusion of digital mobile telephony across developed and developing countries. It was concluded that mandated standards actually hinder competition in both groups. The review of literature thus far points to the changing role of standardization policy as mobile technology and markets continue to develop. It also reveals that while there have been studies on the effects of standardization in early 1G and 2G mobile industry, no empirical work has ventured into the new 3G mobile markets concerning the effects of standardization policy.

Institutional environment might also influence 3G mobile deployment. Employing regression analysis, Andonova (2006) finds institutional environment such as political rights and civil liberties are correlated with deployment of mobile. In spite of these

previous studies, there was no empirical study, which tests the influences of institutional environment on 3G mobile diffusion.

Industry Factors

In addition to policy issues, the characteristics of the mobile industry in a country affect the marketing of 3G services in that country and thus its rate of deployment. Steinbock (2003) suggests that the thrust of change in the mobile industry has shifted from technology to markets in the 3G era. Through a cross-national empirical analysis of a relevant new media technology, broadband telecommunications, in 30 Organization for Economic Co-operation and Development (OECD) countries, Cava-Ferreruela and Alabau-Muñoz (2006) conclude that technological competition is one of the key drivers for broadband supply and demand. Using data from 14 European countries, Distaso and others (2006) suggest that inter-platform competition drives broadband adoption, but that intra-modal competition does not play a significant role. In a separate study, Lee (2006) finds that market-based standardization policy and competition empirically correlate with mobile growth rates. Furthermore, through a longitudinal analysis of 25 Asian countries from 1986 to 1998, Burki and Aslam (2000) find that digital mobile competition did indeed promote mobile diffusion. More recently, in his investigation of the factors affecting the diffusion of digital mobile telephony across developed and developing countries, Rouvinen (2006) conclude that market competition promotes mobile diffusion in both groups.

It is intuitive that the cost of mobile services would affect the demand for such services. A number of empirical studies have investigated the possible causal relationship between mobile service cost and mobile deployment. Ahn and Lee (1999) study the

determinants of demand for mobile telephone networks using observations from 64 ITU member countries and found that price was not a strong predictor of demand. On the other hand, using a panel data set of 56 countries, Madden et al. (2004) examine the economic factors that affect the growth of global mobile telephony and conclude that lower cost contributes to mobile diffusion. There seems to be conflicting results concerning the role of pricing in the development of mobile phone services.

Similar to the factor of mobile phone cost, the prices of non-voice mobile applications in each country may also affect the consumer acceptance and usage of enhanced mobile services in that country. Studies have suggested that mobile applications and services that exploit the value of a wide-area wireless network and customers' needs and desires are important drivers of success for 3G mobile systems (Foster, 2003). The availability of appealing, diverse mobile applications such as multimedia messaging and mobile internet is likely to contribute to the growth of 3G mobile (Wilska, 2003; Nobel, 2004). Specifically, Foster (2003) proposes that the development of mobile applications and services that leverage the unique capabilities of the wireless environment such as personal and ubiquitous capabilities would directly promote 3G mobile deployment.

High level of bandwidth also might be correlated with the mobile broadband adoption. Growth in demand for higher capacity is a key driver of broadband diffusion (ITU, 2006). In spite of importance of bandwidth, there was no empirical work, which tests correlation between bandwidth and 3G mobile deployment. Telecommunication infrastructure investment from private and public sector could be a contributing factor of telecommunication network deployment (ITU, 2003b).

Also, no published empirical study examines the relationship between fixed broadband and mobile broadband (3G mobile). Based upon research that suggest mobile phones serve as a substitute for fixed phone service (ITU, 2003a; Vagliasindi et. al, 2006)), one might expect a similar relationship between mobile broadband (3G mobile services). Fixed broadband service is a complement to or a substitute for mobile broadband.

