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Development Path and Influence Mechanism of the Mobile Communication Industry in China: Theoretical Model and Empirical Analysis

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Abstract: Mobile communication has experienced rapid growth in China. It plays a more and more important role in the process of informationization and economic development. However, as an emerging basic industry, the mobile communication industry also shows great regional imbalance in its development. Why there is still imbalance, since the institutional environment and the development policies are the same or even more favourable? Is it because of path independence, or is there any other reason? This paper improves Mansfield's model by introducing the penetration rate of effective saturation, and better combines the theoretical model with the econometric model. At the same time, by estimating the staged effective saturation parameters, the paper solves the problem that the final saturation parameters in the process of developing are not estimable, which was proposed by Harald and Frank (2000) in their empirical analysis. It successfully describes the differences in the diffusion paths of mobile communication in different regions of China, evaluates the impacts of the degree of urbanization, the intra-regional income gap, and other factors on the diffusion path, and puts forward corresponding policies for the informationization of regional balanced development, based on the results of empirical analysis.

Key words: Mobile communication; diffusion model; penetration rate of effective saturation; regional difference

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I. INTRODUCTION

The mobile communications industry is one of the important supporting industries for socio-economic informatization^①. China's mobile telecommunications industry started in 1987, with a TACS analogue cellular mobile phone system built and successfully used in Guangdong Province. After two decades of development, China's mobile phone industry has made remarkable achievements. By the end of 2006, the scale number of mobile phone users reached 461 million. As early as 2001, China had overtaken the United States to have the largest number of mobile phone users in the world, but because of China's large population base, the penetration level is only 35.3 percent, putting in the global middle range. In addition, it should be noted that China's mobile communication industry development is not balanced. The eastern region has 231 million users, accounting for more than 50 per cent of the total, while the central and western regions only have 27.4 per cent and 26.9 per cent respectively. Since, institutional and policy factors are similar, why is there such a big gap different regions? What development paths have they experienced? What factors have determined the development of different regions? These issues will be examined in this paper.

In research on the development path of new industry, to study the process of penetration in the socio-economic sectors, diffusion theories are often applied. Such theories are concerned with two core issues. The first is intensity of innovation use of a business or a new product purchased by consumers, whether other businesses or individuals. Mason and Clark back in 1941 raised the necessity to study this issue. With new industries and new technologies emerging, the study of this issue is becoming increasingly important. Mansfield (1961) summarized theoretical and empirical results in this area, and established a basic theoretical model of the spread. In this area, a model which had great impact is the Bass (1969, 1988) diffusion model, in which the influencing factors are divided into two categories: internal and external influencing factors. External effects are due to the impact of mass media, while internal effects are mainly brought about by interaction between consumers. Bass called the external effects "innovation", and the internal effects "imitators." The difference between Bass's model and Mansfield's model lies in the fact that the former gives equal importance to internal and external factors, which the other emphasizes the role of internal factors. In fact, there is no conflict between them; each is applicable to different content and industries. Bass's model is mainly used for durable goods, retail, agriculture, industrial innovation, the electronics industry, photography services, and technology innovation in such areas, while Mansfield's model is often used in emerging industries, high technology and innovation management, and telecommunications innovation^②.

No matter what kind of theoretical model is used, to estimated parameters is a problem. The most ideal situation is to have a sufficient sample of data covering the

^① Bouwman et al. (2007) have elaborated the importance of studying the mobile communication industry.

^② Bewley and Fiebig (1988) applied an extension of Mansfield's model to examples of telecommunications innovation.

whole process of diffusion, but in most cases, it is impossible, particularly, for studies that aim to guide the future development of target industries. Some studies (Hyman 1988; Tigert and Farivar, 1981, etc.) have shown that the estimated values of parameters are very sensitive to the collection period of samples. Therefore, in some empirical studies, the researchers (Gruber, 2007; Lee, 2007) had to give up estimating some parameters, particularly with regard to potential saturation rate estimates. To forego estimating potential saturation rate is very regrettable, because it means that we cannot ascertain the market space. In some cases, it may be possible to replace the saturation rate directly with the number of total target consumers. For example, if the process of diffusion is very short, the entry barriers are very low^①, and one consumer purchases only one unit of goods, the research may achieve satisfactory results. However, such situations do not happen often. The major problem is the consumer behaviors frequently change and the innovation process is often interrupted before the diffusion reaches full coverage.

In this paper, the results also show that the theoretical model parameters estimated are closely related to the time covered by the samples. We just evaluate the role of influencing factors by changing the period the sample covers^②. Taking into account that network effects are relatively prominent in the mobile communications industry, we adopt the model form used by Mansfield. The model form has been improved by Bewley and Fiebig (1988) and applied to studying the telecommunications industry. Based on the actual needs of practice, we develop the Mansfield model and econometric model to better estimate the "asymmetry" in reality, describe successfully the diffusion paths of mobile communications in different regions and compare constructively the differences existing between them.

In this paper, section II presents a brief introduction to Mansfield's (1961) model and then develops it, and discusses the parameters of developed model. Section III establishes the estimated Model and presents the data source. Part IV presents model estimates and reports results. The last part gives a simple summary and discussion.

II Theoretical Model

(i) Basic theoretical model

The process of penetration is actually the process by which potential users are

^① With the increase in the number of adopters, and the accumulation of learning experience, the cost of the product reduces due to the scale effect, and the cost of imitation reduces due to the learning effect. All of these may cause the reduction of entry barriers in the process of diffusion.

^② The major concern of his study is not the final saturation penetration rate. In fact, after the equation for determining saturation penetration rate is worked out, the predicted level of the final saturation penetration rate may be calculated on the basis of explaining the predicted values of the variables

continuously transformed into actual users. Then, what affects the speed of diffusion? Given the characteristics of the telecommunications industry, we develop Mansfield's (1961) model to describe the actual diffusion in China.

