

FMS patterns: Penetration vs. traffic substitution in different groups of countries

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Abstract

This paper studies the issue of fixed to mobile substitution, or FMS, which in recent years has become a significant trend. FMS occurs in two ways: one is the effect of a shift of traffic from fixed line to mobile; the other is the effect on fixed line penetration of the growth of mobile subscriptions. These two effects are called traffic substitution and penetration substitution, respectively. This paper, based on data from 1997 through 2004, finds that different substitution effects are taking place in different economies. In the more developed countries (G7 and NIE) FMS models mainly focus on ‘traffic substitution’. However, in the emerging economies (ASEAN and BRIC) FMS patterns mainly focus on ‘penetration substitution’ in association with the income effect. Policy implications on information economics are drawn from the above phenomena.

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1. Introduction

The history of new emerging communications technologies replacing old technologies keeps repeating itself. Since Alexander Graham Bell invented the telephone in 1876, the telephone co-existed with the

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current main technology of the telegram for a long time (the naming of AT&T—American Telephone and Telegraph is historical evidence, the telegraph being the medium for sending telegrams). It took more than a hundred years for the telephone to replace the telegram. The function of the telegram–text transmission—has only recently been replaced by fax. Mobile communication technology, widely deployed in the 1990's, has now begun to take the place of conventional PSTN (Public Switching Telephone Network). This article studies FMS (Fixed to Mobile Substitution), to discover the differences in FMS patterns among the countries at different levels of economic development and to attempt to derive some basic rules for the evolution of the industry and markets.

The object under study for this article is the four groups of regions/countries, namely, G7, NIE, ASEAN and BRIC. Russia has been removed from G8 due to the relative lower per capita GDP and reclassified with the BRIC group. Thailand, Malaysia, the Philippines and Indonesia have been selected as examples from among the ten ASEAN countries, while Singapore has been placed in the NIE (New Industry Economies) group due to similarities in economic development. The spread of fixed and mobile penetration of the four groups reveals significant differences among them during the period 1997–2004 [1,2]. The growth and decline of fixed household penetration and mobile population penetration among the four groups is clearly shown in Fig. 1a and b where the horizontal axis represents fixed penetration and is based on households and the vertical axis represents mobile penetration and is based on population. The trends are very clear; mobile penetration universally increased.

This paper studies fixed penetration based on households, which more closely represents the actual situation of consumer use than that based on population, compares global relative fixed penetration through eight years and distinguishes the two FMS patterns of 'traffic substitution' and 'penetration substitution'. We must here note that in the developed countries the telecom infrastructure is well developed and the investment of connecting lines to every household has already been made. In developing countries, however, the situation is different because the telecom infrastructure is less ubiquitous and therefore the deploying of mobile networks requires less capital and can be done more rapidly. Thus the FMS effect is fairly obvious—in developed countries with 'built out' fixed networks—'traffic substitution' is the dominant effect, while in developing countries with fewer fixed lines one sees 'penetration substitution'. The result shows that 'traffic substitution' occurs mainly in G7 and NIE which have fixed line household penetration higher than 100%, while 'penetration substitution' occurs mainly in ASEAN and BRIC which have lower than 100% fixed line household penetration. This study also suggests the implications of different substitution models for a nation's future telecom infrastructure policy.

The following studies have examined from diverse viewpoints how mobile penetration, having spread widely over a short time, has affected fixed service. Rodini [3] investigated fixed line and mobile substitution. He did a market research of American households covering the years 2000–2001 and used cross-price elasticity to prove that mobile and second fixed lines substitute each other. He indicates that the degree to which mobile substitutes for fixed line has significant implications for the policy of fixed-line unbundling and the policy of fixed line and mobile vertical separation and universal service obligation (USO). Madden [4,5], based on data from 56 countries worldwide during the period 1995–2000, using a dynamic demand model verifies the significant substitution effect of mobile phones substituting for fixed telephony, and he proposes that the reduction of fixed service prices can slow the growth of mobile networks. Banerjee [6] indicates that, according to ITU data, the number of global mobile subscribers (1.15 billion) surpassed the number of fixed subscribers (1.13

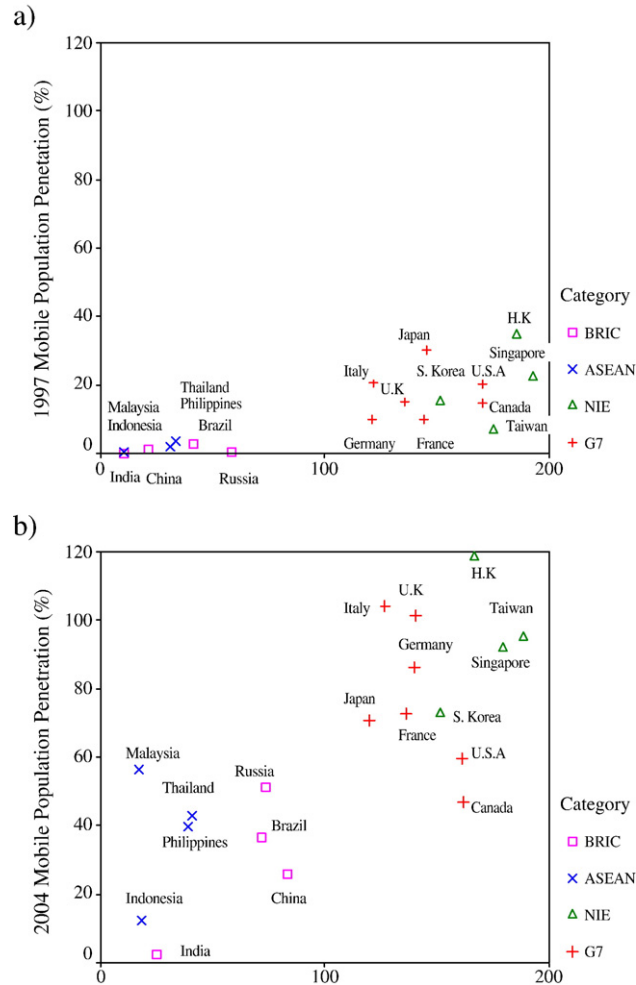


Fig. 1. a) 1997 fixed household penetration (%). b) 2004 fixed household penetration (%).

billion) in 2002. Using cluster analysis he divided 61 countries into four clusters to discover that the expanded model for technology substitution and economic substitution explains that regional connections and economic development will influence the substitution of mobile for fixed telephony. Watanabe [7] indicates that successive innovation and diffusion of technology will bring about complementarities and substitution between the new technology and the existing technology, and he also proposes that the trend from fixed line to mobile phone to mobile Internet is the industry macro-evolutionary trend of the telecommunication ecosystem through competition and cooperation. Gruber [8] studies the effect of competition and innovation on the diffusion of mobile communication in the middle and eastern European countries. Mao [9] indicates that the comparative efficiency of the full service telcos is more competitive than mobile-only and fixed-only telcos.

This study focuses on the nature and process of fixed to mobile substitution (FMS). Four groups of countries, G7, NIE, ASEAN and BRIC, are selected for studying the implications of the growth and

decline of the following indicators which are penetration, traffic volume, revenue and ARPU (average revenue per user) of the mobile and fixed-line services, and further to analyze the relationship between per capita income and these indicators. The structure of this paper is as follows. The topic of Section 2 is the data and hypotheses in which traffic substitution and penetration substitution are defined, and four hypotheses are proposed. Section 3 is the data analysis and testing of the three hypotheses. Section 4 proposes the concept of Income Effect. Section 5 presents the conclusions. Finally, Section 6 discusses topics for further study.

2. Data, measures, assumptions and hypotheses

2.1. Data

This paper covers the eight years from 1997 to 2004. The related data have been retrieved from telecom regulators as published on their websites (Appendix: A), from the telcos' Annual Reports and from ITU Telecommunication Indicators 2005 as reported by ITU (ITU, International Telecommunication Union) [2]. The penetration and subscriber data for fixed and mobile cover the years 1997–2004, while the revenue and ARPU cover the years 1997–2003, because worldwide this duration is the most significant period for FMS substitution effect. Beginning in the 2nd half of the year 2004 new technologies such as VoIP (Voice over Internet Protocol), Wi-Fi and WiMax started to emerge and thus affect the data for fixed revenue, therefore the data for fixed and mobile revenue stop at the year 2003. Because the overall situation becomes more complicated beginning in 2004, therefore the best observation period for studying the growth and decline of fixed and mobile service is from 1997 to 2004. One must remember that during the period of this study, Internet access was growing tremendously in developed nations. Especially in 1997–2000 the dominant access mode was via dial-up access, which caused both a large number of 2nd phone lines to be installed in residences and a significant increase in local call volume. New fixed carriers in Germany entered the market to compete [10], and Chunghwa Telecom in Taiwan provided a fixed line for new DSL subscribers, but both of these new services brought little growth in the number of the fixed lines since 2000. Besides Germany and Taiwan, the other developed countries had slight declines in the number of fixed lines by the year 2000 or 2001 (please see Appendices B, C) [1,2]. Furthermore, after the year 2000 in the US, DSL and Cable Modem access came online thereby reducing network traffic, but this aspect is not part of the focus of our article about FMS.

