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The Role of Digital Technology and Regulations in the Diffusion of Mobile Phones in Asia

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1. INTRODUCTION

More and more people are using mobile (cellular) phones and the world is increasingly becoming unwired due to diffusion of this technology. The cellular technology is present in most Asian countries since 1980s. However, its diffusion process in these countries has largely been affected by technological developments, i.e., transition from analogue to digital, and regulations. The nature of regulations relate to spectrum licensing and the number of competitors allowed by respective governments. These regulatory decisions may explain the current structure of mobile phone industry in most of these countries.

The popularity of cellular communication lies in its appealing advantage as compared with the fixed networks. The most important feature of a cellular phone is its portability in that the call is made to a person and not to a place. In developed countries, the features available on mobile handsets (such as caller line identification, voice mail, call forwarding, call waiting and the facility of receiving and transmitting short text messages) are available free of charge. However, these cell phone facilities are very costly in developing countries as compared with their fixed networks. The regulatory licensing structure prevailing in these countries partly explains this price differential. In effect there has been wide diversity in the speed of introduction of mobile phones and their diffusion across developing countries, which has not been explored. Gruber and Verboven (1998) has recently examined diffusion of cell phones in the European Union. However, this is a neglected area of research in developing countries.

This paper is an attempt to evaluate the determinants of diffusion of mobile phones in selected Asian countries. As noted earlier, diffusion has been largely driven by technological innovation or by regulatory licensing policies. This paper addresses the relative importance of three factors in diffusion speed of mobile telephones. These

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factors are technology (analogue vs. digital), timing of first license granted, and introduction of additional competition. The impact of existing fixed-line network (main telephone lines in operation) and GDP per capita on diffusion speed is also examined.

2. MODEL SPECIFICATION AND ESTIMATION PROCEDURE

We assume that potential subscribers to mobile telephony do not immediately adopt mobile phones after their introduction. The response of potential adopters is expected to vary between particular lower and upper limits. Obviously, there is a lower limit on the dependent variable since people using new technology cannot fall below zero and an upper limit that will be reached at some point in time. More specifically, we define a logistic growth function for potential adopters in a panel data setting by

$$y_{it} = \frac{y^*_{it}}{1 + e^{-(a_{it} + b_{it})}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where y_{it} is the number of mobile subscribers for *i*th country and *t*th time, y^*_{it} is the ceiling or the equilibrium value, *b* is for coefficient of rate of growth and *a* is for constants, which positions the curve on the time scale. In other words, we relate the flow of new adopters of technology to the stock of existing adopters. As the stock comes closer to the total number of potential adopters the flow of new adopters gradually decreases and eventually becomes zero.

Three important elements determine the shape of the logistic function in (1). First, the total number of potential adopters, y^*_{it}, which may be estimated by using the economic determinants. For instance, the level of income in respective countries may influence the total market potential. Hence, y^*_{it} may be written as

$$y^*_{it} = \gamma \; pop_{it} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

In practice, γ poses difficulties in estimation and hence is replaced by a constant fraction of total population in this paper. Second, the variable a_{it} is a location or timing variable given by

$$a_{it} = \alpha_{if} + \alpha_D \; DIG_{it} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

where *DIG* is a dummy variable equal to 1 if *i*th country has already introduced digital technology at time *t*, and 0 otherwise, while α_{if} are fixed effects for each *i*th country capturing an adoption lag or lead to a base country. Finally, b_{it} measures the diffusion speed and is specified as

$$b_{it} = \beta_{if} + \beta_D \; DIG_{it} + \beta_{CA} \; CMPA_{it} + \beta_{CD} \; CMPD_{it} + Z_{it} \; \beta \quad \ldots \quad \ldots \quad (4)$$

where β_{if} is the estimated country specific fixed effects reflecting the autonomous diffusion speed. The parameter β_D is a control for presence of digital technology on the speed of diffusion while $CMPA_{it}$ and $CMPD_{it}$ are two competition dummy variables, which equal one if there are at least two competitors for the analogue and digital technology, respectively. The Z_{it} is a vector representing standard demand side variables such as per capita gross domestic product, GDP_{it}, and number of main lines per capita, $MNLINE_{it}$. By substituting (2), (3) and (4) in (1), we obtain the following specification that will be used for estimation

$$y_{it} = \frac{\gamma \, pop_{it}}{1 + \exp - \{(\alpha_{if} + \alpha_D DIG) + (\beta_{if} + \beta_D DIG_{it} + \beta_{CA} CMPA + \beta_{CD} CMPD_{it} + Z_{it}\beta)\, t\}} \ldots \quad (5)$$

The logistic diffusion model in (5) will be estimated by employing nonlinear least squares procedure. The logit regression is generally used for analysing the relationship between one or more independent variables with a categorical or a continuous dependent variable. However, the logistic regression model in (5) is an extension of the logit for binary responses. This general form allows the response to vary within a particular lower and upper limit.[1] Since this type of logit model does not violate the properties of least squares we have used non-linear least squares to estimate the diffusion model in (5).