Let λ_{it} be the number of potential users turning into actual users,

$$\lambda_{it} = \frac{y_{it+1} - y_{it}}{N_i - y_{it}} \quad (1)$$

Where y_{it+1} and y_{it} are the numbers of actual users at time $t+1$ and t respectively. N_i is the number of potential users (for the mobile communications industry, it is the population).

We have reason to assume that diffusion rate is a function of several factors: (1) the present mobile penetration rate $\frac{y_{it}}{N_i}$ ^①. This variable has dual effect on the rate of diffusion. On the one hand, the higher the rate, the stronger the network effect, and the faster diffusion. On the other hand, the higher the rates, the smaller the number of potential users, and as most of there are marginal low-income users^②, the more difficult it is for the industry to develop. As for which role dominates, it depends on the stage of development. (2) Income IN_i . A mobile phone can be a durable good accompanied by on-going "maintenance" costs. In addition to paying for terminals, users also need to pay for services provided through the terminals, so income is also a very important factor, (3) Population density DEN_i . High population density reduces network building costs and marketing costs, and greater scale economy can support more powerful promotion. Imitation and psychological comparison between people may also play a significant raking role, population density an important influence factor. Of course, there may be many other variables, such as the penetration of the substitute products, fixed telephone, as we will expound in the empirical models in detail. Here, we use the three mentioned variables as representatives. Therefore, the penetration rate λ_{it} is a function of the variables mentioned above,

^① Penetration rate is a concept which is derived when the population number is divided by the number of existing users. But in reality, not all of the population is the potential users, for example, the possibility for the preschool children and extremely poor people to independently own the mobile phone is little; effective penetration rate can be gained if the number of users during saturation is divided by the number of existing users. This paper will make improvement theoretically and innovations empirically at this aspect.

^② The potential users who deliver higher utility evaluation concerning the new communication tools are inclined to make earlier purchasing decisions. Therefore, the general average utility evaluation of the potential users cuts down with the shape of "ladders". In the later stage, developing new users will be correspondingly harder.

$$\lambda_{it} = f_i \left(\frac{y_{it}}{N_i}, IN_i, DEN_i, \dots \right) \quad (2)$$

We assume that the change of the number of users is continuous rather than discrete^①, and then we expand equation (2) using Taylor formula, and leave out the high-end items beyond two, we can conclude:

$$\lambda_{it} = a_{i1} + a_{i2} \frac{y_{it}}{N_i} + a_{i3} IN_i + a_{i4} DEN_i + a_{i5} IN_i \frac{y_{it}}{N_i} + a_{i6} DEN_i \frac{y_{it}}{N_i} + a_{i7} IN_i DEN_i + \dots \quad (3)$$

$$\diamond V_i = a_{i1} + a_{i3} IN_i + a_{i4} DEN_i + a_{i7} IN_i DEN_i + \dots$$

$$\omega_i = a_{i2} + a_{i5} IN_i + a_{i6} DEN_i + \dots$$

Equation (3) is simplified to be :

$$\lambda_{it} = v_i + \omega_i \frac{y_{it}}{N_i} \quad (4)$$

and equation (2) $\lambda_{it} = \frac{y_{it+1} - y_{it}}{N_i - y_{it}}$

$$y_{it+1} - y_{it} = (N_i - y_{it}) \left(v_i + \omega_i \frac{y_{it}}{N_i} \right) \quad (5)$$

If we assume that the time interval is short enough compared to the entire development cycle, then equation (5) can be expressed as

$$\frac{dy_{it}}{dt} = (N_i - y_{it}) \left(v_i + \omega_i \frac{y_{it}}{N_i} \right) \quad (6)$$

Solving the differential equation (6) gives:

$$y_{it} = \frac{N_i \{ \exp[\eta_i + (v_i + \omega_i)t] - (v_i / \omega_i) \}}{1 + \exp[\eta_i + (v_i + \omega_i)t]} \quad (7)$$

It is reasonable to assume that the number of mobile users tends to be zero when t tends to $-\infty$, that is,

$$\lim_{t \rightarrow -\infty} y_{it} = 0$$

We then get $v_i = 0$, Equation (7) can be simplified as follows

^① When the number of the total population is very large, although the growth process is the accumulation of single discrete, whereas the variation may be regarded as approximately continuous.

$$y_{it} = \frac{N_i}{1 + \exp(-\eta_i - \omega_i t)} \quad (8)$$

As mobile communications is an emerging technology, with it can reasonably be assumed that of mobile users will increase over time, therefore, $\omega_i > 0$. Testing shows that, when $t \rightarrow +\infty$, $\lim_{t \rightarrow +\infty} y_{it} = N_i$, which is in line with the development of the theory.