2.2. Measures

To study FMS it is necessary to measure penetration. This study adopts total population, or per capita use, as a basis for measuring the mobile penetration for each country, and the penetration of mobile services into the total population we call mobile penetration. To measure fixed line penetration we use households as the basis for measuring, and the percentage, or penetration rate, of fixed line service reflects how many fixed lines the household has. We call this fixed line penetration. The number may be higher than the actual number of fixed lines in each household because the fixed lines include a small percentage of business customers.

2.3. Assumptions

FMS patterns can be categorized into two types of substitution models. For example, the fixed line and mobile penetration development trend for Taiwan and Malaysia can be seen in Fig. 2a and b. Their similarities are the fast rise of mobile penetration (Taiwan declined in 2004 because mobile carriers were required to cancel invalid pre-subscribed accounts by the regulator-DGT). On the other hand, fixed-line penetration growth in both countries appears to stagnate which may reflect that the PSTN network has been ‘built out’. The main difference between them, however, is in fixed line household penetration. In Taiwan it is over 180%, almost two lines per household, while in Malaysia it is only 18% (the data are retrieved from the published data of Malaysia regulator MCMC), and even this low level of penetration shows some decline.

Therefore, using the data from Malaysia as an example, we can infer an assumption with regard to the FMS pattern: for countries with low fixed line penetration (low means much lower than one fixed line per household), the rapid growth of mobile users will cause fixed line penetration to stop growing. In other words, because mobile penetration allows most families to be no longer dependent on fixed lines for communication, traditional telephone use stays at the current low penetration status or even experiences further decline. That is, they no longer apply for new lines, they cancel their fixed line service, or they can get service more rapidly by acquiring a mobile phone [11]. This situation we call ‘penetration substitution’, and once penetration substitution occurs, the traditional paradigm of fixed line as the universal service obligation (USO) is no longer valid, and the role of mobile communication must be redefined.

As for Taiwan, as mobile penetration grows rapidly, fixed-line penetration does not change to any significant degree, but the overall fixed voice revenue appears to decline when compared to the big increase in mobile revenue. For details see Fig. 2c. Therefore, for Taiwan, mobile penetration did not cause an instant decline of fixed line penetration, but rather replaced its revenue. Therefore, we have a second assumption with regard to the FMS pattern, which is, for countries with high traditional fixed line penetration (each household has more than one fixed line); the growth of mobile subscribers mostly involves replacing the usage of fixed line access. The effect on penetration is secondary. This usage substitution we call ‘traffic substitution’.

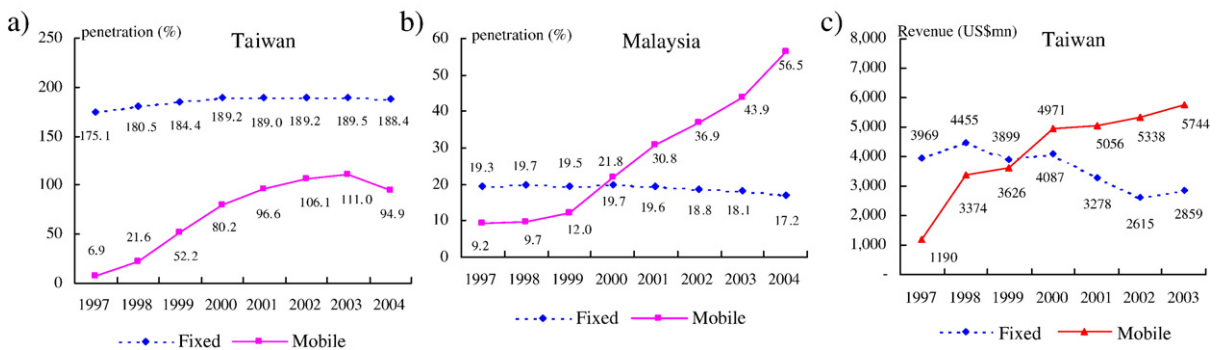


Fig. 2. a) Taiwan fixed-line and mobile penetration growth trend (%). b) Malaysia fixed-line and mobile penetration growth trend (%). c) Taiwan fixed-line and mobile revenue growth trend.

2.4. Hypotheses

Based on the above discussion, we deduce the following hypotheses which are subject to testing.

Hypothesis 1. During the years 1997–2004, for those countries with fixed-line penetration higher than 100%, the FMS is mostly traffic substitution.¹

Hypothesis 2. During the years 1997–2004, for those countries with fixed-line penetration lower than 100%, the FMS is mostly penetration substitution.

In order to test Hypothesis 1, traffic substitution, we first have to solve the problem of measurement. From public sources we can obtain the number of minutes of fixed line use, but we are unable to obtain the number of minutes of mobile use from the relevant mobile businesses of each country. We can, however, obtain the data for revenue [2]. Therefore, in the above description of the effect of traffic substitution we use the growth and decline of revenue to replace traffic volume as a basis for discussion, but whether revenue is suitable to replace traffic volume, as the measurement for FMS analysis needs to be further clarified.

From Fig. 3a–c and d–f we can deduce the following: fixed traffic is composed of local, long distance and international traffic. Because international traffic volume statistics have never separated delivery by fixed phone sets or mobile handsets for the various countries, and also because the mobile phone substitutes for fixed line in making long distance calls, therefore, fixed traffic volume has in fact been influenced by local traffic volume. The following views could be drawn from the two groups of Fig. 3a–c and d–f.

- (1) Local traffic volume shows a rapid decline in the year 2000 in G7 and NIE countries. See Fig. 3a and d. There are no data for Canada; therefore the data for G7 include only six countries. There are also no data for Singapore; therefore the data for NIE include only three countries. The local call rate is basically the same, but overall fixed line revenue, including long distance and international, shows a clear loss starting in the year 2000. In NIE countries, fixed line revenue declined overall in 1998 because local call rates and household monthly fees were lowered quite a bit compared to 1997. In effect, around 2000 some countries within these two groups opened up the fixed line market² and considerably reduced long distance and international call rates, but the overall trend of the changes in fixed line total revenue and local traffic volume are relatively flat and consistent. From this phenomenon we can conclude that the effect of lowering long-distance and international tariffs to cause a decline in revenue cancels out the effect of pricing elasticity from increased traffic volume and its resulting revenue increase.

Because of incremental reduced fixed line tariff (see Figs. 3b, e and 4b, e), fixed telephony revenue started to decline since the year 1999 or 2000 for G7 countries including US, Canada, Japan, France, Italy and U.K. (see Appendices D, E) [2]. In the US, local calls are most often at a

¹ Since the dial-up traffic were included in the local calls, it is difficult to calculate the Internet access effect for the earlier dial-up years.

² The liberalized schedule of fixed markets around the year 2000 has included Germany in Jan. 2000 and France in 2002 for G7, while Singapore in Apr. 2000 and Taiwan in March 2001 for NIE countries.

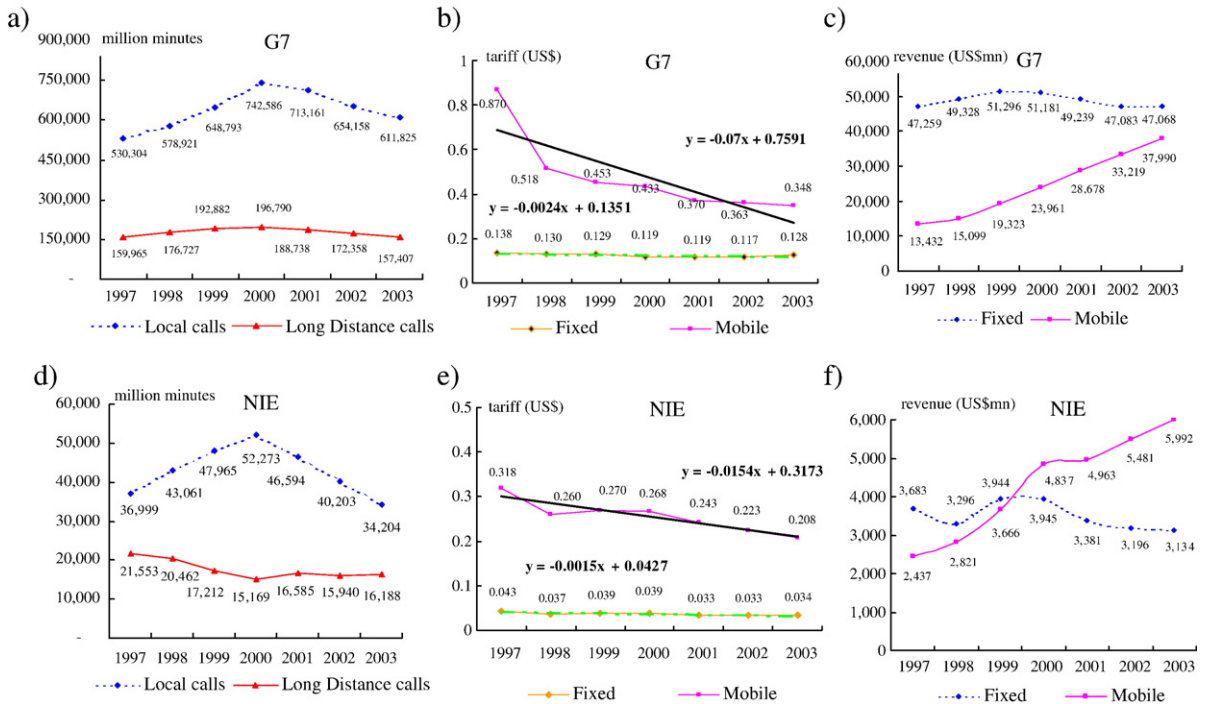


Fig. 3. a) G7 domestic calls growth trend. b) G7 local and mobile cost for a 3-minute call. c) G7 revenue growth trend. d) NIE domestic calls growth trend. e) NIE local and mobile cost for a 3-minute call. f) NIE revenue growth trend.

