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ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY
Lönnrotinkatu 4 B 00120 Helsinki Finland Tel. 358-9-609 900
Telefax 358-9-601 753 World Wide Web: http://www.etla.fi/

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Heli Koski* – Tobias Kretschmer**

THE ROLE OF PRODUCT INNOVATION ON THE DIFFUSION OF MOBILE TELEPHONY

* The Research Institute of the Finnish Economy, ETLA. E-mail: heli.koski@etla.fi

** Institute for Communication Economics, LMU Munich, and Centre for Economic Performance. Email: t.kretschmer@lmu.de

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ABSTRACT: Most existing empirical work on technology diffusion assumes technologies to remain constant throughout the diffusion process. However, many consumer technologies improve significantly over time. Using data on the characteristics of new mobile handsets over a ten-year period and controlling for potential endogeneity problems, we find that handset quality and variety had a significant impact on the global diffusion of mobile telephony. Our estimation results further suggest that earlier empirical studies on diffusion may have attributed too much of diffusion to network effects.

Keywords: Product innovation; Technology Diffusion; Mobile Telephony

JEL codes: L96, O33

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TIIVISTELMÄ: Suurin osa teknologioiden leviämistä koskevista empiirisistä tutkimusta olettaa teknologioiden säilyvän muuttumattomina diffuusioprosessin ajan, vaikka kuluttajaelektroniikassa tapahtuu usein huomattavia parannuksia yli ajan. Tämä empiirinen tutkimus, joka hyödyntää aineistoa uusien markkinoille tulleiden matkapuhelinten ominaisuuksista yli kymmenen vuoden ajalta ja kontrolloi mahdollisia endogeenisuusongelmia havaitsee, että matkapuhelinten laadulla ja variaatiolla on ollut merkittävä vaikutus matkapuhelinten globaaliin diffuusioon. Tutkimustuloksemme viittaavat myös siihen, että aiemmat empiiriset teknologioiden leviämistä koskevat tutkimukset ovat yliarvioineet verkostovaikutusten merkityksen.

Avainsanat: Tuoteinnovaatiot; teknologian leviäminen; matkapuhelinsektori

JEL koodit: L96, O33

1. Introduction

Digital (i.e. second-generation, or 2G) mobile telephony was introduced in different technological flavours globally. Of the different technological standards, the GSM (Global System for Mobile Communication) standard grew dominant and still enjoys over 80% market share worldwide, although it is slowly being replaced by 3rd generation wireless standards.[1] Especially in the early stages of 2G technology diffusion, the diffusion process displayed significant differences across countries – firstly, different regions and countries operated on different standards (sometimes multiple ones in a single country), and secondly, diffusion speed varied vastly over these countries (Gruber and Verboven, 2001; Koski and Kretschmer, 2005; Grajek and Kretschmer, 2009). At the same time, the successful penetration of 2G mobile services coincided with a series of product innovations that transformed cellphones from mere portable telephones to sophisticated pieces of consumer electronics offering users a variety of different functionalities such as playing games, taking photos, browsing the Internet and accessing e-mails (Koski and Kretschmer, 2007).

Worldwide, over 2800 new cellular handset models were introduced in our sample period between 1992 and 2003. Our data show clear differences in the number of new handsets launched for different wireless standards. Most new handsets (about 40% of new handsets) supported GSM technology, followed by CDMA (Code Division Multiple Access) with approximately 20% of new handsets operating on this standard. Interestingly, a relatively large portion of the new handsets (14%) were compatible with the PDC (Personal Digital Cellular) standard used only in Japan, while the remaining competing wireless standards had each less than 5% of new mobile handsets.

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[1] Almost 90% of over four billion people worldwide having wireless connection use mobile devices supporting the GSM technology (including the GSM-based 3rd generation W-CDMA, Wideband Code Division Multiple Access, and HSPA, High Speed Packet Access, standards). Sources: The press release of GSM Association, 11 February 2009 (http://www.gsmworld.com), and the statistics of the Global mobile Suppliers Association (GSA) (http://www.gsacom.com/news/statistics.php4).

The question we ask in this paper is if the introduction of ever-improving handsets played a role in the rapid worldwide diffusion of mobile telephony. We make use of the variability of handsets both in numbers and features across different technological standards to address this question while controlling for potential endogeneity of product introduction – i.e. product introduction depending on the state of technology diffusion rather than vice versa.