(ii) The non-symmetric and assessment model

The basic model is not very different from Mansfield's (1961) classic Logistic model regards the form, the only difference lies in the indication of variables. The model was developed by Harald and Frank (2000) and Kwamena (2004), and directly applied to studying the diffusion of technology. Some scholars, such as Nelder (1962), McGowan (1986), and Bewley and Fiebig (1988) changed the basic model into non-symmetrical form. They went one step further in depicting the actual phenomenon. However, they did not pay much attention to the problem of mismatch between the theoretical saturation rate and the practical saturation rate. For theoretical research, there is no problem, but for evaluating practice, failure to consider such mismatch may lead to serious consequences: due to a variety of factors, the saturation rate may not be known. If we directly substitute the saturation rate with the population, serious consequences may result. In addition to some pre-school children, other groups may not become effective potential users, either due to objective reasons, such as poverty, or simply because they have no need to use the service, for example people who have access to fixed lines and rarely leave home. Under such circumstances, another kind of asymmetry emerges; the diffusion process is non-symmetrical due to the "saturation" level that people directly observe, although if it is symmetrical between the starting point and the actual saturation point.^①

So, how can we solve this mismatch problem? We can assume that, in a certain region, the actual saturation level is a function of the observed population. For

^① It is easy to prove that the spread function in (8) is symmetrical concerning the inflection point $(-\eta_i/\omega_i, N_i/2)$. Change the coordinate system. Assume $t = t' - \eta_i/\omega_i$, $y_i = y'_i + N_i/2$. And regard $(0,0)$ as the inflection point. Then the spread function in the new coordinate system becomes $y'_i = 0.5[1 - \exp(-\omega_i t')]/[1 + \exp(-\omega_i t')]$. It is obvious that the new function is symmetrical concerning the initial point, and the original function is symmetrical concerning $(-\eta_i/\omega_i, N_i/2)$.

However, if the observed N_i is not the actual saturation rate, this symmetry does not exist. Figure 1 (a) clearly shows this point. When $\delta_i = 1$ is the situation in which the observed value is the saturation value, the penetration rate will be symmetrical at the position $1/2$, but it is asymmetrical under the other two conditions.

simplicity, we assume $N_i = \frac{POP_i}{\delta_i}$, substitute it into equation (8) and transform the expression,

$$y_{it} = \frac{POP_i}{\delta_i + \delta_i \exp(-\eta_i - \omega_i t)} = \frac{POP_i}{\delta_i + \exp(\ln \delta_i - \eta_i - \omega_i t)}$$

Let $\rho_i = \ln \delta_i - \eta_i$, The above equation can be simplified into

$$y_{it} = \frac{POP_i}{\delta_i + \exp(\rho_i - \omega_i t)} \quad (9)$$

$\delta_i, \rho_i, \omega_i$ Do all parameters need to be estimated?

Now, let us set the econometric model. Change equation (9) into:

$$\ln\left(\frac{POP_i}{y_{it}} - \delta_i\right) = \rho_i - \omega_i t \quad (10)$$

as δ_i is unknown, we can estimate it utilizing the above equation now. We derive for equation (9):

$$\frac{dy_{it}}{dt} = \frac{\omega_i y_{it}^2}{POP_i} \left(\frac{POP_i}{y_{it}} - \delta_i \right) \quad (11)$$

We take the log for both sides of equation (11):

$$\ln\left(\frac{POP_i}{y_{it}} - \delta_i\right) = \ln\left(\frac{dy_{it}}{dt}\right) - \ln \omega_i - 2 \ln y_{it} + \ln(POP_i) \quad (12)$$

By (10) and (12) :

$$\ln\left(\frac{dy_{it}}{dt}\right) - 2 \ln y_{it} + \ln(POP_i) = \rho_i + \ln \omega_i - \omega_i t \quad (13)$$

The three terms are new subscribers, total number of subscribers and the population size in log form in year t in region i . We can get the data from statistics, then by estimating equating (13), we can get ρ_i and ω_i . Substituting ω_i into equation (11) and performing simplification transformation: gives:

$$1 - \frac{1}{\omega_i} \frac{dy_{it}}{dt} \frac{1}{y_{it}} = \delta_i \frac{y_{it}}{POP_i} \quad (14)$$

$\frac{dy_{it}}{dt} \frac{1}{y_{it}}$ and $\frac{y_{it}}{POP_i}$ are the growth rate and the penetration rate in year t in

region i respectively, and ω_i has been estimated, then we can get the value of

parameter δ_i through no intercept constrained regression for equation (14).

(iii) The economic implications of model parameters

Now we discuss the economic implications of parameters:

We can know from $\lim_{t \rightarrow +\infty} y_{it} = \frac{POP_i}{\delta_i}$, that δ_i is the parameter to determine the

level of the saturation rate. δ_i is positive, the greater its value, the smaller the rate of saturation. Under normal circumstances it should be more than 1. However we cannot rule out the situation where it is less than 1 when one subscriber owns more than one mobile phone.

We transform equation (9)

$$PEN_{it} = \frac{y_{it}}{POP_i} = \frac{1}{\delta_i + \exp(\rho_i - \omega_i t)} \quad (15)$$

We have

$$t = \frac{\rho_i - \ln\left(\frac{1}{PEN_{it}} - \delta_i\right)}{\omega_i} = t(\rho_i, \delta_i, \omega_i, PEN_{it}) \quad (16)$$

If the penetration rate reaches the basic level PEN_0 , by partially deriving

$t(\rho_i, \delta_i, \omega_i, PEN_0)$ toward $\delta_i, \rho_i, \omega_i$ respectively, we can conclude,

$$\frac{\partial t(\rho_i, \delta_i, \omega_i)}{\partial \rho_i} \Big|_{PEN_{it} = PEN_0} > 0, \frac{\partial t(\rho_i, \delta_i, \omega_i)}{\partial \delta_i} \Big|_{PEN_{it} = PEN_0} > 0, \frac{\partial t(\rho_i, \delta_i, \omega_i)}{\partial \omega_i} \Big|_{PEN_{it} = PEN_0} \leq 0$$

We can see the bigger is δ_i , the bigger is ρ_i and the smaller is ω_i , the longer it takes to reach the basic penetration level. We can directly observe this From figure 1 (a), (b), (c).