Demographic Factors

Many studies have empirically supported the importance of national economic health in stimulating the demand for mobile services. Ahn and Lee (1999), in their study of the determinants of demand for mobile telephone networks, find that the probability of subscribing to the telephone networks was positively correlated with per capita GDP. Using a panel data set of 56 countries to investigate the economic factors influencing the growth of mobile phone services, Madden et al. (2004) conclude that higher income and a large user base tend to promote mobile diffusion. In a separate empirical study about the same topic, Andonova (2006) also find GDP per capita to be major contributing variable to mobile diffusion.

Communication research has long identified the importance of demographic factors as antecedents in new media adoption (Atkin and LaRose, 1994). It was suggested that early adopters tend to have higher socio-economic status (Rogers, 2003). Various studies have reported a positive relationship between education and new media technology adoption (Lin, 1998; LaRose &Atkin, 1992). Wareham and Levy (2002) report that education is a steady indicator of wireless phone diffusion because achieving higher education has a positive association with being comfortable with higher technology use.

In addition to socioeconomic factors, there seems to be a positive linkage between population density and mobile penetration rates as countries/areas like Hong Kong and Luxemburg have been garnering mobile penetration rates over 120 and 150 percent (ITU, 2005). Through the analysis of approximately 100 countries, Garcia-Murillo (2005) finds that population density has positive effects on the number of broadband subscribers. Kim and et al. (2003) also suggest that population density should be considered the cost conditions of deploying advanced networks and is one of the influential factors in explaining broadband uptake. However, some empirical studies examining the relationship between mobile diffusion and share of urban population find no significant correlation between the two variables (Gruber, 2001; Koski & Kretschmer, 2002).

Age might be a factor of new media technology adoption. Recently, through a household-level analysis, Clements and Abramowitz (2006) found income, age, educational attainment, and the presence of children influence adoption of broadband service in the United States. Recently Ridder (2007) and Atkinson (2008)'s empirical study found age is negatively correlated to the broadband adoption in OECD countries.

ICT Factors: Existing Information and Communication Environment

The existing information and communication infrastructure in a country is also a potential factor that might affect the adoption of 3G mobile services. Some countries might be more prepared than others to adopt new communications technology because of their existing information and communications technology (ICT) development and consumers' experience with relevant information/communication services. Some ITU Internet reports have suggested that the countries that already have high PC and Internet penetration have seen users embrace broadband services more readily (ITU, 2003b; ITU

2003c). Kim et al. (2003) found that the preparedness of a nation, which is measured by the attitudes of a nation towards advanced information technology and the availability of complementary technologies, such as computers, is one of the important factors in explaining new media technology adoption such as broadband services. Specifically, through a panel data analysis, Denni and Gruber (2005) finds that telecommunication density has a positive impact on broadband diffusion.

3G mobile enables the delivery of new services such as mobile Internet and mobile multimedia (Foster, 2003). High level of usage in Internet and PC is important for successful introduction of 3G mobile markets. It is evident in the case of leading 3G economies such as Korea and Japan, which has a solid infrastructure of information and communication environment (Henten et. al, 2004; Srivastava, 2004).

In spite of a growing body of literature that addresses the factors contributing to mobile adoption at the country level, few empirical studies have focused on the factors that affect 3G mobile adoption globally. In spite of a growing body of literature that addresses the factors contributing to mobile adoption at the country level, few empirical studies have focused on the factors that affect 3G mobile adoption globally (see Table 1). In addition, 3G mobile is not a brand new innovation, but an evolving new communication/media technology that might be affected differently by existing mobile policy, industry, demographic and ICT factors.

Table 1 about here

Based on the literature reviewed, this paper proposes the following research questions (RQs):

RQ1: Have policy factors, market mediated standardization policy, and institutional environment such as political and economic freedom contributed to the adoption of 3G mobile services?

RQ2: Have industry factors, specifically, mobile service price, mobile application price fixed-broadband price, bandwidth, and telecommunication infrastructure investment contributed to the adoption of 3G mobile services?

RQ3: Is 3G mobile (mobile broadband) a complement to or substitute for fixed-broadband?

RQ4: Have demographic factors, specifically income, education, urban population share, population density and age influenced the deployment of mobile broadband services?