We extend the established Bass (1969) diffusion model to include the role of product variety and quality within a technological generation to investigate to what extent between-standard differences in vertical and horizontal innovation of handsets account for differences in adoption rates. Empirical diffusion studies typically use a time trend or past diffusion to proxy for network effects and/or increasing information available over time. Given that technologies also improve with time and existing studies typically do not include measures for (average) technological quality, the estimated coefficients of the time trend or installed base for the epidemic/network effect may be overestimated, i.e. too much of diffusion is attributed to the installed base and exogenous changes over time.

Our study deviates from the previous empirical studies (e.g., Gruber and Verboven, 2000, 2001; Koski and Kretschmer; 2005; Liikanen et al., 2004) on the diffusion of mobile telephony in various respects. First, unlike previous studies, we do not only consider aggregate country-level diffusion of mobile phones but take a step further and investigate the role of technology mix and different standards on diffusion.[2] Second, we explicitly consider the role of new product introduction and technological progress in the diffusion of different technological standards. Our empirical study proposes that the nature and extent of horizontal and vertical innovations, have played a significant role in the success of different standards. This empirical finding, however, does not seem to apply to the aggregate diffusion of 2G mobile telephony in countries in which multiple 2G standards compete.

[2] Gruber and Verboven (2000, 2001) and Koski and Kretschmer (2005) do this only by considering aggregate diffusion as a function of the number of competing standards in a country. However, they do not measure standard-level diffusion.

This paper is organized as follows. Section 2 reports descriptive findings concerning product innovation and diffusion of different 2G wireless telephony standards. It also introduces an empirical model on new product introduction and technology diffusion and introduces explanatory variables used in the empirical exploration. Section 3 presents the estimation results and discusses the major findings. Section 4 concludes.

2. Mobile handset introduction and diffusion

2.1 Descriptive Observations

Countries in the EU chose a single second generation wireless standard, GSM, while in other countries, most notably the US, Canada, Korea and Japan various standards were competing. For example, in North America the standards launched were CDMA, TDMA (Time Division Multiple Access) and GSM. Moreover, Motorola developed its own TDMA-based technology iDEN (Integrated Digital Enhanced Network) that was launched only in North America. In Japan, the TDMA-based PDC standard (launched only in Japan) dominated in the 1990s, until CDMA and W-CDMA entered the market in 1999 and 2001, respectively. Korea was offering wireless telecommunications services using CDMA with 800 MHz and 1700 MHz frequencies. The 1700 MHz network was used only in Korea, meaning that only mobile phones supporting Korean CDMA-1700 were compatible with the local network.

The data used in this study cover the diffusion and introduction of new handsets supporting all 2G wireless standards: GSM (frequencies (MHz): 900, 1800, 1900, and dual band 900/1800), CDMA (frequencies (MHz): 800, 1700, 1900, and dual band 800/1900), US TDMA (frequencies (MHz) 800, 1900, and dual band 800/1900), iDEN, and PDC. We have monthly data from 21 industrialized countries[3] from the years 1992 to 2003. To capture the link between innova-

[3] The countries in our sample were: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK and USA.

tion and diffusion – as wireless handsets supporting a certain standard can be used only in a compatible network using the same frequency[4] – we use frequency-level data on 2G telephony (e.g., the GSM standard is separated into the four technologies: GSM-900, GSM-1800, GSM-1900 and GSM-900/1800) in our estimations. Our diffusion data (i.e. the number of new wireless subscribers) and information on the number of new handsets and their features (i.e. weight, standby and talk times) are extracted from the EMC World Cellular Database.