flat rate (revenue is not traffic sensitive), and long distance calling began a trend to flat rate service during this time. In addition, the statistical data of international calls have not separated fixed-terminal calls from mobile-terminal calls. The relationship of revenue to traffic for the two groups of G7 and NIE has been made according to the study data. In conclusion, the correlation between the variables of revenue and of fixed line traffic volume (including local and long distance calls) are 0.6430 for G7 and 0.7258 for NIE, both displaying a strong relationship as shown in Table 1a and b. In other words, using the trend of changes in revenue as a replacement for using changes in traffic volume is valid.

- (2) Mobile tariff clearly declined for both G7 and NIE, but mobile revenue rose substantially. There are three possible reasons: a) the natural growth of mobile demand; b) the price elasticity for mobile demand; and c) fixed traffic substitution. From the large decline in fixed line local and long-distance calls since the year 2000 we can deduce that based on global economic trends there is no reason for overall communication demand to decline significantly since 2000. For mobile service to be so attractive arises from the synergistic effect of the above items a), b), and c).

For ASEAN and BRIC countries we can summarize as shown in Fig. 4a, b, c, d, e, and f. First, ASEAN mobile revenue increased considerably since 1998, but mobile tariff has been declining which implies that the growth of mobile traffic volume is very strong. The decline of fixed line revenue in 1998 is because monthly fees and local call tariffs were much lower when compared to 1997. During the study period 1997–2003 ASEAN fixed line tariffs basically remained flat.

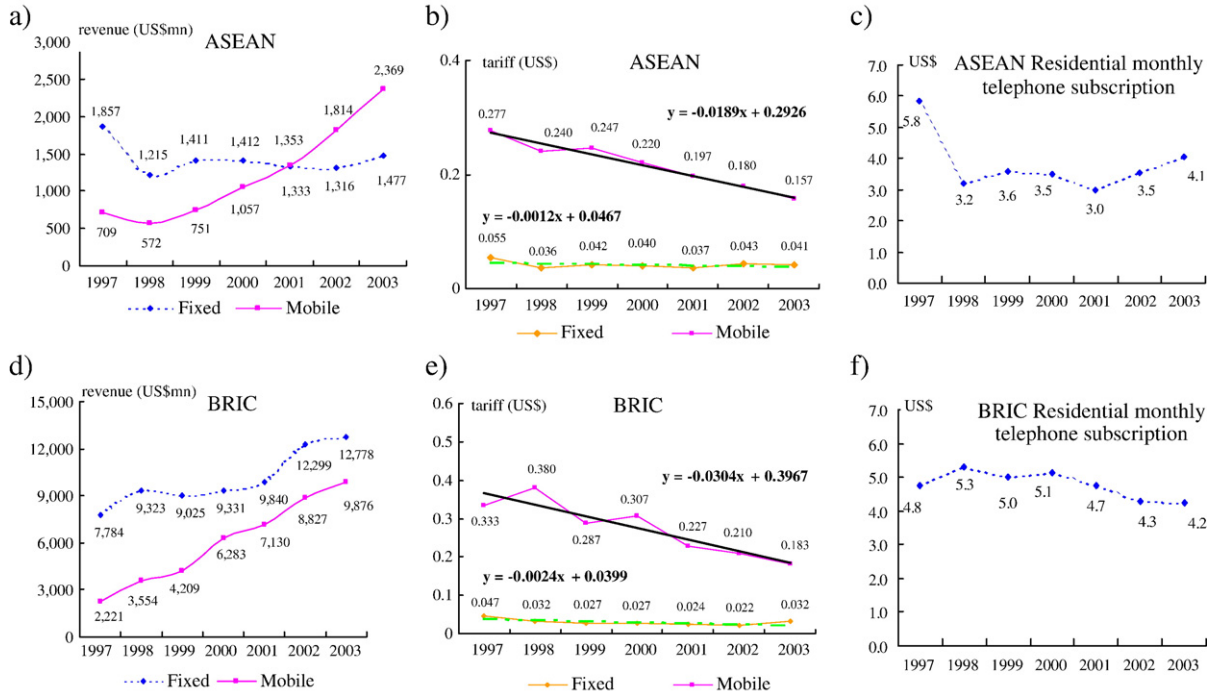


Fig. 4. a) ASEAN revenue growth trend. b) ASEAN local and mobile cost for a 3-minute call. c) ASEAN residential telephony monthly rental. d) BRIC revenue growth trend. e) BRIC local and mobile cost for a 3-minute call. f) BRIC residential telephony monthly rental.

Interestingly, the changes in fixed line revenue and fixed line monthly fees show a parallel up and down movement. This indicates two points: a) In ASEAN countries basic fixed line monthly fees compared to their traffic fees may be too high. Therefore the trend of fixed line revenue depends mainly on the up and down movement of their fixed line basic monthly fee. b) Because fixed line traffic volume in ASEAN countries is relatively low, therefore the main focus of FMS substitution is

Table 1a
G7 correlation between fixed traffic and revenue (1997–2003)

G7	Local+long distance (mn minutes)	Revenue (US\$ mn)
	690,269	47,259
	755,648	49,328
	841,675	51,296
	939,376	51,181
	901,899	49,239
	826,516	47,083
	769,232	47,068
Correlation		0.6430

Table 1b
NIE correlation between fixed traffic and revenue (1997–2003)

NIE	Local+long distance (mn minutes)	Revenue (US\$ mn)
	58,552	3683
	63,523	3296
	65,177	3944
	67,442	3945
	63,179	3381
	56,143	3196
	50,392	3134
Correlation		0.7258

not fixed line traffic volume but fixed line penetration. This in effect indirectly supports the above Hypothesis 2.

Second, both fixed line and mobile revenue for BRIC countries have been growing continuously. For example, the Brazilian government's mandated program to improve 'teledensity' probably had a major effect on fixed line growth. In addition, the PHS (Personal Handyphone System) lines offered by China Telecom with a limited wireless service in major cities may have also had an effect on the growth of total local fixed lines. There are two points worth mentioning: a) mobile tariff is declining while fixed line tariff remains the same. Fixed line monthly fees declined but the scale is very small. Therefore we can deduce that the growth of mobile traffic volume should be faster than fixed line growth. This situation does not exclude possible FMS traffic substitution in BRIC countries. b) In BRIC countries fixed line monthly fees do not dominate fixed line revenue.

Based on the above discussions this study assumes that for FMS analysis fixed line and mobile revenue are suitable measurements to replace traffic volume. In order to establish a basis for cross-country comparison and analysis, this study further converts the absolute value of each country's fixed line and mobile revenue into annual average revenue per user, ARPU. Fixed line ARPU is calculated by dividing the total annual revenue by total number of fixed lines, and mobile ARPU is calculated by dividing the total annual revenue by total number of mobile users. Because the four groups of countries or regions studied in this paper have great inter-group differences as well as intra-group differences in level of economic development, therefore we propose a third hypothesis.

Hypothesis 3. There exists an 'income effect' in telecom penetration, i.e., when the ratio of fixed line and mobile expenditure (combined or separate) to annual personal income (abbreviated as *T/I* ratio) is high, then fixed line or mobile penetration is not easily increased.

Telecommunication satisfies a basic need in daily life, but if the cost of this basic need takes a higher percentage of the users' disposable income so as to reduce the satisfaction of other basic needs such as food, clothing, or housing, then this telecommunication need will not necessarily have a high priority among users. Therefore, when the ratio of the expense of fixed line or mobile communication to annual income (can be measured by ARPU) is too high, then neither fixed line nor mobile penetration can increase easily. In addition, mobile service when first available was priced relatively much higher compared to fixed line service, especially for those countries with lower per capita income, and this unavoidably became an obstacle for the growth of telecommunication penetration.

3. Analyses and verification

The growth of local traffic during 1997–2000 comes in part from the increase in local dial-up calls, while the decline of local traffic during 2001–2004 comes in part from the shift in fixed traffic from dial-up to high-speed access. One must note that, Internet dial-up traffic has been combined with local calls and it is difficult to separate the two for accounting purposes by the telcos. Additionally, the data of Internet revenue for most countries are insufficient to be used according to ITU Telecommunication indicators. One may assume that the loss of fixed line traffic can be attributed to a transfer of that traffic to the mobile market. Therefore, this study to explore FMS effect for both elements of fixed line and mobile are inferred to be appropriate to address the validity of the linear lines and their slopes. Now we shall use the relative data from the four groups of countries to analyze and verify the above three hypotheses.