To assume $PEN_{i2} \geq PEN_{i1}$, we now inspect the time required for the penetration rate to rise from PEN_{i1} to PEN_{i2} :

$$\Delta t = \omega_i^{-1} \ln\left(\frac{1 - \delta_i PEN_{i1}}{1 - \delta_i PEN_{i2}} \frac{PEN_{i2}}{PEN_{i1}}\right) = \Delta t(\omega_i, \delta_i, PEN_{i1}, PEN_{i2}) \quad (17)$$

It is very interesting that the speed of penetration diffusion has no relationship with ρ_i after penetration surpasses the zero level. By partially derivation toward

ω_i, δ_i , we have $\frac{\partial t(\omega_i, \delta_i)}{\partial \omega_i} < 0$, $\frac{\partial t(\omega_i, \delta_i)}{\partial \delta_i} > 0$. These inequalities show that the

bigger is ω_i , the faster the diffusion, just as figure 1(d) shows. ω_i is said to be the imitation spread parameter.

δ_i determines not only the final saturation level (see Figure 1 (a)), but also the speed of diffusion (see Figure 1 (d), the bigger the δ_i , the smaller the proportion of potential users. Diffusion becomes more difficult, so we call it the effective saturation parameter.

As derived in the forgoing process, $\rho_i, \delta_i, \omega_i$ all impact the starting period of market, and ρ_i is the direct factor. Once the penetration surpasses zero level, ρ_i 's influence disappears, so we call ρ_i the Start Damping parameter.

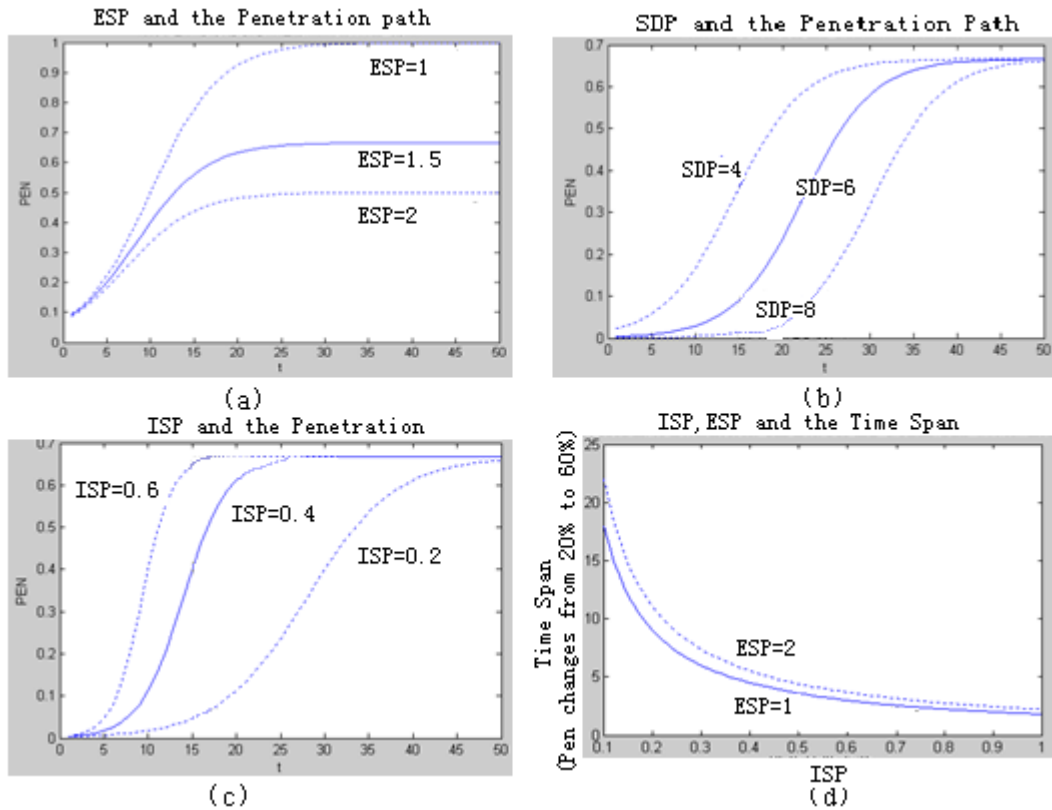


Figure 1 The impact of ESP (the Effective Saturation Parameter), SDP (the Start Damping Parameter) and ISP (the Imitation Spread Parameter) on the penetration path

III Econometric Model and Data

(i) Econometric Model Set

Based on theoretical models, the diffusion path of mobile phone users can be estimated through the following two equations:

$$Y_{it} = \alpha_i + \beta_i t + \xi_{it} \quad (18)$$

$$Z_{it} = \delta_i PEN_{it} + \zeta_{it} \quad (19)$$

$$\text{and } i = 1, 2, \dots, 30, \quad t = 1990, 1991, \dots, 2006, \quad Y_{it} = \ln\left(\frac{dy_{it}}{dt}\right) - 2 \ln y_{it} + \ln(POP_i),$$

$$\alpha_i = \rho_i + \ln \omega_i, \quad \beta_i = -\omega_i, \quad Z_{it} = 1 - \frac{1}{\omega_i} \frac{dy_{it}}{dt} \frac{1}{y_{it}}, \quad PEN_{it} = \frac{y_{it}}{POP_i}.$$

If ρ_i , δ_i and ω_i determine the diffusion of mobile subscribers and can be estimated, then what determines these parameters? Why are these diffusion paths different in different districts? Factors that influence these three parameters may be various, such as per capita income, population density, the proportion of urban population, service charges and handset prices, the amount of investment in telecommunications, fixed telephone penetration rate, and so on. These factors influence the whole process variously. We cannot collect complete data to estimate the various effects. However, we can distinguish what determined the different paths for the characteristics that have been comparatively stable under the situation that no huge change has occurred since 1990. In order to consider the impact of changes in factors, based on the data from 1990 to 2002-2006, we estimate the corresponding parameters, and then regress these parameters to explanatory variables.