Figure 1. Average Diffusion of 2G Telephone Standards in the Sampled Countries, 1992-2003

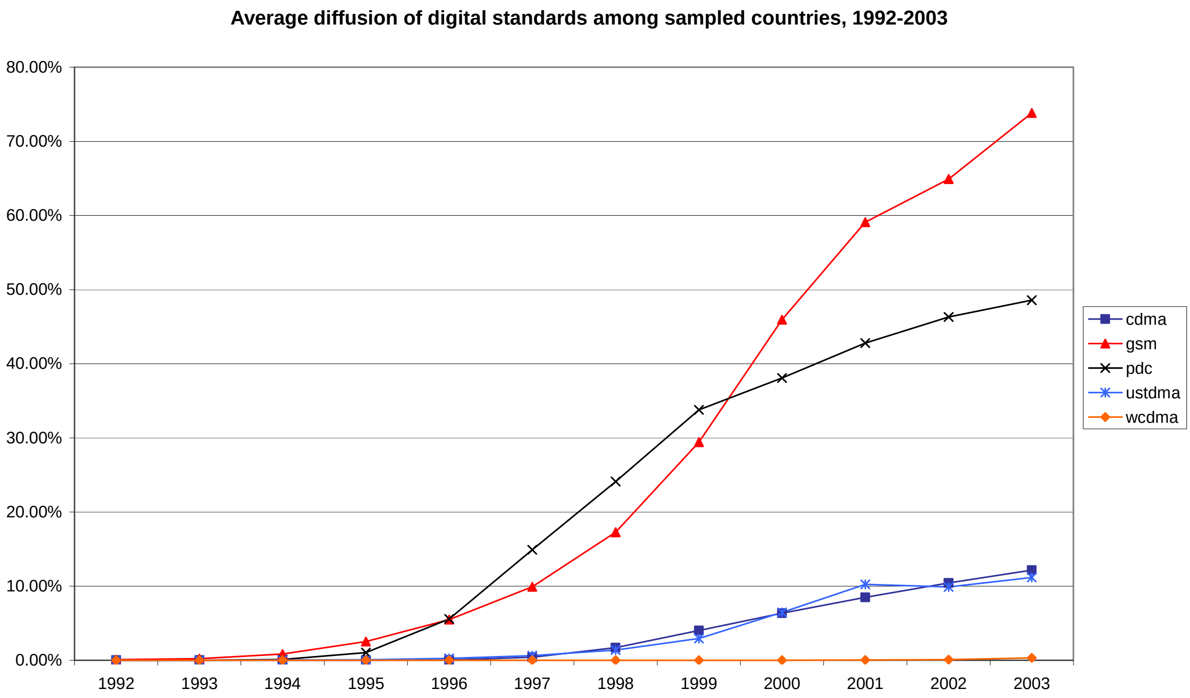

Figure 1 shows the average diffusion rates (measured in percent of the population) of the wireless standards in our sample countries. The diffusion of GSM phones was strong and steady, while diffusion speed of other 2G technologies was much slower. One exception is the Japanese PDC standard that was adopted rapidly in the second half of the 1990s: between the mid 1990s and the year 2000, the PDC subscriber share grew from zero to about 40% of the

[4] For instance, GSM-900 compatible mobile phones cannot be used in the GSM-1800 network unless they are dual band.

population in Japan. Figure 1 also illustrates that the diffusion of 3G WCDMA standard – which we exclude from our estimations as we want to focus on the same technological generation, 2G – was still in its very early phases in our sample time period.