3.1. G7 substitution pattern

During the years 1997 to 2004 the average fixed line penetration in the G7 countries is higher than 140%. The basic trend is a slight increase from 1997 to 1999 and a slight decrease from 1999 on, making the overall trend flat. Mobile penetration shows rapid growth from 1997 to 2004 with the average penetration rising from 17% to 77% (Fig. 5a). As for revenue during the same period, fixed line service revenue is similar to its penetration curve, peaking in 1999. Mobile revenue grew similarly to mobile penetration (Fig. 5b). In analyzing their ARPU, fixed line ARPU in G7 countries has been higher than mobile ARPU. Fixed line ARPU shows the same tendencies as fixed line penetration and revenue with 1999 as a turning point. Mobile ARPU shows first a decline and then a rise (Fig. 5c). Now we look at the relationship between these curves.

First, the relationship among the three curves of fixed line penetration, fixed line revenue and ARPU is explored. From 2000 to 2003 fixed line tariff remained basically the same, averaging 0.12 USD (Fig. 3b). Residential monthly fees increased about 12% (the available data for four countries among G7 countries averaged from US\$ 13.2 to US\$ 14.8), but during this period fixed line revenue declined 8% (Fig. 3c), and ARPU dropped 7.4% (Fig. 5c). This clearly shows a big loss of fixed line traffic volume, consistent with the data shown in Fig. 3a. The year 2000 is a turning point with local traffic volume dropping 17.6% and long distance traffic volume dropping 20%.

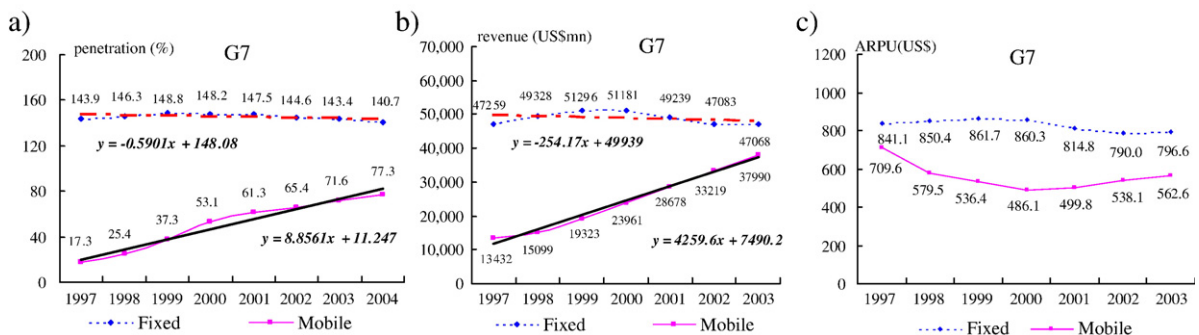


Fig. 5. a) G7 average penetration growth trend. b) G7 average revenue growth slope. c) G7 average ARPU growth trend.

Next, the relationship among the three curves of mobile penetration, total revenue and ARPU. Mobile tariff dropped 60% (Fig. 3b) from 1997 to 2003, and mobile annual ARPU dropped 20.7% (Fig. 5c). During this period mobile tariff dropped more than the ARPU dropped. Therefore, the growth of mobile traffic volume is very significant. This tariff drop not only increased mobile penetration from 17.3% in 1997 to 61.3% in 2001 but also further increased it to 71.6% in 2003 (Fig. 5a). The decline in tariff rates not only enabled mobile penetration to increase but also enabled mobile total revenue to have a 183% growth rate from 1997 to 2003 (Fig. 3c). This reflects the price elasticity of mobile demand. It also indicates a huge growth of mobile traffic volume during this period. Therefore, we may infer that some of this traffic volume was originally carried by conventional PSTN, but because of the decline of mobile tariff, and because of mobile convenience, the use of mobile took away the conventional PSTN voice market. This phenomenon is what this paper calls FMS ‘traffic substitution’ and this is consistent with the statement of Hypothesis 1. See Fig. 5a–c.

Finally for G7 countries, the growth slope of fixed line penetration is -0.5901 and that of fixed line revenue is -254.17 , both showing a linear downward trend. The growth slope of mobile penetration growth is 8.8561 and that of the mobile revenue is a high value of 4259.6 , both showing a linear growth trend. The trend of fixed penetration clearly shows a small decline, while the trend of mobile penetration displays obvious growth. The decline of fixed line revenue is much more than the decline of fixed line penetration; it is obvious that the loss of the fixed traffic has resulted in a dramatic decline of fixed revenue. In the meantime mobile revenue shows very strong growth; in addition to the traffic shift from fixed to mobile, mobile service itself also has very high growth. Because the penetration of mobile phone has not resulted in an immediate decline of the fixed penetration, the phenomenon of FMS is mainly centered on traffic substitution. This conforms to Hypothesis 1. Please see Fig. 5a–b.

3.2. NIE substitution pattern

During the years 1997 to 2004 the average fixed line penetration in NIE countries is higher than 170%. The basic fixed line growth curve is flat, showing a slight decline beginning in the year 2000. During the same period the mobile penetration rate grew rapidly from 19.7% in 1997 to 94.5% in 2004 (Fig. 6a). Mobile revenue exceeded fixed line revenue beginning in 1999, and the growth trends of fixed line revenue and fixed line penetration and ARPU are similar. Mobile ARPU falls below fixed line ARPU from 1999 on (Fig. 6c), and the mobile penetration rate shows a large increase (Fig. 6a). Following is a discussion of the relationship among these trends.

First, the relationship among the three trends of fixed line penetration, revenue and ARPU is examined. Fixed line penetration declined from its peak at 183.7% in 2000 to 171.5% in 2004 (Fig. 6a), a 6.6% decline. Local traffic also started to decline drastically beginning in 2000. By 2003 it had dropped by 34.6%. From its peak in 1997 long-distance traffic had dropped 33% by 2003 (Fig. 3d). Fixed line traffic volume loss is much higher than its penetration loss. Therefore, the loss of NIE fixed line traffic cannot be attributed to penetration decline but to mobile use taking away the voice market. Furthermore, fixed line residential monthly fees increased 18.8% from 2000 to 2003. The local tariff declined slightly, by 1.7% (Fig. 3e), but fixed line revenue declined 20.6% (Fig. 3f), and fixed line ARPU declined 23.4% (Fig. 6c). Therefore, the average increase of fixed line fees did not increase fixed line revenue and ARPU (Fig. 6c). The loss of fixed line traffic volume is obvious.

Next, the relationship among the three trends of mobile penetration, revenue and ARPU is examined. During the time when mobile penetration increased rapidly there was no obvious change

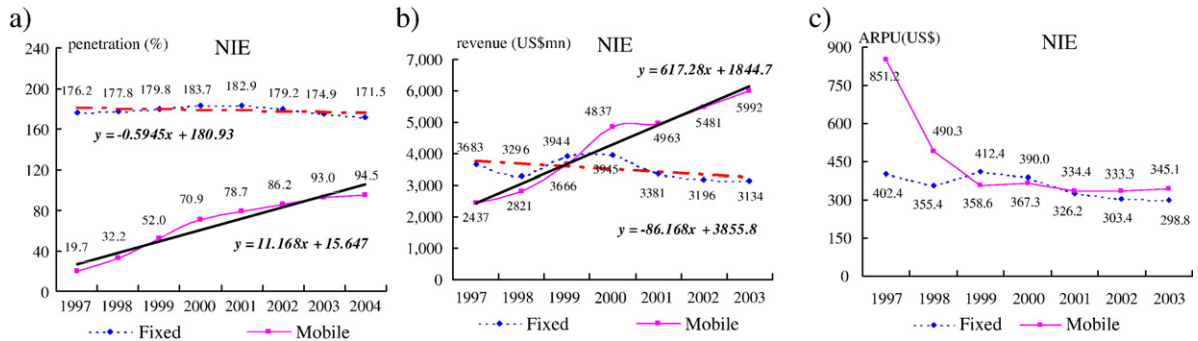


Fig. 6. a) NIE average penetration growth trend. b) NIE average revenue growth slope. c) NIE average ARPU growth trend.

of fixed line penetration. The average increase of fixed line residential monthly fees was not sufficient reason to cause fixed line revenue to drop drastically. But, from the years 2000 to 2003, mobile tariff dropped 22% (US\$0.268 to US\$0.208 per 3-minute call). Price elasticity caused the increase of mobile traffic volume. During this same period mobile revenue growth increased 23.9% while mobile ARPU declined about 6%. The reason for the increase of mobile traffic volume is the growth of mobile penetration and also, clearly, fixed line traffic substitution. Therefore, by the end of 2004 FMS substitution is mostly traffic substitution. The influence on penetration (cancellation of fixed line subscriptions) is secondary. This FMS pattern of ‘traffic substitution’ is consistent with Hypothesis 1.