The Econometric model is structured as follows:

$$\begin{pmatrix} \rho_i \\ \delta_i \\ \omega_i \end{pmatrix} = \Gamma X = \begin{pmatrix} \tau_{10} & \tau_{11} & \tau_{12} & \dots \\ \tau_{20} & \tau_{21} & \tau_{22} & \dots \\ \tau_{30} & \tau_{31} & \tau_{32} & \dots \end{pmatrix} \begin{pmatrix} 1 \\ AGDP_{it} \\ DEN_{it} \\ \dots \end{pmatrix} + \begin{pmatrix} \zeta_{1i} \\ \zeta_{2i} \\ \zeta_{3i} \end{pmatrix} \quad (20)$$

$$\text{and } i = 1, 2, \dots, 30, \quad t = 2002, 2003, \dots, 2006.$$

(ii) Data sources and data-processing

For 1990 to 1998 in various provinces and cities, data of mobile phone users and mobile phone penetration rate, the number of fixed telephone subscribers and fixed telephone penetration rates are taken from the "China Communications Statistical Yearbook (1991-1999)". For 1999-2006, data for mobile phone users, mobile phone penetration rate, the number of fixed telephone subscribers, fixed telephone penetration rate, operating income, business output, the amount of completed investment in telecommunications industries, and the number of employees are taken from the Ministry of Information Industry. GDP, population, the urban population, urban and rural household disposable income, geographic area and other indicators

are from the "China Statistical Yearbook (2001 - 2007)."

Some indicators are calculated from the original data as follows:

$$\text{Population density of province } i = \frac{\text{Population of province } i}{\text{Geographic area of province } i} \quad (21)$$

$$\text{Urban population proportion in province } i = \frac{\text{Urban population in province } i}{\text{Total population in province } i} \quad (22)$$

$$\text{Income difference between urban and rural areas} = \frac{\text{Urban household average disposable income} - \text{Rural household average disposable income}}{\text{Rural household average disposable income}} \quad (23)$$

$$\text{Service price in province } i = \frac{\text{Operating income in province } i}{\text{Business output in province } i} \quad (24)$$

IV Model estimation and results

We take two steps to estimate the model. First step, we estimate the model parameters; second, we use the parameters estimated in the first step as our dependent variables and identify their determinants in our sample.

(i) Estimation of Model parameters: the impact of ESP (Effective Saturation Parameter), SDP (Start Damping Parameter) and ISP (the Imitation Spread Parameter) on the penetration path

Although the parameter values we used in the second step are those for 30 provinces and cities^①, for brevity, we will report results of region-level estimations. As shown in table 1, the estimated values of ISPs are surprising. ISPs in the Middle and the West are higher than that in the East, that is, the diffusion in the Middle and the west is faster than in the East. This is inconsistent with what we observe from figure2. The diffusion line in the East is steeper than those in the Middle and the West. Moreover, the growth rates calculated for the period 2002-2006 also support the conclusion indicated in Figure2; the average growth rate in the East is 6.20 per cent,

^①In order to achieve continuity of the sample, the paper continues the administrative divisions before 1997 to include Chongqing City in Sichuan Province.

higher than the Middle's 3.40 per cent and the West's 3.36 per cent. So why do we draw such contradictory results?

Assume that other conditions are totally identical, but actually the penetration rates of effective saturation in different regions are not identical. At present, the effective saturation parameter of the east is relatively low, which indicates that the east has a relatively high penetration rate of effective saturation^①. If the effect caused by the differences in the penetration rate of effective saturation in the east, middle and west is eliminated, that is, the average growth of penetration rate / the penetration rate of effective saturation, the relative growth rate for the east, middle and west will be 11.00%, 11.56%, and 11.71% respectively. This shows that the west has the fastest rate, which is consistent with both the theoretical and estimated result. However, this seems to conflict with the intuitive feeling that the east should have the fastest rate. In fact, as the statistics show, the east has the higher absolute growth rate, but it is slower than the middle and the west with regard to the penetration rate of effective saturation. The reason why the middle and west areas are "faster" in the process of approaching the penetration rate of effective saturation is related to their late start and the large-scale reduction in the price of mobile communication terminals and charges at a later stage. Based on the start-up damping parameters, the differences in the starting stage of the mobile communication industry in different regions can be found; the middle and the west have higher start-up damping parameter compared with the east, which indicates that the starting stage of the middle and west areas is much slower than that of the east, but there is no clear difference between the middle and the west.

Figure 2 presents the actual penetration rate and the theoretical penetration rate calculated based on the estimated results. These are consistent.

Table 1 Regional Diffusion Parameters of Mobile Phones in China Estimated Based on the Data in 1990-2006

Parameters	Model 1			Calculated Values	Model 2		
	$-\omega$ (ISP)	$\rho + \ln \omega$	R^2		δ (ESP)	R^2	Obs
The East	- 0.652** * (0.027)	8.778*** (0.288)	0.98	9.206	1.776*** (0.482)	0.83	16
The Middle	- 0.763** * (0.051)	11.204** * (0.540)	0.94	11.474	3.398*** (0.671)	0.62	16
The West	- 0.771**	11.473** *	0.96	11.733	3.486***	0.71	16

^①The penetration rate of effective saturation varies when the time of estimate differs, so directly assuming $\delta = 1$ in the quantitative analysis is problematic.

	*					
	(0.040)	(0.423)			(0.743)	

Note: *** means it is significant at the confidence level of 1%.