Figure 2. Introduction of New 2G Handsets by Standard, 1992-2003

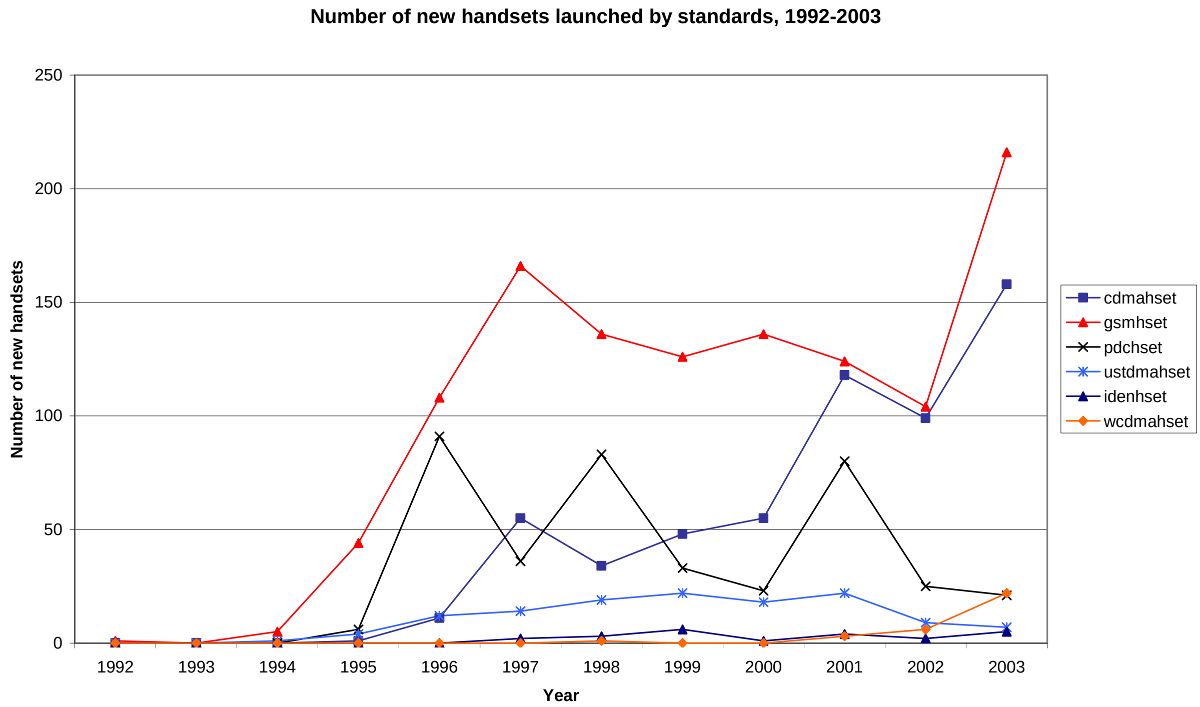

Figure 2 shows the number of new handsets supporting different standards launched between the years 1992 and 2003, and thus reflects the order of magnitude of variety or horizontal innovation of handsets supporting different 2G standards. The number of new iDEN handsets as well as US TDMA handsets remained relatively low through the observed time period. Interestingly, there was rapid growth in new Japanese PDC phones in the mid 1990s, but since then, the number of PDC handsets declined steadily. Clearly, the most handsets were introduced for the GSM standard during the 1990s, although in 2001 and 2002 there was a rise in the number of new CDMA handsets, and manufacturers introduced almost as many CDMA as GSM phones. We can also observe that the supply of 3G WCDMA handsets was still, as its diffusion, very limited during the sample time period.

2.2 An Empirical Model on New Product Introduction and Technology Diffusion

Our empirical model captures the dynamics of horizontal and vertical product innovation and the diffusion of 2G wireless standards in our sample countries. Our main focus is on first-time buyers of a technology, i.e. the extensive diffusion of mobile telephony (Comin et al., 2008).[5] We assume that the share of technology adopters of the number of potential adopters follows a logistic growth curve, and over time more people learn about the technology or find it profitable to adopt it given the number of previous adopters:[6]

$$N_{ijt} = \frac{N_{ij}^{*}}{1 + \exp(-\beta_0 - \beta_1(t + HI_{ijt} + VI_{ijt} + X_{ijt})}, \text{ or}$$

$$\log\left(\frac{\hat{N}_{ijt}}{1 - \hat{N}_{ijt}}\right) = \beta_0 + \beta_1(t + HI_{ijt} + VI_{ijt} + X_{ijt}) \qquad (1)$$

where N_{ijt} is the number of adopters of standard i in country j at time t, N_{ij}^{*} equals the number of users when diffusion of technology i is complete, β_1 captures the epidemic and/or network effect, and $\hat{N}_{ijt} = N_{ijt} / N_{ij}^{*}$. The two main explanatory factors, horizontal and vertical innovation are captured by HI and VI. We further assume that there is a vector of standard- and country-specific explanatory variables, X_{ijt}, that may affect diffusion speed of a standard.

Horizontal and vertical innovation are the key variables of interest in our study. They are likely to affect the diffusion speed of new technologies – to the best of our knowledge, their impact on mobile phone diffusion was not been studied previously. We define vertical and horizontal innovation as several EU publications on innovation: "*Vertical innovation takes place where all customers consider a product to be improved at the same price, whereas horizontal innovation occurs where only some customers regard a product as*

[5] Grajek and Kretschmer (2009) study intensive diffusion, i.e. the extent to which adopters use the technology.