Finally, for NIE countries, the growth slope of fixed line penetration is -0.5945 and that of fixed line revenue is -86.168 , both showing a linear downward trend. The growth slope of mobile penetration is 11.168 and that of mobile revenue is a high value of 617.28 , both showing a linear growth trend. In contrast to the jump in mobile revenue, fixed line revenue shows an obvious decline. Although fixed line penetration declines only slightly, fixed line revenue has a considerable loss. Obviously the shift of fixed line traffic has resulted in the decline of fixed line revenue. The spread of mobile service has not caused an immediate decline of fixed line penetration. Therefore, the FMS phenomenon is mainly centered on traffic substitution. This conforms to Hypothesis 1. Please see Fig. 6a–b.

3.3. ASEAN substitution pattern

For the years 2000 to 2004 the average fixed household penetration for ASEAN countries is about 28%. Except for Thailand with a slightly higher penetration at 40.5% the other countries all have very low penetration relative to the G7 or NIE countries. The growth trends of fixed line revenue and ARPU are similar, both being basically stagnant since 1999. The growth trend of mobile revenue is similar to that of mobile penetration, both showing a significant increase. Mobile revenue exceeded fixed line revenue during the period 2000–2001. Following is a discussion of the relationship of these trends.

First, the relationship among these three trends of fixed line penetration, revenue and ARPU is examined. The basic growth trend of fixed line penetration increased slightly from 1997 to 2002, and declined slightly after 2002. Fixed line revenue showed an obvious decline in 1998. In 1998 local

tariff declined 13.4% and monthly fees declined 25.5% compared to the previous year (Fig. 4b–c). As a result, fixed revenue dropped 34.6% in 1998 (Fig. 4a). During the period 2000 to 2003 fixed line tariff remained essentially the same (Fig. 4b), but monthly residential fees increased 17% (Fig. 4c) while fixed revenue declined 6.7% and fixed ARPU also declined 4.5% (Fig. 7c). The increase of fixed line monthly fees did not much change fixed line penetration, but fixed line revenue and ARPU declined. This shows that in ASEAN countries when fixed line penetration is still much lower than one line per household, an increase in mobile penetration not only stops the growth of their fixed line penetration but also causes a certain degree of traffic substitution. One special thing worth noting about ASEAN countries is that without strong growth of mobile services each household in these countries may eventually connect to a fixed line, but use of mobile services causes the substitution effect for those families without a fixed line because there is then no need to subscribe to a fixed line. Therefore, even though there is a certain degree of traffic substitution, relatively speaking, the growth trend of fixed line penetration has been replaced by mobile penetration. Penetration substitution is the main FMS pattern for these countries.

Next, the relationship among the three trends of mobile penetration is examined, total mobile revenue and mobile ARPU. Mobile ARPU initially was higher than fixed ARPU, but mobile penetration had no obvious growth. Only in the year 2000 was mobile ARPU lower than fixed line ARPU (Fig. 7c). Mobile penetration began to grow considerably from 9.2% in 2000 to 37.9% in 2004 (Fig. 7a). The mobile revenue of ASEAN countries had a big increase since 1998, but tariffs have been decreasing. Compared to the year 2000 mobile tariff in 2003 dropped 28.6%, but mobile revenue grew 124% (Fig. 4a). This indicates that mobile traffic growth is very strong. Fixed line growth during the same time was only 4.6%. One may say that mobile penetration, besides inhibiting the growth of fixed line penetration, also has to a certain degree traffic substitution effect. This resulted in the mobile penetration rate of 37.9% exceeding the fixed line penetration rate of 28.8% in the year 2004. In sum, because of the fast growth of mobile penetration in ASEAN countries the growth of fixed penetration was obviously being suppressed. This verifies Hypothesis 2: for the countries with fixed household penetration much less than 100% the FMS pattern is mainly ‘penetration substitution’.

Finally, for ASEAN countries, the growth slope of fixed line penetration is 0.7386 showing a linear growth trend and that of fixed line revenue is -36.202 showing a linear downward trend. The growth slope of mobile penetration is 4.9824 and that of mobile revenue is a high value of 288.08 both showing a

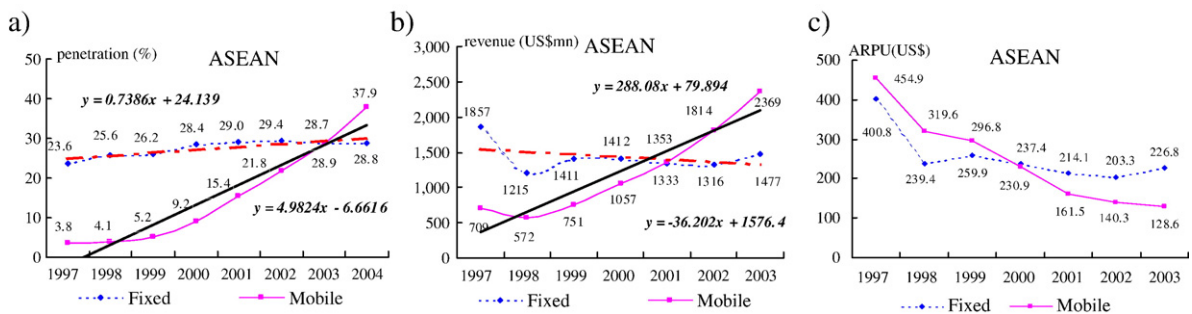


Fig. 7. a) ASEAN average penetration growth trend. b) ASEAN annual average revenue growth slope. c) ASEAN average ARPU growth trend.

linear growth trend. The growth of mobile penetration is higher than that of fixed-line penetration; therefore FMS penetration substitution has happened. Even the slope of fixed penetration shows a slight growth, while the slope of fixed line revenue shows an obvious decline. Therefore, the FMS model also includes some traffic substitution. Please see Fig. 7a and b.

3.4. BRIC substitution pattern

The group of BRIC countries is the most diversified among the four groups in the study, and the intra-group differences are significant. Therefore, the following discussion is about average tendencies. Implementation of USO is far from ideal in the BRIC countries as, for example, telecom penetration in China occurs mostly in metropolitan areas or in the coastal provinces which are like developed countries, but in the inner agricultural areas penetration is very low. There is a significant difference in the penetration in BRIC countries divided by the year 2001. Mobile ARPU initially was much higher than fixed line ARPU, but it became lower starting in 2002. The following is a discussion of the relationship among these growth trends. The mobile growth rate is thus much faster than fixed line. This is without taking into account the possibility of FMS traffic substitution in BRIC countries. This is consistent with Hypothesis 2. For details see Fig. 8a–c.

For BRIC countries, over the entire 1997–2004 periods, the linear slope of fixed line penetration is 4.7348 and that of mobile penetration is 3.6645 (Fig. 8a). The growth of fixed line penetration has surpassed mobile penetration. But when the eight years are divided into the periods 1997–2000 and 2001–2004, then there are obviously different results which will be discussed in the next paragraph

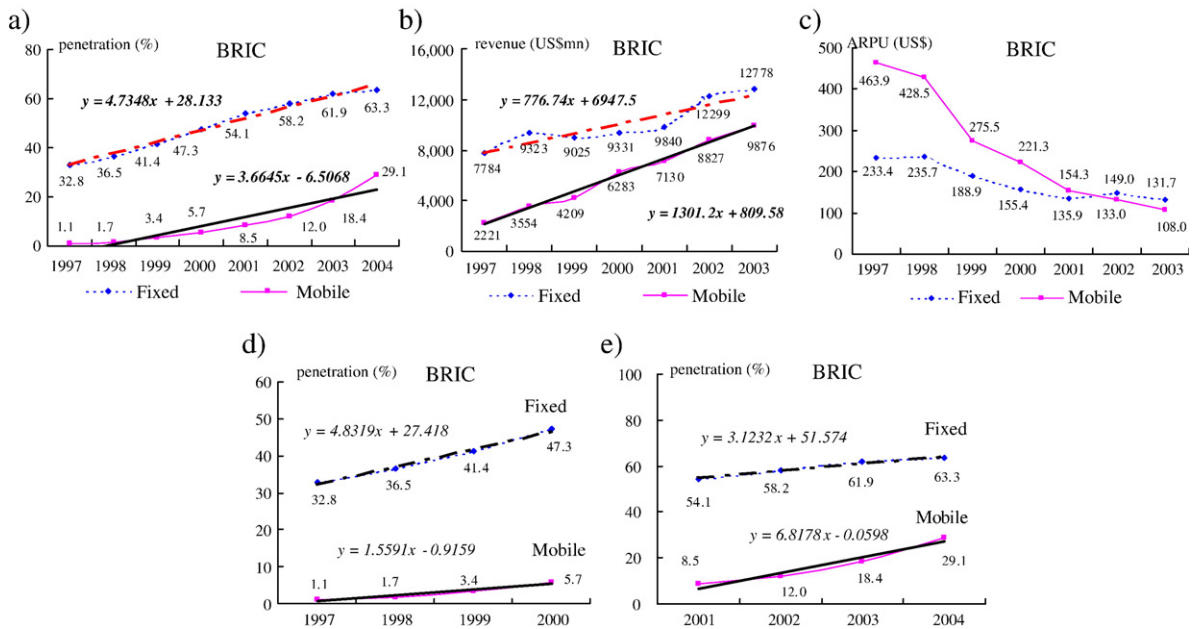


Fig. 8. a) BRIC average penetration growth slope. b) BRIC average revenue growth slope. c) BRIC average ARPU growth trend. d) BRIC average penetration growth slope (1997–2000). e) BRIC average penetration growth slope (2001–2004).