3. DATA AND CONSTRUCTION OF VARIABLES

We use unbalanced panel data of 25 randomly selected Asian countries for the period 1986–1998. The countries were randomly selected from the list of Asian countries for which data on mobile subscribers was reported in the *Yearbook of International Telecommunication Union* [ITU (1999a)]. The selected countries are Azerbaijan, Bangladesh, Brunei, Cambodia, China, Hong Kong, India, Indonesia, Japan, Khazakhastan, Laos, Macau, Malaysia, Myanmar, Pakistan, Philippines, South Korea, Singapore, Sri Lanka, Taiwan, Thailand, Uzbekistan, Vietnam, Iran and Saudi Arabia. Altogether we have 223 observations to work with.

The data on total mobile subscribers (including analogue and digital technologies), y_{it}, population, *pop,* gross domestic product, *GDP*, and main telephone lines in operation, *MNLIN,* was obtained from the *Yearbook of Statistics of International Telecommunication Union* [ITU (1999a)]. The data on *GDP* was reported in local currencies that was converted into US dollars by using respective exchange rates. The variable, main telephone lines per capita, *MNLINE*, was obtained by dividing *MNLIN* by respective populations of each country. We constructed dummy variable, *DIG,* for digital technology, which equals one if the *i*th country already had introduced digital

[1] For example, suppose we are interested in population growth of a species that is introduced to a new habitat as a function of time. The dependent variable would be the number of individuals of that species in the respective habitat. Obviously, there is a lower limit on the dependent variable, since fewer than zero individuals cannot exist in the habitat. However, there also is most likely an upper limit that will be reached at some point in time.

technology and zero otherwise. Finally, two other dummy variables namely, cellular mobile phone analogue, *CMPA*, and cellular mobile phone digital, *CMPD*, were constructed representing analogue and digital technology competition, respectively. Data on country-wise cellular operators was obtained from *World Telecommunication Development Report, Mobile Cellular* for the period 1986-1998 [ITU (1999)]. The dummy variable, *CMPA* equals one if the *i*th country has two or more analogue cellular operators and zero otherwise. The dummy variable *CMPD* equals one if the *i*th country has two or more digital cellular operators in respective countries, and zero otherwise.

4. EMPIRICAL RESULTS FOR THE DIFFUSION MODEL

We estimate the empirical specification in (5) by using nonlinear least squares and annual data of 25 selected Asian countries covering period from 1986 to 1998. Table 1 reports parameter estimates for the regression that includes gross domestic product, main lines per capita, location fixed effects and diffusion speed parameter fixed effects. Most of the estimated parameters are statistically different from zero at the 1 percent level. The estimate for γ or the fraction of population is 0.41 indicating that on average about 41 percent of the population is expected to adopt a mobile phone in the long run.

The coefficient β_D in Table 1 measures the role of transition from analogue to digital technology in speeding up of the diffusion of mobile services. Since the parameter estimate for β_D is statistically in significant, it implies that technical change from analogue to digital alone was not instrumental in bringing about diffusion. This may be explained by the presence of diversity in the selected sample. For instance, Bangladesh, Cambodia, Khazakhastan and Laos introduced digital technology in cellular phones as late as 1997 or 1998. The question of affordability of mobile phones in selected developing countries may also explain this result.

The effect of entry of a second competitor for analogue and digital competition is measured by the coefficients β_{CA} and β_{CD}, respectively. Our results show that the effect of entry of a second competitor has been of great significance in the digital period than the analogue, which is quite understandable due to considerably higher prices experienced during the analogue period. Moreover, many Asian countries had granted exclusive license to only one service provider for an extended period. The difficulty in allocating frequency spectrum to cellular operators in earlier period may also explain fewer licences. We find that the introduction of more competition has led to lower prices and consequently more adopters of cellular phone.

The parameter estimate for main lines per capita is positive but statistically insignificant while the parameter estimate for GDP_{it} (gross domestic product per capita) is negative and statistically insignificant which illustrates that there is no multi-collinearity between the two variables GDP_{it} and $MNLINE_{it}$.