RQ5: Have ICT factors, specifically PC penetration, content, Internet usage, and teledensity, 1G and 2G mobile penetration influenced the deployment of mobile broadband services?

Research Method

This study utilizes a secondary dataset and employs quantitative methodologies such as regression analysis and one-way ANOVA to investigate the role of the aforementioned factors in affecting 3G mobile diffusion at the national level. 106 observations were examined to assess the relationships between the proposed variables and the 3G subscription rates in those countries (see Appendix B for the list of countries).

Measurement and Data Sources

Appendix A shows the variables, their measures, and the corresponding data sources. Mobile diffusion can be measured either at the household or individual level. Wareham and Levy (2002) used the proportion of households that owned a mobile telephone to measure mobile diffusion. Most other mobile studies (Madden et al. 2004; Koski & Kretschmer, 2002; Gruber 2001; Ahn & Lee, 1999) used mobile penetration rates at the individual level for such a measurement. In the context of this paper, 3G mobile diffusion rate (dependent variable) was measured by the number of 3G mobile subscribers per 100 inhabitants in a country.

Policy Factors

To examine the standardization policy factor, a dummy variable (0 or 1) is employed (i.e., if a country employed multiple standards, 1 was coded). Political freedom is measured by the inverse of the score on civil liberties (originally ranging from 1 to 7; Andonova, 2006). For the measurement of economic freedom, the index of economic freedom index has been used.

Industry Factors

Because of the variability of mobile services and thus their pricing, this study adopted per minute local call peak charge (USD) to measure the cost of mobile services in each country. Previous studies have used the local call peak charge (USD) per minute (or per month) measure to indicate the relative level of prices for residential mobile voice services (ITU, 2005; Rouvinen, 2006). Regarding the factor of non-voice mobile applications, the cost of short message services (SMS) is employed as the price proxy for mobile broadband relevant applications. SMS is a feature available in many new digital phones that lets users receive and send short text messages. Fixed-broadband price is measured by broadband monthly charge (in U.S. Dollars). This study also includes

telecommunication infrastructure investment in the empirical model. It is measured by annual telecommunication investment (USD). For the measurement of bandwidth, international Internet bandwidth (bits per inhabitants) is used.

Demographic Factors

In terms of demographic variables, level of education could be measured by illiteracy rate and average education/degree level (Garcia-Murillo, 2005; Clements & Abramowitz; 2006). For the measurement of education, this study uses the UNDP education index. The UNDP education index measures a country's relative achievement in both adult literacy and combined primary, secondary and tertiary gross enrollment. Studies have used a share of urban population to measure the demographic aspect of population density (Gruber, 2001; Liikanen et. al, 2004; Koski & Kretschmer, 2002). In this study, population density is measured by population per km². Urban population is measured by the percentage of urban population and age is measured by percentage of age between 35 and 44. In the previous study, Ridder (2007) suggested only age groups 35-39 and 40-44 were correlated with fixed-broadband deployment in his correlation study. For the measurement of income, the typical GDP per capita is used.

ICT Factors

Teledensity is measured by main telephone lines per 100 inhabitants. To assess PC infrastructure, estimated PCs per 100 inhabitants are used. For the proxy measurement of content, Internet hosts per 10000 inhabitants is employed. Internet usage is measured by Internet users per 100 inhabitants. Previous study by Liikanen et al. (2004) suggested 1G (2G) has a positive (negative effect) on 2G (1G) diffusion. Based on this empirical result, this study examines relationship between 3G (mobile broadband) mobile penetration and

1G and 2G penetration. 1G and 2G penetration is gauged by 1G and 2G mobile subscribers per 100 inhabitants in a country.

This study also examines the independent variable of income and regions using categorical variable to examine the difference of 3G mobile deployment between high, medium, and low income countries and different regions (Africa, America, Asia, Europe, Oceania). Data were collected from ITU, OECD, World Bank, IDATE, Heritage Foundation and Freedom House. This study applied the statistical analyses of log linear regression analysis, and one-way ANOVA to assess the influential factors of mobile broadband deployment. A total of 106 observations were available for regression analysis and one-way ANOVA.