[6] The Bass (1969) model interprets the (linear and squared) coefficients of previous adopters on diffusion speed as epidemic effect, although this woudl also be consistent with network effects (Koski and Kretschmer, 2005).

improved".[7] In other words, vertical innovation establishes a clear quality ranking among all consumers and refers to technological advancement in product quality, whereas horizontal innovation refers to increased product variety or new features that are not equally valued by all users (Koski and Kretschmer, 2007).

2.3 Variable Definitions and Descriptive Statistics

Our variable definitions and descriptive statistics are given in Table 1. We first discuss the rationale for our key independent variables and then introduce our control variables.

Table 1. Descriptive Statistics

Name	Description	Mean	S.D.
Dependent Variable			
L_DIFF	(Log) (# 2G mobile phones/population)/(1-(# 2G mobile phones/ population))	-5.05	4.36
Product Innovation Variables			
NEW_HSETS	Log number of new handset models introduced within the month.	-1.95	5.02
NEW_HSETS_YEAR	Log number of new handset models introduced within the past year.	2.71	3.01
WEIGHT	Log average weight (grams) of the new handsets launched supporting a certain standard within the month.	4.83	0.29
TALK_TIME	Log average talk time (minutes) of the new handsets launched supporting a certain standard within the month.	5.25	0.25
STANDBY_TIME	Log average standby time (hours) of the new handsets launched supporting a certain standard within the month.	-1.95	5.02
Control Variables			
ENTRY	Log number of months it took before a wireless standard became available in a country after its first introduction (in the global markets).	5.01	0.58
PRICE	Log monthly mobile cellular prices of 3-minute local peak hour calls (in USD and PPPs).	1.03	5.32
COMP	Dummy variable = 1 if # 2G competitors > 2, 0 otherwise.	-0.69	1.81
STAND	Dummy variable = 1 if country has one 2G standard, 0 otherwise.	0.95	0.22
GDP/POP	(Log) gross domestic product per capita.	0.37	0.48
GDP_GROWTH	% growth of GDP per capita	10.18	0.18
TIME	Time trend measured in months.		

[7] See, e.g., http://aoi.cordis.lu/print_version.cfm?article=1115.

Vertical innovation providing higher quality as well as horizontal innovation increasing product variety for a given standard is likely to speed up its adoption as the benefits from adopting a technology exceed its adoption costs for a greater number of non-users at a given point of time. Our hypothesis is thus that 2G wireless standards with comparably more and better new handsets diffuse faster than other standards. Innovation and technological advancement of mobile handsets supporting certain wireless standard are captured by the following variables. (i) First, the log number of new handset models supporting each wireless frequency-standard combination launched in the past month (NEW_HSETS) and aggregated over the past twelve months (NEW_HSETS_YEAR) globally gives a measure of product variety, or horizontal product innovation.[8] NEW_HSETS is used for measuring the short-term or immediate impact of product introduction on demand for wireless services, whereas NEW_HSETS_YEAR measures the longer-term effect of past product introductions. (ii) Second, technological quality over time is a direct measure of technological advancement. We measure vertical innovation or technological advancement of handsets supporting each standard-frequency combination by three variables: 1) the log average weight in grams (WEIGHT), 2) the log average handset talk time in minutes (TALK_TIME)[9], and 3) the log average handset standby time duration in hours (STANDBY_TIME)[10] of new handsets launched for a given standard and month.

Further, we expect that demand (and therefore diffusion) for a new technology is affected (negatively) by price and (positively) by population wealth. We measure the level of wealth by the log quarterly gross domestic product per capita (in USD and PPPs) of a country (GDP/POP) and its growth by the quarterly GDP growth per capita (GDP_GROWTH). These data are obtained from the Quarterly National Accounts of the OECD.stat database. The price

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[8] As new handsets are typically targeted at a standard (wherever it is being used) rather than a particular country, we believe that this measure adequately represents the situation in our sample.
[9] Talk time indicates the duration a battery will last if calls are made continously.
[10] Standby time indicates how long a handset can remain switched on but not used before it has to be recharged.

variable (PRICE) is extracted from the ITU World Telecommunication/ICT Indicator 2008 database and measures the log annual mobile cellular prices of 3-minute local (peak) calls (in USD and PPPs). Unfortunately, more detailed or frequently measured wireless prices statistics are not available – this proxy variable captures roughly the differences in monthly wireless service prices between the sample countries.