Table 1

Parameter Estimates for Logit Diffusion Model: GDP and MNLINE Included

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
γ	0.41	α_{19}	–10.75	β_{12}	1.67
	(26.08)		(–7.74)		(3.58)
α_1	–40.49	α_{20}	–14.81	β_{13}	2.26
	(–4.74)		(–4.28)		(8.13)
α_2	–40.29	α_{21}	–6.83	β_{14}	3.08
	(–4.06)		(–6.30)		(4.11)
α_3	–17.40	α_{22}	–12.71	β_{15}	2.67
	(–4.09)		(–6.42)		(7.35)
α_4	–13.87	α_{23}	–28.63	β_{16}	2.31
	(–3.95)		(–5.06)		(7.66)
α_5	–12.18	α_{24}	–14.45	β_{17}	3.10
	(8.70)		(–6.61)		(7.84)
α_6	–13.66	α_D	1.05	β_{18}	2.57
	(–4.27)		(0.63)		(5.10)
α_7	–14.18	β_1	4.65	β_{19}	1.20
	(–6.94)		(5.54)		(4.29)
α_8	–10.99	β_2	3.26	β_{20}	2.91
	(–7.14)		(3.50)		(4.98)
α_9	–12.95	β_3	3.18	β_{21}	2.18
	(–8.70)		(6.43)		(8.33)
α_{10}	–24.70	β_4	2.58	β_{22}	2.33
	(–2.50)		(5.37)		(7.13)
α_{11}	–29.47	β_5	2.53	β_{23}	3.65
	(–4.98)		(9.16)		(5.84)
α_{12}	–13.47	β_6	3.07	β_{24}	2.01
	(–4.63)		(5.71)		(9.59)
α_{13}	–6.67	β_7	1.89	β_D	–0.148
	(–4.88)		(8.12)		(–0.78)
α_{14}	–38.82	β_8	2.35	β_{CA}	–0.59
	(–5.31)		(7.53)		(–4.34)
α_{15}	–16.33	β_9	2.99	β_{CD}	–1.17
	(7.91)		(8.54)		(–14.44)
α_{16}	–8.93	β_{10}	2.13	ETA	–.00
	(–6.26)		(2.41)		(–0.92)
α_{17}	–16.28	β_{11}	2.49	Log-Likelihood	–3063.01
	(–7.75)		(3.94)		
α_{18}	–8.74	θ	0.174		
	(–4.10)		(0.22)		

In Table 2 we present the results for logit regression where *GDP* and *MNLINE* variables are excluded. We find that excluding these variables the results remain the same, which indicates that these results are quite robust. Table 3 presents the results of a

Table 2

Parameter Estimates for Logit Diffusion Model: GDP and MNLINE Excluded

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
γ	0.41	α_{18}	–9.08	β_{11}	2.59
	(41.83)		(–5.93)		(4.37)
α_1	–41.91	α_{19}	–10.89	β_{12}	1.77
	(–5.23)		(–8.19)		(4.49)
α_2	–41.26	α_{20}	–15.41	β_{13}	2.34
	(–5.10)		(–5.82)		(8.73)
α_3	–18.09	α_{21}	–7.03	β_{14}	3.15
	(–4.34)		(–6.51)		(4.45)
α_4	–14.23	α_{22}	–12.63	β_{15}	2.72
	(–4.79)		(–7.72)		(8.49)
α_5	–12.36	α_{23}	–29.34	β_{16}	2.35
	(–9.46)		(–5.34)		(8.72)
α_6	–13.37	α_{24}	–14.65	β_{17}	3.23
	(-4.38)		(–6.81)		(9.61)
α_7	–14.13	α_D	0.92	β_{18}	2.66
	(–7.36)		(0.69)		(9.51)
α_8	–11.06	β_1	4.80	β_{19}	1.25
	(–7.87)		(6.10)		(4.62)
α_9	–13.38	β_2	3.37	β_{20}	3.05
	(–9.55)		(4.30)		(8.44)
α_{10}	–25.80	β_3	3.26	β_{21}	2.24
	(–3.16)		(6.62)		(8.90)
α_{11}	–30.41	β_4	2.64	β_{22}	2.36
	(–5.46)		(6.70)		(8.36)
α_{12}	–14.02	β_5	2.59	β_{23}	3.74
	(–4.79)		(9.51)		(6.38)
α_{13}	–7.03	β_6	3.11	β_{24}	2.05
	(–5.34)		(8.13)		(9.98)
α_{14}	–39.51	β_7	1.89	β_D	–0.14
	(–5.71)		(9.84)		(–0.95)
α_{15}	–16.62	β_8	2.39	β_{CA}	–0.622
	(–8.38)		(8.82)		(–4.65)
α_{16}	–9.03	β_9	3.07	β_{CD}	–1.175
	(–6.69)		(10.97)		(–24.09)
α_{17}	–16.79	β_{10}	2.26	Log-Likelihood	–3065.82
	(–8.15)		(2.90)		