(Fig. 8d, e). The slope for fixed line revenue during the period 1997–2003 is 776.74 and the slope for mobile revenue reaches a high of 1301.2. Both fixed line and mobile revenue grow rapidly with the growth rate of mobile revenue being much higher than that of fixed line revenue.

In summary, during the years 1997–2004 the FMS pattern in G7 and NIE countries is mainly traffic substitution. For ASEAN the pattern is penetration substitution. In BRIC countries the tendency toward penetration substitution begins to become obvious from 2001. But the difference between fixed line and mobile tariffs is much smaller in ASEAN countries than in BRIC. This makes ASEAN mobile penetration exceed BRIC. In BRIC countries because fixed line revenue is not heavily dependent on monthly fees and also because fixed line tariff is much lower than mobile tariff, BRIC countries are heavily dependent on fixed line, and this makes fixed line penetration much higher than in ASEAN countries.

Reexamining the slopes after dividing the entire study period into the two separate time periods finds that for the 2001–2004 periods there is penetration substitution which thus conforms to Hypothesis 2. For the 1997–2000 periods, the fixed penetration slope is 4.8319 and the mobile penetration slope is 1.5591, the growth rate of fixed penetration is faster than that of mobile penetration. But for the 2001–2004 periods, the slope of mobile penetration is 6.8178 which are greater than the 3.1232 of fixed penetration. The growth rate of mobile penetration has exceeded that of fixed penetration during 2001–2004. This conforms to Hypothesis 2. Please see Fig. 8d and e.

3.5. Comparison of the slopes

For the two groups of G7 and NIE, the decline of fixed line penetration is small and about the same for both, but the decline of fixed line revenue is more significant for both groups with G7 (–254.170) declining much more than NIE (–86.168). In other words, the trend of traffic substitution for G7 is more significant. The growth rate of mobile penetration for NIE is higher than that of G7; however, the growth of mobile revenue for G7 is much higher than NIE. This indicates the strong growth of G7 mobile service. For ASEAN countries, the growth slope for mobile penetration (4.9824) is much greater than the slope of fixed penetration (0.7386) and thus FMS penetration substitution exists. But fixed line revenue declines in spite of the increase of fixed line penetration; therefore the FMS model also contains some traffic substitution. For BRIC countries, there is a difference between the two time periods, and penetration substitution exists in the later period. Please see Table 2.

Table 2
The penetration and revenue growth slope for four groups

Group/ service	Penetration (1997–2004)		Revenue (1997–2003)	
	Fixed growth slope	Mobile growth slope	Fixed growth slope	Mobile growth slope
G7	–0.5901	8.8561	–254.170	4259.60
NIE	–0.5945	11.1680	–86.168	617.28
ASEAN	0.7386	4.9824	–36.202	288.08
	Penetration (1997–2000)		Penetration (2001–2004)	
	Fixed growth slope	Mobile growth slope	Fixed growth slope	Mobile growth slope
BRIC	4.8319	1.5591	3.1232	6.8178

3.6. Substitution rates as a function of price differences

Substitution rates as a function of price differences are estimated from three aspects and summarized in Table 3.

- (1) The effect of reduced fixed tariff on the growth of fixed penetration (1997–2004)
Reducing the three-minute local call tariff by USD\$0.001, the rate of fixed line penetration increase is -0.25% for G7, -0.40% for NIE, 0.62% for ASEAN and 1.97% for BRIC. Because of the FMS effect, both G7 and NIE's fixed penetration decreased despite the reduced tariff. Growth of fixed penetration in BRIC group is most affected by reduced fixed tariff.
- (2) The effect of reduced mobile tariff on the growth of mobile penetration (1997–2004)
Reducing the three-minute local call tariff by USD\$0.001, the rate of mobile penetration growth is 0.13% for G7, 0.73% for NIE, 0.26% for ASEAN, and 0.12% for BRIC. The reduced mobile tariff has helped the growth of mobile penetration of all four groups with the NIE group being most affected.
- (3) Substitution rates as a function of price differences between mobile and fixed tariffs (1997–2003)
The substitution rate as a function of price difference is calculated by reducing the three-minute local call tariff by USD\$0.001 and dividing the slope of mobile tariff by the slope of fixed tariff. The results are 2.92% for G7, 1.03% for NIE, 1.58% for ASEAN, and 1.27% for BRIC. G7 has the highest substitution rate among the four groups. This suggests that the telecom market for G7 is the most competitive among the four groups. NIE has the highest penetration of mobile and fixed line with both service markets having reached saturation, and thus the substitution rate for the price difference is least significant.

4. Income effect

In economics the concept of disposable income means that for each household the portion of their disposable income that they spend on food, housing, clothing and transportation, the basic needs, will normally be adjusted according to the urgency of need and the actual cost. When income level is low

Table 3
Substitution ratio for the function of price difference (1997–2004)

Substitution ratio for four groups		G7	NIE	ASEAN	BRIC
Fixed	Tariff slope	-0.0024	-0.0015	-0.0012	-0.0024
	Absolute value for tariff slope	0.0024	0.0015	0.0012	0.0024
	Penetration slope	-0.5901	-0.5945	0.7386	4.7348
	Penetration/tariff slope (per reduced US\$ 0.001)	-0.25%	-0.40%	0.62%	1.97%
Mobile	Tariff slope	-0.07	-0.0154	-0.0189	-0.0304
	Absolute value for tariff slope	-0.07	-0.0154	-0.0189	-0.0304
	Penetration slope	8.8561	11.168	4.9824	3.6645
	Penetration/tariff slope (per reduced US\$ 0.001)	0.13%	0.73%	0.26%	0.12%
Mobile/tariff slope (per reduced US\$ 0.001)		2.92%	1.03%	1.58%	1.27%

and disposable income is limited and there is difficulty in meeting even the basic needs of food, housing, etc., then for the relatively higher cost and lower urgency of telecommunication, the need for it will be delayed or given up. In other words, when communication expense occupies a high proportion of disposable income then only higher income people will use this modern communication tool. In this circumstance telecommunication penetration will be difficult to expand. Only when the ratio of communication expense to disposable income is lower than a certain threshold will telecommunication service be widely used. This paper uses fixed line and mobile expenditure (excluding ARPU data) as a measurement of each individual's annual fixed line or mobile expenditure, then finds the ratio of this to annual per capita income as *T/I* ratio and uses these indicators to analyze the relationship among income level, telecom expenditure and telecom penetration. The effect that only when the *T/I* ratio is lower than a certain level will telecom penetration start to increase considerably is called 'Income effect'.

In G7 and NIE countries each household already had more than one fixed line before 1997. Therefore, fixed line service for these two groups of countries has no such thing as an income effect, and mobile markets began to be developed after 1997. For example in G7, the *T/I* ratio (combined fixed line and mobile expenditure to per capita income) dropped from 5.8% in 1997 to 4.6% in 1999 and 3.7% in 2003. For NIE this ratio dropped from 8.6% in 1997 to 4.8% in 2000 and to 4.3% in 2003. Overall, in both G7 and NIE, beginning in 1999 and 2000 respectively, the *T/I* ratio dropped below 5%. Mobile penetration turned around and increased considerably. Within a four or five year, by 2004 mobile penetration in both groups of countries reached 77.3% and 94.5% respectively. Based on these data, we therefore deduce that for G7 and NIE 5% is the upper threshold for income effect. In other words, when the *T/I* ratio is lower than 5% mobile penetration will rapidly display significant growth. For details see [Tables 4 and 5](#).

For the G7 and NIE countries, France and U.K. were the first to cross that threshold point for income effect, and mobile penetration began to take off in 1998, followed by Canada, Germany and Taiwan in 1999, then Italy, HK and Singapore in 2000, and, last, the U.S.A. in 2001. Taiwan was the first NIE country to cross the income effect threshold, and had the highest mobile penetration in the world during 2000–2003. In 2003 the *T/I* ratio of Japan was 5.6% and South Korea was 5.4%, still slightly higher than the upper threshold. Therefore, mobile penetration rate in Japan is low among G7 countries, only higher than that of U.S.A. and Canada. South Korea has the lowest mobile penetration of the NIE countries.