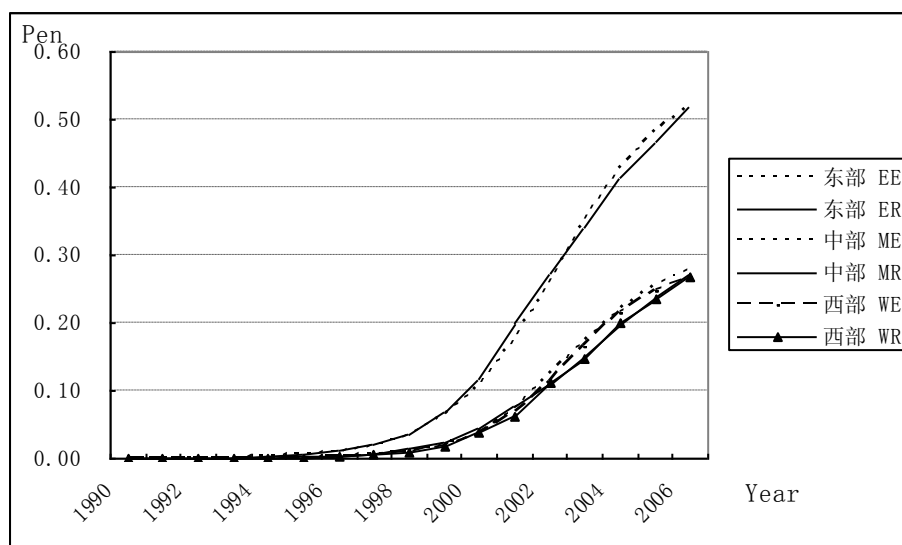


Figure 2 Theoretical and Actual Diffusion Paths of the Regional Penetration Rate in China (1990-2006)

(ii) Estimated Roles of Factors Influencing the Diffusion Path

The estimate is based on the panel data, regarding the diffusion path parameters of the mobile phone users in each province in 2002-2006 as variables. The Breusch - Pagan Lagrangian Multiplier Test is used to choose a fixed effect model. In order to avoid the influence of heteroscedasticity between groups, the standard deviation is adjusted, and consistent standard deviation after the adjustment is adopted. See the estimated results in table 2.

The mobile phone penetration rate is the indicator usually used or to measure the network effect. According to the Theory of Diffusion, the penetration rate should have significant positive impact on the diffusion speed. However, viewed from the regression result, there are negative values which are not significant^① in affecting the imitation diffusion parameters^②. The diffusion of mobile communication is believed to have its own particularities. Also the stock penetration rate is considered to play two roles in growth: relatively large-number of stock users means a relatively large network effect, which is more attractive to new users, and increases the "contact" among users. This has positive effects on diffusion. On the other hand, the increase of stock users means a decrease in the potential users, which will lead to more invalid contact. In this way, the diffusion speed will be weakened. The impact on the diffusion speed is finally determined by the combined effect of these two aspects. Since the paper uses the data for 30 provinces and cities, which are at different stages

^①The indicator of the penetration rate of mobile phone is not significant. This does not mean that there is no network effect, but that such impact is cancelled out by other impacts.

^② Because the capacity of the sample is limited, these two effects cannot be separated.

of development, the results will be mixed. Therefore, there will be results that are not significant^①. However, this effect can be partially found in the estimation of the start-up damping parameter. At an early stage, the positive effect of the stock is dominant, so the starting speed will be accelerated. Therefore, a negative impact of the mobile phone penetration rate on the start-up damping parameter is seen. However, this result is not statistically significant. If the penetration rate of mobile phone is higher, the network effects will be greater, that is, if the value to the users is higher, a relatively high penetration rate of effective saturation will be caused. The estimated result is consistent with the theoretical expectations. The study of Harald and Frank (2000) does not lead to the effective estimation of saturation penetration parameters. Their explanations are that the process of diffusion is not complete, and effective saturation parameters are not estimable. It is admitted that it is difficult to evaluate the final effective saturation parameters before the diffusion process. However, the staged effective saturation parameters are estimable, and will converge toward the final effective saturation parameters with the change of influencing factors and the passage of time. The theoretical model proposed by this paper provides good support for this estimate. As shown in Figure 2, estimated effective saturation parameters in different regions in the last year are calculated and are substituted into the theoretical model, together with other corresponding estimated values of parameters, so that a good fit is achieved.

The relationship between the fixed telephone and mobile phone is complex; they are both alternative and complementary. Owning fixed telephones will reduce the demand for mobile phones, and on the other hand, the associated network effects between fixed telephones and mobile phones will also increase the demand for interconnection and intercommunication^②. The estimated results show that the penetration rate of fixed telephones has only slight negative effect^③ on the imitation diffusion parameters of the mobile phone users. A significant negative impact on the start-up damping parameter indicates that the existence of fixed telephones has accelerated the start of the mobile communication industry. It is speculated that not only is the demand for interconnection and intercommunication increased, but also the learning cost in areas with a relatively high penetration rate of fixed telephone is relatively low, because the mobile communication services and the fixed communication services belong to the same information communication tool. The penetration rate of fixed telephones has also played a positive role in the penetration rate of effective saturation. However, this result is not statistically significant.

^① Because the capacity of the sample is limited, these two effects could not be separated.

^② M.L. Katz and C. Shapiro (1986) studied the impact of network effect on different technology diffusions, and the consumers' choice of techniques, which are influenced not only by the degree of normality, but also by the sequence of choices, the degree of imperfection and variation of information, and the lock-in effect and the conversion cost, using Game Theory.

^③ In the study of Harald and Frank (2000), it is statistically significant, which may be related to the differences of the sample selection areas. Their samples were collected from 15 countries in the EU, whose mobile communication industry developed relatively earlier. Also the charges for mobile communication and fixed communication are almost on the same level, so the substitution effect is relatively significant. However, in China, the charges for mobile communication have been kept at a relatively higher level than that for fixed communication in the past periods, so the substitution effect is not significant in China.