Previous studies also use a set of additional factors affecting diffusion speed of mobile telephony. Competition, standardization, and market entry appear particularly significant determinants of mobile phone diffusion (Koski and Kretschmer, 2005), and are therefore included in our model. The dummy variable COMP measures whether 2G service providers face competition and takes value 1 if there are at least two active providers of 2G services in a country, and 0 otherwise. The dummy variable STAND takes value 1 if the country has chosen a single technological standard for 2G telephony, and 0 otherwise. Moreover, we capture the timing of first 2G service by measuring the log number of months until a wireless standard became available in a country after its first introduction globally (ENTRY).

A time trend variable (TIME) captures network and epidemic effects in line with existing studies suggesting that a greater number of users of a new technology positively relate to further adoption by non-users. As discussed elsewhere, this variable is difficult to interpret unambiguously, but by including it enables us to compare our results to existing diffusion studies and to capture other unobserved trends over time that might otherwise be picked up by our variables of interest. Finally, to control for the potential seasonal variety in demand for mobile telephony we include monthly dummy variables in our estimations.

Especially price, the timing of market entry, and the number of new handset models for a given standard are likely to be endogenous in our estimation equation as they may be correlated with the error term. This endogeneity problem arises as it seems likely that the (expected) adoption rates of 2G cellular handsets affect the profitability of 2G mobile phone production, and thus the 2G market entry, and also the decisions of cellular handset manufacturers to launch new handset models and the pricing of 2G mobile telephony services.

We use a constant term, all exogenous variables, as well as standard and country-specific dummies as instruments for these endogenous variables. We also use the one-period lagged dependent variable as instrumental variable as it is (contemporaneously) uncorrelated with the error term of the equation, and thus provides a good instrument

3. Empirical Findings

3.1 Econometric model and estimation results

We estimated the following 2SLS random effects[11] IV model for standard-level diffusion:

$$DIFFUSION_{ijt} = \alpha_0 + \alpha_1 NEW\_HSETS_{jt} + \alpha_2 NEW\_HSETS\_YEAR_{jt} + \alpha_3 WEIGHT_{jt}$$
$$+ \alpha_4 TALK\_TIME_{jt} + \alpha_5 STANDBY\_TIME_{jt} + \alpha_6 PRICE_{it} + \alpha_7 ENTRY_i + \alpha_8 COMP_{it}$$
$$+ \alpha_9 STAND_{it} + \alpha_{10} GDP/POP_{it} + \alpha_{11} GDP\_GROWTH_{it} + \alpha_{12} TIME + \sum_{k=12}^{23} \sum_{d=2}^{12} \alpha_k month_d + u_{ij} + \varepsilon_{ijt} \quad (2)$$

In equation (2), t denotes monthly observations and i and j refer to the 2G standard and country, respectively. The *month* dummy takes on values from 2 to 12 (with January the reference group). As there is a relatively large number of missing observations concerning the technological quality of the new handset models, we estimate the econometric model both with and without the technology quality and new handset introduction variables (Models Ia., Ib. and II, respectively). Model Ia. excludes all innovation variables (i.e. basically estimates a basic Bass (1969) model without any product portfolio indicators) and Model Ib.excludes technology quality variables. These separate estimations also let us assess if and how the magnitude of the time trend coefficient, which is typically used for capturing network and epidemic effects, but may also capture part of ongoing technological progress is affected.

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[11] The estimations of the fixed effects model were not possible as the entry variable is time-varying.