The same criteria are used to examine the relationship of income level, telecom expenditure and telecom penetration among the ASEAN and BRIC countries. In 1997 for ASEAN and BRIC countries only a few households had fixed line services, and mobile communication was even more limited. This situation caused users to make a choice between the two rather than subscribe to both. Therefore, either fixed line ARPU or mobile ARPU can be used to compare to per capita income as the reference point for the growth of penetration. Thus the *T/I* ratio for these countries is either fixed line expenditure to per capita income or mobile expenditure to per capita income. Then we use this ratio to find the starting point of the penetration growth, followed by a discussion of the upper threshold of income effect. For details see [Tables 4 and 5](#). The data show that during 1997–2003, except for Russia's fixed line service, in ASEAN and BRIC countries *T/I* ratios are higher than 5%. This study also concludes that for ASEAN and BRIC countries one can use the 5% *T/I* ratio as an indicator of income effect. The turning point of income effect for ASEAN and BRIC countries is described below.

Table 4
G7 Penetrations vs. ARPU/per capita GDP

G7	Service	ARPU/GDP/year	1997	1998	1999	2000	2001	2002	2003
France	Fixed	Penetration (%)	143.8	144.0	141.4	140.5	138.7	138.5	136.7
		ARPU/GDP (%)	2.1	1.9	1.9	1.8	1.7	1.6	1.1
	Mobile	Penetration (%)	10.0	19.2	35.5	48.9	58.4	61.6	66.5
		ARPU/GDP (%)	2.6	1.6	1.1	1.1	1.2	1.2	1.1
U.K.	Fixed	Total ARPU/GDP	4.7	3.5	3.0	2.9	2.9	2.8	2.2
		Penetration (%)	135.7	137.4	141.3	144.6	146.1	140.9	138.7
		ARPU/GDP (%)	2.9	2.6	2.5	2.2	2.0	1.9	1.9
	Mobile	Penetration (%)	15.0	25.1	45.7	72.7	77.2	83.6	90.8
ARPU/GDP (%)		2.7	1.8	1.3	0.9	1.0	1.0	1.2	
Total ARPU/GDP		5.6	4.4	3.8	3.1	3.0	2.9	3.1	
Germany	Fixed	Penetration (%)	120.7	124.0	127.6	131.7	136.4	138.9	139.5
		ARPU/GDP (%)	2.2	2.1	1.9	1.7	1.6	1.6	1.7
	Mobile	Penetration (%)	10.1	17.0	28.5	58.6	68.1	71.6	78.5
		ARPU/GDP (%)	4.7	2.9	2.3	1.8	1.6	1.6	1.5
Canada	Fixed	Total ARPU/GDP	6.9	5.0	4.2	3.5	3.2	3.2	3.2
		Penetration (%)	170.2	173.6	178.1	182.6	177.6	171.5	169.4
		ARPU/GDP (%)	2.2	2.3	2.1	2.1	2.0	2.0	1.7
	Mobile	Penetration (%)	14.7	18.3	22.7	28.4	34.3	38.0	42.3
ARPU/GDP (%)		2.6	2.7	2.2	2.0	1.8	1.9	1.9	
Total ARPU/GDP		4.8	5.0	4.3	4.1	3.8	3.9	3.6	
Italy	Fixed	Penetration (%)	121.3	122.6	125.1	128.9	127.3	136.2	132.3
		ARPU/GDP (%)	3.3	3.9	3.6	3.1	3.0	2.7	2.6
		Total ARPU/GDP	6.1	6.0	5.1	4.4	4.3	4.0	3.9
	Mobile	Penetration (%)	20.5	35.7	52.4	74.2	88.8	91.6	101.8
ARPU/GDP (%)		2.8	2.1	1.5	1.3	1.3	1.3	1.3	
Total ARPU/GDP		8.9	8.1	6.6	5.7	5.6	5.3	5.2	
U.S.A.	Fixed	Penetration (%)	170.3	175.2	176.4	177.3	178.6	170.9	165.1
		ARPU/GDP (%)	3.8	3.7	3.6	3.5	3.4	3.1	3.0
		Total ARPU/GDP	10.4	11.2	11.2	11.2	11.0	10.1	9.5
	Mobile	Penetration (%)	20.4	25.2	31.6	38.9	45.1	49.1	54.7
ARPU/GDP (%)		2.0	1.7	1.7	1.6	1.6	1.6	1.5	
Total ARPU/GDP		5.8	5.4	5.3	5.1	5.0	4.7	4.5	
Japan	Fixed	Penetration (%)	145.3	147.2	151.9	131.7	127.7	125.3	122.4
		ARPU/GDP (%)	3.1	3.0	3.0	2.6	2.5	2.3	2.2
		Total ARPU/GDP	7.6	7.7	8.0	5.7	5.2	4.8	4.4
	Mobile	Penetration (%)	30.3	37.4	44.9	50.3	57.2	62.1	66.9
ARPU/GDP (%)		3.9	3.6	3.6	3.5	3.4	3.4	3.4	
Total ARPU/GDP		7.0	6.6	6.6	6.1	5.9	5.7	5.6	
Average	Fixed ARPU/GDP		2.8	2.8	2.7	2.4	2.3	2.2	2.0
	Mobile ARPU/GDP		3.0	2.3	2.0	1.7	1.7	1.7	1.7
	Fixed+Mobile ARPU/GDP		5.8	5.1	4.6	4.2	4.0	3.9	3.7

Source: per capita GDP statistics from ITU data.

- (1) The turning point of Income effect for ASEAN countries. During the period 1997 to 2003 the fixed line penetration rate for Malaysia, Thailand and the Philippines stagnated and even declined. Only Indonesia was still growing. The turning point for mobile *T/I* ratio decline is the year 2000 for the Philippines, Malaysia and Thailand and 2001 for Indonesia. After these years the mobile penetration rate grew considerably. The turning point for each country is further analyzed below (details see Table 6).

Table 5
NIE penetrations vs. ARPU/ per capita GDP

NIE	Service	ARPU/GDP/year	1997	1998	1999	2000	2001	2002	2003
Taiwan	Fixed	Penetration (%)	175.1	180.5	184.4	189.2	189.0	189.2	189.5
		ARPU/GDP (%)	3.1	3.1	2.4	2.3	2.0	1.6	1.7
	Mobile	Penetration (%)	6.9	21.6	52.2	80.2	96.6	106.1	111.0
		ARPU/GDP (%)	6.8	5.6	2.3	2.0	1.9	1.8	1.8
		Total ARPU/GDP	9.9	8.7	4.7	4.3	3.9	3.4	3.5
Singapore	Fixed	Penetration (%)	192.6	196.5	198.0	200.8	198.0	193.2	186.0
		ARPU/GDP (%)	4.1	3.8	3.4	2.3	2.3	2.3	2.2
	Mobile	Penetration (%)	22.4	27.9	40.9	68.4	72.4	79.6	85.5
		ARPU/GDP (%)	3.5	3.4	2.2	1.4	1.6	1.7	1.6
		Total ARPU/GDP	7.6	7.2	5.6	3.7	3.9	4.0	3.8
H.K	Fixed	Penetration (%)	185.7	188.0	190.5	191.6	189.1	178.0	171.3
		ARPU/GDP (%)	3.2	3.8	3.4	2.3	2.3	2.3	2.2
	Mobile	Penetration (%)	34.4	48.5	64.4	78.0	84.4	91.2	105.6
		ARPU/GDP (%)	4.4	3.0	2.4	2.3	2.3	2.2	2.1
		Total ARPU/GDP	7.6	6.8	5.8	4.6	4.6	4.5	4.3
S. Korea	Fixed	Penetration (%)	151.4	146.0	146.2	153.2	155.7	156.6	152.7
		ARPU/GDP (%)	2.5	2.4	3.6	3.1	2.8	2.4	2.2
	Mobile	Penetration (%)	15.2	30.9	50.3	57.0	61.4	67.9	70.1
		ARPU/GDP (%)	6.6	4.4	3.4	3.5	3.6	3.3	3.2
		Total ARPU/GDP	9.1	6.8	7.0	6.6	6.4	5.7	5.4
Average	Fixed ARPU/GDP		3.2	3.3	3.2	2.5	2.4	2.2	2.1
	Mobile ARPU/GDP		5.3	4.1	2.6	2.3	2.4	2.3	2.2
	Fixed+Mobile ARPU/GDP		8.6	7.4	5.8	4.8	4.7	4.4	4.3

Source: per capita GDP statistics from ITU data.