The Proposed Empirical Model

To examine determinants of 3G mobile deployment, this study employs a log linear regression model. In the model, the dependent variable (Y_t) is 3G mobile diffusion. The linear regression model employs approximately 106 observations for mobile broadband services from the ITU (International Telecommunication Union) membership countries.

To examine the influences of quantifiable variables on the diffusion patterns of 3G mobile, this study formulates the following log linear regression model. Since the distribution of dependent variable and many independent variables in this linear regression model is positively skewed, data transformation with logarithm was utilized.

$$\begin{aligned} \ln Y_t \text{ (3G Mobile Deployment)} = & \beta_0 + \beta_1(\text{Standardization Policy}) + \\ & \beta_2(\ln \text{ Political Freedom}) + \beta_3(\ln \text{ Economic Freedom}) + \\ & \beta_4(\ln \text{ Fixed-broadband Price}) + \beta_5(\ln \text{ Mobile price}) + \beta_6(\ln \text{ Bandwidth}) + \\ & \beta_7(\ln \text{ Investment}) + \beta_8(\ln \text{ Mobile Application Price}) + \\ & \beta_9(\ln \text{ Income}) + \beta_{10}(\ln \text{ Education}) + \beta_{11}(\ln \text{ Population Density}) + \\ & \beta_{12}(\ln \text{ Urban Population}) + \beta_{13}(\ln \text{ Age}) + \beta_{14}(\ln \text{ PC Penetration}) + \end{aligned}$$

$$\beta_{15}(\ln \text{ Content}) + \beta_{16}(\ln \text{ Internet usage}) + \beta_{17}(\ln \text{ Teledensity}) + \beta_{18}(\ln \text{ 1G and 2G Penetration}) + \varepsilon_t \quad (1)$$

The empirical model (1) for multivariate analysis was a composite model from previous empirical studies about mobile diffusion. This study includes independent variables such as standardization policy, political freedom, economic freedom, mobile price, bandwidth, telecommunication investment, mobile application price, income, education, population density, urban population, age, PC penetration, content, Internet usage, teledensity, and 1G and 2G penetration. To examine whether fixed-broadband is a complement to or a substitute for 3G mobile, fixed-broadband price was also included in the linear regression model. In addition, one-way ANOVA is used to test the influence of income (high/medium/low income countries) and region on 3G mobile deployment.

Results

Regression Analysis

A total of 106 observations were analyzed employing the multiple regression analysis. Extended and reduced model were identified for the analysis. To meet the assumptions of regression analysis, dependent variable and independent variables were transformed using logarithmic function since data were positively skewed. Also, after testing outliers for Mahalanobis chi square χ^2 , four cases were removed from the analysis.

Extended Model

In the initial model, all eighteen independent variables were included for the multiple regression analysis. A correlation analysis was conducted to check potential multicollinearity problems. To assess the strength of correlations, the .80 Pearson correlation benchmark was employed. PC penetration, Internet use, bandwidth, and content were removed from the initial model because of its high correlation with other

independent variables. Some independent variables, which have unexpected sign, such as teledensity, mobile price, political freedom, and urban population were removed from the model. Also, some insignificant variables such as education and cost of mobile application were removed from the initial model. Table 2 provides the ANOVA table of the extended regression model, which illustrates the model's significance at the .01 level.

Specifically, multiple standardization policy and income were statistically significant at the .01 level. 1G and 2G mobile penetration was statistically significant at the .1 level, which suggests 3G mobile is a substitute of 1G and 2G mobile. Other variables such as fixed broadband price, telecommunication investment, economic freedom, population density, and age (35-44) were not statistically significant. R-square for the extended model was .49 and adjusted R-square was .46.

Reduced Model

To check the stability of results in the empirical study, non-significant variables such as fixed broadband price, telecommunication investment, economic freedom, population density, and age (35-44) were removed from the reduced model. The reduced model is significant at the .01 level. In the reduced model, multiple standardization policy, and income were statistically significant at the .01 level. 1G and 2G mobile penetration was negatively correlated to the dependent variable and was significant at the .05 level. Also, higher level of population density was associated with higher level of mobile broadband penetration. R-square for the extended model was .47 and adjusted R-square was .45 (see Table 2).