Table 3

Results for Diffusion Equation, Excluding Country-fixed Effects

Parameter	Estimate	Parameter	Estimate
γ	0.41	α_{15}	–11.79
	(23.07)		(–11.95)
α_1	–10.05	α_{16}	–8.99
	(–10.15)		(–8.97)
α_2	–2.98	α_{17}	–5.03
	(–1.64)		(-6.09)
α_3	–5.16	α_{18}	–3.49
	(–5.27)		(–4.67)
α_4	–10.48	α_{19}	–0.153
	(–10.58)		(–0.08)
α_5	–9.21	α_{20}	–6.03
	(–9.08)		(–6.62)
α_6	–2.62	α_{21}	–8.44
	(–3.73)		(–8.26)
α_7	–2.56	α_{22}	–12.47
	(–.81)		(–12.35)
α_8	–10.48	α_{23}	–11.29
	(–10.46)		(–11.36)
α_9	–3.18	α_{24}	–1.04
	(–4.89)		(–0.33)
α_{10}	–1.91	α_D	–10.54
	(–1.06)		(–3.57)
α_{11}	–2.15	β_D	1.63
	(–1.17)		(5.52)
α_{12}	3.56	β_{CA}	0.73
	(1.90)		(2.51)
α_{13}	–6.71	β_{CD}	0.76
	(–6.27)		(3.94)
α_{14}	–3.87	Log-Likelihood	–3420.62
	(–2.10)		

logit regression when all country fixed effects as well as the variables for gross domestic product and main telephone lines per capita are excluded. It can be seen that even by excluding these variables the results more or less remain the same. More specifically, the variables used for competition in analogue and digital technology remain significant as before. The coefficient for digital technology, $DIG_{it,}$ is statistically significant and larger than the first and the second regressions. However, this small variation in results does not alter our major findings.

5. CONCLUSIONS

This paper studied the determinants of diffusion of mobile phone services in selected Asian countries by employing a logistic model of technological diffusion. We find that 41 percent of total population will eventually adopt cellular phones in selected Asian countries. We also find that transition in early nineties from analogue to digital technology and corresponding increase in capacity impacted on diffusion of mobile telecommunications. It appears that technological developments in this sector induced even single operators to reduce their prices to attract more adopters. Nonetheless, the policy of introducing competition also paid off since competition played a dominant role in the digital period in reducing prices and in augmenting the process of diffusion of mobile phones in the included countries.

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Comments

Abid Burki and Shiren Aslam in their paper try to address the relative importance of three factors in the diffusion speed of mobile telephone in 25 randomly selected Asian countries.

Three factors which are analysed in the papers are:

(i) The technology (analogue vs digital).

(ii) The timing of first licensed granted.

(iii) The introduction of additional complication.

The impact of existing fixed-line network and GDP per capita on diffusion speed is also examined. The authors have used extended logistic regression model (given in Equation 5) for his analysis.

The authors are trying to estimate the number of adopters (Y_{it}^{*}) of new technology. However, they have mentioned that in practice it is difficult to estimate and hence it is be replaced by a constant fraction of total population as potential adopters. The authors have not mentioned what fraction they have taken and on what statistical ground. It is not clear whether they have done any statistical test and simulation to see the sensitivity of their consultant fraction.

In the denominators of Equation (5) the authors are trying to capture the effects of several variables by using dummy variables. Previous studies warn that such specification in logistic model may violate the assumption of homogeneity. The authors should check up and mention that their specification has not violated this basic assumption.

Furthermore, economic literature warns that if you are using the logistic function and you are using non-linear ordinary least squares, it may create problems for forecasting purposes. It is suggested that in such cases the maximum likelihood method should be used. The authors are advised to look up the literature and see what they can do to resolve this issue.

The last comment is regarding the validity of the result. The authors claim that from the data of random 25 countries, 41 percent of the total population are expected to adopt mobile phones in the long run. The authors have not defined long-term, i.e., one-year, three-year, or ten-year period.

The authors have used panel data of 25 countries but in my view better and more meaningful results can be achieved if this sample is divided into sub-samples.

These sub-samples may be on the basis of income, i.e., high income group, medium income group, or low income group; or it may be decompose on a regional basis, i.e., South Asia, East Asia, and so on. These revisions will make the results of this study more meaningful.

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