Table 2 Estimated Roles of Factors Influencing the Diffusion Path

	Model 1	Model 2	Model 3
	Intimation Diffusion Parameters (ω)	Start-up Damping Parameters (ρ)	Effective Saturation Parameters (δ)
Penetration Rate of Mobile Phone	-0.103 (0.108)	-0.450 (0.521)	-1.682* (0.942)
Penetration Rate of Fixed Phone	-0.001 (0.001)	-0.007** (0.003)	-0.037 (0.031)
Charge of Telecom services	-0.047*** (0.015)	0.299*** (0.099)	0.286* (0.165)
Investment in Telecom (logarithm)	0.070* (0.040)	-0.126** (0.061)	-0.175 (0.268)
Trade Advantage Index of Communication Equipment	0.004** (0.002)	-0.025* (0.014)	-0.477* (0.261)
Per Capita GDP (logarithm)	0.043 (0.036)	-0.304** (0.151)	-4.490** (2.186)
Population Density (logarithm)	0.904** (0.420)	3.713 * (2.141)	0.481*** (0.162)
Urban Population Proportion	0.001 (0.005)	-0.069** (0.028)	-0.618** (0.303)
Rural-urban Income Gap	0.046* (0.025)	0.252 (0.246)	-2.021** (0.918)
Constant Term	-4.006* (2.132)	-9.594 (8.530)	2.116 (1.310)
Goodness of Fit (R^2)	0.88	0.82	0.65
F Value	68.61	74.59	17.82
Obs	150	150	150
Breusch - Pagan Lagrangian Multiplier Test(chi2)	148.32	165.90	10.15

Note: * means it is significant at the confidence level of 10%, ** means it is significant at the confidence level of 5%, and *** means it is significant at the confidence level of 1%; After the Breusch - Pagan Lagrangian multiplier test, the paper adopts the fixed effect model. The bracketed figures are the adjusted standard deviation (Std. Err. adjusted for 30 clusters in provinces).

The charges of telecom services have significant negative impact on the imitation diffusion parameters. If the charges for communication services are higher, the diffusion spread of mobile phone will be slowed down. This has significant positive impact on both the start-up damping parameter and the effective saturation parameter, which indicates that a relatively high charge will lead to relatively slow

start of the industry and relatively low penetration rate of effective saturation. Clearly, price is still the key factor affecting the start of the industry, the diffusion speed, and the penetration rate of effective saturation of mobile phone.

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The investment in telecom has opposite effect on the diffusion path to charges for telecom services. A higher level of investment will lead to higher diffusion speed, start-up speed, and penetration rate of effective saturation. However the impact on the effective saturation parameters is not significant^①.

The trade index of communication equipment reflects the comparative advantages of the communication equipment manufacturing industry in China to the OECD. The increase in comparative advantage enhances the penetration of mobile phones, and promotes the starting speed of the industry and the penetration rate of effective saturation. The development of the manufacturing industry of China-made communication equipment will not only reduce the cost of network creation and terminal prices, but also accelerate the efficiency of supply. Therefore, the development of related industries in the country also has a very important promoting effect on the development of its mobile communication industry.

The estimated influence of per capita GDP on the imitation diffusion parameters is consistent with the estimate made by Harald and Frank (2000), that is, per capita GDP is positively, but not significantly related to the diffusion parameters. Although the impact of per capita GDP on the diffusion speed is not significant, it is very important to the starting of the mobile communication industry and the development perspectives of the industry. A high level of income is accompanied by a rapid start and a high penetration rate of effective saturation.

Population density plays a significant promoting role on the imitation diffusion parameters. A denser population will lead to more contact among people, which in turn will create higher demand for mobile communication, and the diffusion speed will be faster. The population density also has a significant positive impact on the start-up damping parameter, which means that a larger population base will need a longer time to reach a certain penetration level of the industry. Similarly, a large population base will directly affect the penetration rate of effective saturation.

The urban population proportion reflects the influence of the degree of urbanization on the diffusion path of mobile communication. Based on the estimated results, if the proportion of urban population is higher, the starting speed of the industry will be faster. However, in the process of diffusion, although the function is positive, however not significant; if the degree of urbanization is higher, the penetration rate of effective saturation will be higher.

The rural-urban income gap is a key factor in reasoning the effect of the dual economic structure on the diffusion path of mobile communications in China. contrary to most expectations, if the gap between urban and rural areas is greater, after the industry starts, the diffusion speed of mobile phone will be faster. The authors

^① Nir Kshetri and Maggie Kei Cheung (2002) have discussed the functions of investment in telecom on the rapid diffusion of mobile phone in China in many of their academic articles.

think that greater intra-regional economic development encourage large-scale population mobility, so that the demand for mobile phones will be higher, and the diffusion speed will be faster^①. However, the rural-urban income gap has positive impact on the start-up damping parameter. That is, if the gap between rural and urban areas is greater, the start up of the industry will be slower, although this effect is not significant. There is also a relatively high penetration rate of effective saturation in regions with a relatively great rural-urban gap. That a surprising phenomenon, which may be result from the situation in which minimum consumption, has been reduced and the income gap has no longer been a major obstacle since 2002^②.

V. Research Conclusions and Policy Suggestions

In order to further and specifically study the development of the mobile communication industry in China, the present paper improves Mansfield's model by introducing the penetration rate of effective saturation, combines the theoretical model and the econometric model, and solves the problem of weak correspondence between the empirical and theoretical rate of saturation in previous studies. It successfully explains the differences in the diffusion paths of mobile communication in different regions of China. Moreover, this paper also solves the problem that the final saturation parameters in the development process are not estimable, as proposed by Harald and Frank (2000). At each development stage, there is one effective scale of saturation, as estimable. These may be extended over time, and gradually approach to the final effective saturation parameter.