Table 2 about here

One-Way ANOVA Analysis

Table 3 offers the data analysis employing one-way ANOVA. Mean difference of 3G mobile penetration between high, medium, and low income countries was statistically significant at the .1 level (F-statistic: 2.75, $P < .1$). Higher income countries tend to have higher mobile broadband penetration. This result may suggest that there is digital divide between countries by income (see Table 3).

Mean difference of 3G mobile penetration between regions (Africa, America, Asia, Europe, and Oceania) was also statistically significant at the .1 level (F-statistic: 2.38, $P < .1$). Asian countries have the highest 3G mobile penetration than other countries in other regions.

This result of one-way ANOVA analysis for 3G mobile diffusion suggests that there are significant differences in the diffusion of 3G mobile by income and region. This result is consistent with the result of previous by Chinn and Fairlie (2006), which found that the global digital divide is mainly explained by income differentials.

Discussion and Conclusions

It was said that the transition of the mobile industry from second to third generation is not a simple technology upgrade but a major economic transformation of the mobile sector as the industry moves from the provision of gradually commoditized voice services to an array of converging communication, information, and entertainment enhanced data services (Tilson & Lyytinen, 2006). While the mobile industry is reconfiguring itself to enter its next stage of development, a better understanding of the means to foster 3G diffusion is fundamental to the continuous growth of this market. The current study identifies various factors that might affect 3G mobile deployment at the country level.

In regards to the role of standardization policy, the results from the regression analysis suggest that market-based multiple standards policy significantly contributes to the adoption of 3G mobile services. As discussed earlier, during the early stage of mobile technology, the diffusion of 2G services was actually faster in Europe where most of its countries employed a single mandated standard than in the United States where market-based multiple standards were used. Our finding here supports the notion proposed by Cabral and Kretschmer (2004) and Kauffman and Techatassanasoontorn (2005). That is, as the mobile technology becomes more mature, the factor of standardization and its scale and efficiency benefits seem to become less relevant. The result from this empirical study illustrates the importance of market mediated multiple standards when a new technology evolves into a different stage of development characterized by more advanced, differentiable features. This result also suggests that path dependence theory, which refers to the dependence of a system or network on past decisions of producers and consumers, might be related to 3G mobile deployment. The finding from the regression study indicates that, in spite of EU's success story of mandated standard (GSM) in the initial stage of 2G, the 3G standard policy that may have assumed WCDMA or locked operators into WCDMA might be a costly public policy decision (Gandal et al., 2003). In a sense, technological diversity, while possibly serving as an impediment at a new medium's early stage, is likely to foster innovative applications and better consumer choices eventually. But again, the positive effects of platform competition on broadband diffusion may decrease as the broadband market matures. Thus, the applicability of path dependence theory is limited and the effect of EU's mandated single standard policy on mobile broadband diffusion is unclear in the long term (Lee, 2008). Considering all these

points, it is still important to note that the concepts of efficiency and ease of integration (i.e., the anticipated benefits of standardization) are critical during the 3G stage as more new mobile applications are being introduced. As suggested by Tilson and Lyytinen (2006) and Noam (2003), instead of government mandated standards, industry-wide coordination, mutual learning processes, and an open system that discourages vertical integration (i.e., preventing mobile service providers from acting as the gatekeeper to all services, technology, and applications) are more imperative in fostering attractive, enhanced mobile services in the 3G era.

This study also examined the causal relationship between 1G and 2G mobile penetration and 3G mobile deployment. Considering the negative relationship between these two variables in the final reduced model of mobile broadband diffusion, 3G mobile can be considered a substitute of 1G and 2G mobile services. While this result of inter-generation effects on mobile diffusion is different from the previous study by Liiknen et al. (2004), which found that 1G has positive effect on 2G, it is nevertheless an expected result because many mobile users prefer 3G mobile services that offer more diverse mobile applications than 1G or 2G mobile services. This finding implies that relative advantage, which is one of perceived characteristics suggested by Rogers (2003), is a factor of 3G mobile diffusion at the individual level of analysis.