Table 2.2 SLS Random Effect IV Model for 2G Standard Diffusion, all countries

Explanatory variable	MODEL Ia. No vertical/ horizontal innovation	MODEL Ib. No vertical innovation	MODEL II Vertical and horizon-tal innovation included
NEW_HSETS		0.26**	0.21
		(7.72)	(1.20)
NEW_HSETS_YEAR		0.05**	0.57**
		(2.25)	(4.84)
WEIGHT			-1.02**
			(-2.67)
TALK_TIME			0.04
			(0.17)
STANDBY_TIME			0.65**
			(3.92)
ENTRY	0.05**	-0.03	-0.12**
	(3.03)	(-1.89)	(-11.37)
PRICE	-0.33**	-0.29**	-0.15**
	(-10.32)	(-8.28)	(-6.30)
COMP	1.21**	1.95**	3.12**
	(4.55)	(5.77)	(7.12)
STAND	-1.43**	-1.71**	-2.60**
	(-14.60)	(-14.76)	(-31.73)
GDP/POP	-1.90**	-1.42**	-0.60**
	(-5.75)	(-3.81)	(-2.50)
GDP_G	0.00	0.00	0.00
	(0.00)	(0.58)	(-0.30)
TIME	0.06**	0.04**	0.02**
	(57.23)	(22.38)	(6.59)
Constant	-15.33**	-10.73**	-9.42**
	(-4.83)	(-2.96)	(-2.25)
MONTHLY DUMMIES	YES	YES	YES
Number of observations	2607	2607	1750
R^2	0.48	0.51	0.58

Notes: ** indicates 1% significance, * indicates 5% significance

Both the number of new handsets introduced in the current month and the past year appear to facilitate the diffusion of 2G standards, although the short-term or immediate impact captured by NEW_HSETS is not significant when the technological advancement variables are added to the model. This provides some suggestive evidence on the direct impact of handsets manufacturers' product introduction strategies for certain technological standards on the diffusion speed of these technologies – especially the long-term impact is robust and highly significant, suggesting that a portfolio for a particular standard comprises a number of available handsets, not just the ones introduced very recently. As a greater number of new handset models at any given point of time implies greater product variety on the market, this finding suggests a positive relationship between horizontal innovation and diffusion speed.

Our results also indicate that the technological quality of new handsets is positively related to the diffusion speed of standards. Standards for which there existed lighter and technologically superior – in terms of standby times – handsets diffused faster than others. Thus, vertical innovation has played a significant role in the diffusion of different 2G standards.

Also note that the magnitude of the time trend coefficient decreases from the estimate of basis Bass diffusion model (i.e. Model Ia.) 0.06 to 0.04 when we include horizontal innovation variables (Model Ib.), and further to 0.02 when also vertical innovation is controlled for (Model II.). The estimated coefficient of time variable remains statistically significant when technological advancement is controlled for. This suggests that when the development of technological quality is not taken into account, as typically has been the case in the empirical studies, the importance of network and/or epidemic effects is overestimated. Nevertheless, even when the role of technological advancement is "stripped" from the time trend variable, there is still a significant and positive time trend, which strengthens the notion of network and/or epidemic effects in mobile diffusion.

Our findings on the role of standardization are similar to those found in the previous studies. Ex-ante (*de jure*) standards, which conceivably reduce uncertainty among consumers, spread faster than standards competing with incompatible alternatives within a country (Kretschmer, 2008). Our results also suggest that competition between wireless operators in a country facilitates wireless diffusion, whereas higher prices are negatively related to the diffusion speed of mobile telephony, as expected (Koski and Kretschmer, 2005). The estimation results further show that the ENTRY variable is negatively and statistically significantly related to the diffusion of mobile telephony. This means that in the countries in which 2G was introduced later have also witnessed slower diffusion speed of mobile telephony on average.

It is also interesting to consider whether horizontal and vertical innovation affect diffusion dynamics differently when a country has chosen a single ex-ante standard compared to when there are multiple competing standards. Table 3 shows the estimation results for the separate samples of single- and multiple-standard countries.

Table 3.2 SLS Random Effect IV Model for 2G Standard Diffusion: Single-standard vs. multiple-standard countries

Explanatory variable	Single-standard countries	Multiple-standard countries
NEW_HSETS	0.20	8.99
	(1.21)	(1.11)
NEW_HSETS_YEAR	0.72**	-5.51
	(6.25)	(-1.02)
WEIGHT	-1.29**	-1.83
	(-2.85)	(-0.64)
TALK_TIME	-0.23	2.89
	(0.76)	(1.23)
STANDBY_TIME	0.65**	1.38
	(3.38)	(0.96)
ENTRY	-0.04**	-0.49**
	(-2.78)	(-5.59)
PRICE	-0.13**	-0.98**
	(-4.44)	(-3.15)
COMP	3.45**	5.90
	(8.40)	(0.15)
GDP/POP	-0.08	-1.09
	(-0.31)	(-0.55)
GDP_G	-0.00	0.00
	(-0.33)	(0.78)
TIME	0.01**	0.09
	(3.83)	(0.04)
Constant	-9.58	
	(-2.01)	dropped
MONTHLY DUMMIES	YES	YES
Number of observations	1052	698
R^2	0.55	0.06
Notes: ** indicates 1% significance, * indicates 5% significance		