This study shows that the industry in the middle and west areas started relatively late. Although they had relatively fast diffusion speed with regard to the penetration rate of effective saturation, attention should be paid to the follows: By the end of 2006, the estimated penetration rate of effective saturation in the middle and west regions was still a relatively low, at only 29.4 mobile phones/ 100 people and 28.6 / 100 people respectively, while, the rate in the east was 56.3 / 100 people. There are still significant gaps among different regions. The relatively low penetration rate of effective saturation does not mean that the demand for mobile communication services is low, but that the effective demand is low. Because mobile communication services belong to the basic information services, bridging the digital divide plays an important role in narrowing the economic gap between the east, the middle and the west regions. The penetration rate of effective saturation in the middle and west areas must be improved. Viewed from the influencing factors, the network effect of mobile phones is significant. The stock users will greatly promote the growth of the penetration rate of effective saturation; and secondly, the charges for telecommunication services are included in the daily expenses. A high level of charges goes against the increase of the penetration rate of effective saturation.

^① In August 2008, Microsoft announced the launch of a “rural phone” with complete functions and low price for the large number of floating rural migrant workers in China, which is due to the great demand brought by the large population flow in China.

^② The emergence of flea markets and the launch of text message services make it possible to meet the need for communication at a low cost.

Thirdly, the trade advantage index of communication equipment indicates the relatively developed state of the communication equipment industry in China. The strengthening of related industries will be propitious to reduce the prices of communication terminals and the cost of communication tools, so their development will have a very important and positive impact on the growth of the penetration rate of effective saturation. The fourth key influencing factor is the per capita GDP. This stands for the consumption capacity of people. The need for communication is a relatively high level needs^①. Therefore, income level is the fundamental factor influencing the diffusion of mobile communication, especially for regions with a relatively low income level^②. Fifthly, the urban population proportion represents the degree of urbanization. People in urban areas have relatively more income and higher communication demand^③, so increase in the degree of urbanization will help promote the penetration rate of effective saturation. Finally, the rural-urban income gap within the same region plays positive role in promoting the penetration rate of effective saturation, as the rural-urban income gap will lead to the floating of population, which will create a higher demand for mobile communications^④. However, this does not mean that the rural-urban income gap should be encouraged or enlarged in order to accelerate the development of mobile communications. Rather obstacles to labour mobility between urban and rural area should be eliminated, which would essentially solve the problem. The factors influencing the start up and development of the mobile communication industry and those factors influencing the effective saturation parameters are similar. The main difference lies in investment. Investment in telecoms does not have significant influence on the penetration rate of effective saturation, while it has a significant impact on the start-up damping parameter.

Based on the above conclusions, the paper suggests:

1. In the early stage of the development of mobile communication, preferential policies should be undertaken to increase the penetration rate of mobile phone to a certain level as soon as possible, and to upgrade the promoting effect of network effect subsequent development; at present, there is no such problem in the more developed regions. Mostly, the remote areas still remain in the initial stage of communication services. In these areas: (1) improve network creation to accelerate

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Maslow's motivation theory divides human needs into five categories: physiological need, security needs, social needs, esteem needs, and self-actualization needs, which are ordered from the lower to upper level. Only the basic needs of physiological and security needs are met, will the people have the demand for the relatively higher level of need, such as the social needs. And the demand for communication belongs to the social needs.

② If the income is high, there will be no restriction, so the impact may be not significant. For instance, the study of Harald Gruber and Frank Verboven (2000) found that the influence of GDP to the diffusion of mobile communication in countries of EU is not significant.

③ Generally speaking, industry and service trade have much higher demand for daily communication.

④ It is speculated that the effect of income gap on the penetration rate of effective saturation is uncertain. If the income gap is too large, the gap between urban and rural economic structure may be too great, which may impede labor mobility, and its role in promoting the development of mobile communication is difficult to play. Because the indicators of rural-urban income gap within the same province or city is adopted here, the differences in economic structure may not reach the extent of the obstacles to mobility, the result is positive.

the start of the mobile communication industry by increasing investment in telecommunications; (2) provide tariff subsidies^①, to reduce the consumption cost to consumers in poor areas, to speed up imitation diffusion, and promote the development of information technology in these areas;

2. The development of the communication equipment manufacturing industry in China is of great significance for the start, diffusion, and enhancement of the penetration rate of effective saturation of mobile communications. A special venture capital fund for the technology research and development of the communication equipment manufacturing industry could be set up to support SMEs in the communication equipment manufacturing industry. The government should continue to open up the communication equipment manufacturing sector and activate competitions in the market to create effective support for telecom operations and services;

3. Per capita GDP growth is both the direct goal of economic development, and plays an important role in the process of economic growth. Per capita GDP has decisive influence on the industrialization of product innovation and the scope for market growth. Therefore, maintaining a continued growth in the backward areas is also the main driving force to promote the penetration and informationization of mobile communications.

4. The degree of urbanization and population flow between urban and rural areas will cause relatively high demands, thus speeding up the process of informationization. Therefore, countries should eliminate barriers to mobility between urban and rural areas, promote the urban industrial chain to extend to the rural areas, and encourage rural residents to participate in economic activities in the urban areas. This is not simply to create the demand for mobile communication, but to promote the informational role of mobile communications to facilitate in the process of urbanization.

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^①At present, among the services implemented in most countries, this part of subsidies is included besides the investment capital for network building.

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