Our linear regression of 3G mobile found that higher income as measured by GDP per capita is associated with a higher level of mobile and ubiquitous broadband deployment (see Table 3). These results imply that consumers with higher incomes are more likely to purchase 3G mobile services and suggest the applicability of market segmentation strategy by income in mobile broadband markets.

This study also made a preliminary discovery that fixed broadband is not yet a complement or a substitute for 3G mobile. This finding is based upon the 2004-06 data and therefore might be premature as 3G mobile continues to grow in comparison to fixed broadband. The relationship between fixed broadband and 3G mobile should be examined again in future studies. Finally, this paper is limited by the paucity of its cross-sectional data. With a small number of observations over a comparatively short period, nonlinear nature of 3G mobile diffusion could not be easily captured. When more observations over a longer time period are available, a more refined analysis will be possible. In addition, since the 3G networks are still relatively new in many countries, the numbers of 3G mobile penetration are comparatively small, preventing more extensive empirical analyses. Further empirical research on the relationship between 3G deployment and other influential factors such as 3G application types and the openness (vertical integration) of 3G networks would be useful in identifying the specific marketing and market structure drivers that might foster the further growth of 3G mobile.

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Table 1. Cross-National empirical studies on mobile adoption factors

Study	Main independent variables	Significant findings
Gruber (2001) 140 countries	Income Urban population Fixed penetration Wait time Digital mobile competition Number of mobile operators Market transition index	Late mobile adoption Multiple operators High fixed penetration Wait time
Gruber and Verboven (2001) 140 countries	Income Fixed penetration Digital mobile Standard Competition	Competition Single standard Incumbent pre-empt sequential entry
Koski and Kretschmer (2002) 32 countries	Income Urban population Competition Analog mobile penetration Dominant digital mobile standard Mobile operators (dummy)	Between and within standards Competition Lower user cost
Liikanen et al. (2004) 80 countries	Income Urban population Fixed penetration Number of analog/digital standards Years since introduction Standard (dummy) Mobile telephony operation Age-dependency ratio	Digital mobile introduction hinders analog mobile diffusion Generation-specific results differ from generic results
Kauffman and Techatassanasoontorn (2005)	Years since introduction Standard (dummy) Mobile telephony operation Age telephony operation Mobile telephony operation Age-dependency ratio Income Fixed phone penetration	Number of digital mobile phone standards Mobile service price Analog mobile phone penetration Multiple standardization policy Licensing policy Income
Rouvinen (2006) 165 countries	Income Population Standard Fixed Penetration/user cost Technology Democracy Development	Standards Competition Network effects

Table 2. Results of regression analysis of 3G mobile deployment

Variable	Log linear (extended model)		Log linear (reduced model)	
	Coefficients		Coefficients	
	B	t-stat	B	t-stat
Constant	-3.08	-.96	-4.79	-7.46
Standardization policy	.91	4.99***	.90	5.23***
1G and 2G penetration	-.85	-1.68*	-.99	-2.22**
Income	1.36	4.46***	1.40	5.88***
Fixed broadband price	-.06	-.22	-	-
Age (35-44)	2.16	1.18	-	-
Telecom investment	.04	.45	-	-
Economic freedom	-2.23	-1.22	-	-
Population density	.18	1.34	.23	1.86*
R-Square	.49		.47	
Adjusted R-Square	.46		.45	
Number of observations	98		102	

* Statistically significant at the 10% level. ** Statistically significant at the 5% level.
 ***Statistically significant at the 1% level

Table 3. Difference in 3G mobile penetration by income and region

Dependent Variable	Source	SS	Df	MS	F	Variable	Mean
3G Mobile Penetration	Income	442.06	2	221.03	2.75*	High Income	6.14
	Error	8262.58	103	80.21		Medium Income	2.06
						Low Income	.51
	Region	750.29	4	187.57	2.38*	Africa	.39
	Error	7954.34	101	78.75		America	3.10
						Asia	9.44
					Europe	3.55	
					Oceania	7.19	

Note. Categorization of countries by income and region are based on the ITU's categorization of countries by income and region.