Our results for single-standard countries are very similar to the ones presented in Table 2 using the entire sample. In other words, both vertical and horizontal innovation affect 2G standard diffusion in single-standard economies. For multiple standard countries, however, our empirical model does much worse in terms of predicting standard diffusion. Only the estimated coefficients of price and market entry have the expected sign and are statistically significant. There are two issues in this context that have to be discussed. First, as we are estimating an s-curve, in a single-standard setting we are effectively estimating the diffusion of 2G in the entire country. In a standards battle between multiple standards, there is no particular reason to believe that all standards should diffuse in this fashion – especially if the standards battle results in winning and losing standards. Therefore, the lack of fit in multi-standard environments is not especially surprising. However, this does not automatically imply that product variety and quality should not affect the success of particular standards in such a situation – in other words, there is no reason to expect that these variables should carry insignificant coefficients in our estimations. Our results however suggest that neither vertical innovation nor horizontal innovation notably affect the diffusion speed of 2G standards if there are several competing ones in a country. A possible interpretation is that imitation across different standards results in fairly similar portfolios of available handsets for each competing standard. Then, while single-standard markets react positively to improved technologies, the same technological progress of different standards over time within a country does not reduce the corresponding uncertainty of the ongoing competition, so that markets do not react strongly to the technological advancements. Koski and Kretschmer (2005) find that competition between incompatible standards triggers more intense price competition as the switching costs to a rival incompatible network are higher and firms consequently price more aggressively. Thus, in countries with one standard and less aggressive pricing strategies, quality improvements may matter more for consumers.

Further, the coefficient of the time trend variable is not significant in our multi-standard regression, suggesting that over time an increase in the number of users does not reduce consumer uncertainty regarding new technologies in the same way it does when there is a single ex-ante selected network standard.

4. Conclusions

In this study, we provide evidence on the relationship between new product introduction and the diffusion of mobile telephony. Both horizontal and vertical innovation clearly affected the diffusion speed of 2G wireless standards in our sample of OECD countries over the 1992-2003 time period. Our data suggest that 2G standards that offered a product portfolio with superior technological characteristics (vertical innovation) and higher product variety (horizontal innovation) were able to spread faster than other standards. Our analysis shows that our empirical findings on the relationship between horizontal and vertical innovation and technology diffusion hold only in the countries that have adopted ex-ante a single 2G wireless standard. Neither horizontal innovation nor vertical innovation appears statistically significant in a subsample of countries with multiple competing standards. These findings are intriguing as they suggest that consumer reaction to product introductions may differ significantly depending on the technological fundamentals of the market, and in particular if a standard has been set ex-ante or is set by the market.

Our work shows that existing studies on the diffusion of new technologies may have overestimated the epidemic and network effects by ignoring the role of technological progress over the lifetime of a technology. This bias is important for firms and policymakers as new product introduction and technological improvement have to be incentivized accordingly. Failing to take this into account and assuming that self-reinforcing processes such as information transmission and network effects will help the technology diffuse could lead to an overestimation of market potential. In our empirical setting, the incentives were provided because handset manufacturers supplied operators with new products, but in other settings with less clear-cut incentives to improve a baseline technology, the shortfall of actual market penetration to predicted market penetration may be significant.

Further research should try to explore the role of product variety and quality in multiple- versus single-standard settings in more detail, as this might yield interesting conclusions about the effectiveness of strategic variables under different technological settings. For this, further research into the relationship between service prices and handset quality could also prove fruitful – in the market for mobile telephony, handsets are often subsidized, and profits are made through increased revenues per minute, and it would be interesting to see if this intuition indeed holds for markets with frequent product introductions and competition both on prices and technologies.

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