* Statistically significant at the 10% level

Appendix A: Variables, measurement and data sources for mobile broadband adoption

Variables	Measurement	Data Sources
3G Mobile Deployment	Mobile broadband subscribers per 100 inhabitants	ITU (2004-2006), IDATE (2006)
Economic Freedom	Index of economic freedom	Haritage Foundation (2004-2006)
Political Freedom	Inverse of the score on civil liberties Categorical variable	Freedom House (2004-2006)
Standardization Policy	Dummy (1 for multiple standard, 0 for single standard)	ITU (2004-2006)
Price of Fixed-broadband Service	Lower speed broadband monthly charge (USD)	ITU (2004-2006)
Mobile Service Price	Per minute local call (USD) peak charge	ITU (2004-2006)
Income	GDP per capita	ITU (2004-2006)
PC Infrastructure	Estimated PCs per 100 inhabitants	ITU (2004-2006)
Education	UNDP education index	UNDP (2004-2006)
Population Density	Population density (per km ²)	ITU (2004-2006)
Internet Usage	Internet user per 100 inhabitants	ITU (2004-2006)
Urban Population	Percentage of urban population	Euromonitor (2004-2006)
Telecommunication Infrastructure Investment	Annual telecommunication investment (USD)	ITU (2004-2006)
Teledensity	Main telephone lines per 100 inhabitants	ITU (2004-2006)
Mobile Application Cost	Cost of SMS service	ITU (2004-2006)
Age	Percentage of Age between 35-44	World Bank (2004-2006)
Content	Internet hosts per 100 inhabitants	ITU (2004-2006)
Bandwidth	International Internet bandwidth (bits per inhabitant)	ITU (2004-2006)
1G and 2G Penetration	1G and 2G mobile subscribers per 100 inhabitants	ITU (2004-2006)

Appendix B: List of countries examined for 3G mobile deployment (ITU, 2005)

Country	3G mobile subscribers per 100 inhabitants (2004)	Number of 3G mobile subscribers	Country	3G mobile subscribers per 100 inhabitants (2004)	Number of 3G mobile subscribers
Angola	1.598	225000	Latvia	.044	1000
Argentina	.052	20000	Luxembourg	.828	3810
Australia	3.862	76900	Mauritius	.041	500
Austria	2.488	20200	Mexico	.019	20000
Bahrain	.128	950	Moldova	.070	3000
Belgium	.013	1391	Netherlands	.166	27000
Brazil	.945	1706660	New Zealand	18.721	732000
Canada	23.314	7400000	Nicaragua	.357	20000
Chile	.485	74730	Norway	.154	7000
China	.066	8711300	Peru	1.088	300000
Colombia	.011	5000	Poland	.003	1000
Czech Republic	.479	49000	Portugal	.983	99000
Denmark	2.317	124650	Romania	1.254	279408
Ecuador	1.516	200000	Russia	.127	181000
Finland	.141	7361	Slovenia	.318	6300
France	.063	38000	South Africa	.007	3000
Germany	.297	245000	Spain	.187	77000
Greece	.084	9250	Sweden	3.241	288150
Guatemala	.395	50000	Switzerland	.140	10000
Hong Kong	2.949	210000	Taiwan	1.318	300000
Indonesia	.022	50000	Thai	.969	615000
Ireland	.075	3000	UAE	.176	5370
Israel	27.790	1823000	UK	4.765	2832000
Italy	4.882	2800000	USA	16.681	49550000
Japan	20.110	25700000	Uruguay	.006	193
Kazakh	.649	100000	Venezuela	.764	200000
Korea	57.370	27509000			

Note. Data were derived from the International Telecommunication Union (2005).

Source: ITU Internet Reports 2005. Geneva: ITU.