- ◇ Malaysia: the fixed line *T/I* ratio declined from 9.5% in 1999 to 8.9% in 2000. At the same time fixed line penetration grew from 19.5% to its peak of 19.7%. Without crossing the income effect threshold fixed penetration growth already showed a tendency toward stagnation. In 2003 the fixed line *T/I* ratio was even higher than in 1997, and the fixed line penetration rate declined to 18.1% in 2003. This conforms to the statement of Hypothesis 3. The mobile *T/I* ratio dropped from 12% in 1999 to 8.3% in 2000 at which time the turning point of mobile growth appears, and the mobile penetration rate increased from 12% to 21.8%. By 2003 mobile *T/I* ratio is 5.5%, which is close to the upper threshold, and the mobile penetration rate grew considerably to 43.9%. This is the highest penetration rate among ASEAN countries, and it conforms to the statement of Hypothesis 3.
- ◇ Thailand: The fixed line *T/I* ratio dropped from 15.9% in 2001 to 12.5% in 2002. At the same time fixed line penetration grew from 38.5% to its peak of 41.3%. This conforms to the statement of Hypothesis 3. The mobile *T/I* ratio dropped from 17% in 2000 to 10% in 2001, at which time the growth of mobile penetration appeared to reach a turning point when penetration increased from 4.9% to 12.1%. Both the fixed line and mobile *T/I* ratios are too high, and therefore penetration growth is difficult. This conforms to Hypothesis 3.
- ◇ Philippines: The fixed line *T/I* ratio dropped from 17.2% in 1999 to 13.6% in 2000. Fixed line penetration increased from 39.9% to its peak of 45.2%. The mobile *T/I* ratio dropped from 11.3% in

Table 6
ASEAN Penetrations vs. ARPU/per capita GDP

ASEAN	Service	ARPU/GDP/year	1997	1998	1999	2000	2001	2002	2003
Malaysia	Fixed	Penetration (%)	19.3	19.7	19.5	19.7	19.6	18.8	18.1
		ARPU/GDP (%)	10.7	10.9	9.5	8.9	9.6	9.4	12.3
	Mobile	Penetration (%)	9.2	9.7	12.0	21.8	30.8	36.9	43.9
		ARPU/GDP (%)	13.6	13.9	12.0	8.3	7.8	7.0	5.5
Thailand	Fixed	Total ARPU/GDP	24.3	24.8	21.5	17.2	17.4	16.4	17.8
		Penetration (%)	33.5	35.0	33.4	35.7	38.5	41.3	39.6
		ARPU/GDP (%)	16.4	16.1	18.6	17.4	15.9	12.5	11.0
	Mobile	Penetration (%)	3.4	3.7	3.8	4.9	12.1	25.7	36.2
ARPU/GDP (%)		17.4	17.2	16.8	17.0	10.0	6.4	5.6	
Philippines	Fixed	Total ARPU/GDP	33.8	33.3	35.4	34.4	25.9	18.9	16.6
		Penetration (%)	31.3	36.6	39.9	45.2	44.4	43.3	41.3
		ARPU/GDP (%)	23.4	21.6	17.2	13.6	12.6	11.3	11.2
	Mobile	Penetration (%)	1.9	2.4	3.9	8.5	15.6	19.4	27.8
ARPU/GDP (%)		26.0	23.4	16.6	11.3	9.8	9.0	8.1	
Indonesia	Fixed	Total ARPU/GDP	49.4	45.0	33.8	24.9	22.4	20.3	19.3
		Penetration (%)	10.3	11.3	11.9	12.8	13.6	14.4	15.6
		ARPU/GDP (%)	39.5	27.5	25.9	23.6	21.0	17.0	15.1
	Mobile	Penetration (%)	0.5	0.5	1.1	1.7	2.9	5.0	7.5
ARPU/GDP (%)		30.1	44.2	35.0	30.1	17.3	14.2	12.8	
Average	Fixed+Mobile	Total ARPU/GDP	69.6	71.7	60.9	53.7	38.3	31.2	27.9
		ARPU/GDP	22.5	19.0	17.8	15.9	14.8	12.6	12.4
		ARPU/GDP	21.8	24.7	20.1	16.7	11.2	9.2	8.0
		Fixed+Mobile ARPU/GDP	44.3	43.7	37.9	32.6	26.0	21.7	20.4

Source: per capita GDP statistics from ITU related data.

2000 to 9.8% in 2001. The growth of mobile penetration reached a turning point, and mobile penetration increased from 8.5% to 15.6%. Both the fixed line and mobile *T/I* ratios are too high, and therefore penetration growth is difficult. This conforms to Hypothesis 3.

◇ Indonesia: The fixed line *T/I* ratio was 39.5% in 1997 and fixed line penetration only 10.3%. The fixed line *T/I* ratio dropped to 27.5% in 1998 and fixed line penetration grew slightly to 11.3%. In 2003 the fixed line *T/I* ratio dropped to 15.1% and the fixed line penetration rate grew to 15.6%. The mobile *T/I* ratio dropped from 30.1% in 2000 to 17.3% in 2001, and mobile penetration increased from 1.7% to 2.9%. Both the fixed line and mobile *T/I* ratios are too high, and therefore penetration growth is difficult. This conforms to Hypothesis 3.

(2) The turning point of Income effect for BRIC. During the years 1997 to 2003 all BRIC countries, except for fixed line service in Russia, have fixed or mobile *T/I* ratios that are higher than the upper threshold. The turning point of each country's income effect is analyzed below (details see Table 7).

◇ Russia: Russia's fixed line service is the only one in the BRIC countries to have income effect. During the period 1997 to 2003 the fixed line *T/I* ratio was lower than 5%, and fixed line penetration grew from 58.6% in 1997 to 71.3% in 2003. The mobile *T/I* ratio dropped from 23.8% in 2000 to 11.6% in 2001, at which time the turning point for mobile growth appeared and mobile penetration grew from 2.4% to 5.5%. But the *T/I* ratio is still too high and therefore penetration is still low. This conforms to statement of Hypothesis 3.

Table 7
BRIC penetrations vs. ARPU/per capita GDP

BRIC	Service	ARPU/GDP/year	1997	1998	1999	2000	2001	2002	2003
Russia	Fixed	Penetration (%)	58.6	60.8	60.7	61.7	63.5	68.3	71.3
		ARPU/GDP (%)	1.9	3.1	4.8	3.6	2.9	2.8	4.0
	Mobile	Penetration (%)	0.3	0.5	0.9	2.4	5.5	12.4	25.2
		ARPU/GDP (%)	13.7	32.7	49.8	23.8	11.6	7.1	6.9
China	Fixed	Penetration (%)	15.6	35.8	54.6	27.4	14.5	9.9	10.9
		ARPU/GDP (%)	21.1	26.1	32.0	41.6	50.8	61.7	72.7
	Mobile	Penetration (%)	26.8	26.7	22.2	14.6	12.1	10.9	8.3
		ARPU/GDP (%)	1.1	1.9	3.4	6.7	11.3	16.1	20.9
Brazil	Fixed	Penetration (%)	59.0	40.3	27.1	21.4	14.3	12.5	8.9
		ARPU/GDP (%)	85.8	67.0	49.3	36.0	26.4	23.4	17.2
	Mobile	Penetration (%)	41.5	46.9	58.3	68.7	82.2	81.6	78.6
		ARPU/GDP (%)	12.7	13.3	12.6	11.3	10.7	18.4	16.6
India	Fixed	Penetration (%)	2.8	4.4	9.0	13.6	16.7	19.0	26.2
		ARPU/GDP (%)	13.2	17.0	12.3	9.2	7.7	6.8	5.3
	Mobile	Penetration (%)	25.9	30.3	24.9	20.5	18.4	25.2	21.9
		ARPU/GDP (%)	10.2	12.1	14.5	17.3	20.1	21.3	24.8
Average	Fixed	Penetration (%)	64.9	55.6	42.6	36.8	31.2	28.2	22.4
		ARPU/GDP (%)	0.1	0.1	0.1	0.2	0.3	0.6	1.2
	Mobile	Penetration (%)	–	98.4	124.8	120.2	79.9	43.2	25.1
		ARPU/GDP (%)	64.9	154.0	167.4	157.0	111.1	71.4	47.5
Average	Fixed ARPU/GDP	26.6	24.7	20.6	16.6	14.2	15.1	12.8	
	Mobile ARPU/GDP	28.6	47.1	53.5	43.7	28.4	17.4	11.6	
	Fixed+Mobile ARPU/GDP	48.1	71.8	74.1	60.2	42.6	32.5	24.4	

Source: per capita GDP statistics from ITU related data.

- ◇ China: The fixed line T/I ratio dropped from 22.2% in 1999 to 14.6% in 2000. The growth of fixed line service shows that it reached a turning point, and the fixed line penetration rate grew from 32% to 41.6%. The mobile T/I ratio dropped from 21.4% in 2000 to 14.3% in 2001, at which time mobile growth showed a turning point, and its penetration rate grew from 6.7% to 11.3%. But the T/I ratio is still high and penetration is still low. This conforms to the statement of Hypothesis 3.
- ◇ Brazil: The fixed line T/I ratio dropped from 12.6% in 1999 to 10.7% in 2001. During the same period fixed penetration grew from 58.3% to 82.2%. During 2002 to 2003 instead of declining, the fixed line T/I ratio increased, and fixed line penetration dropped to 81.6% in 2002. The mobile T/I ratio declined from 12.3% in 1999 to 9.9% in 2000, at which time the growth of mobile showed a turning point, and mobile penetration increased from 9.0% to 13.6%. Because the T/I ratio is still too high therefore the penetration rate is still low. This conforms to the statement of Hypothesis 3.
- ◇ India: The fixed line T/I ratio was as high as 55.6% in 1998, and fixed line penetration rate was only 12.1%. In 1999 the T/I ratio dropped to 42.6% and penetration grew to 14.5%. The mobile T/I ratio dropped from 43.2% in 2002 to 25.1% in 2003, and mobile penetration increased from 0.6% to 1.2%. Because of the income effect it is difficult to grow either the fixed line or mobile penetration. This conforms to the statement of Hypothesis 3.

In summary, in 1997 mobile business was still in its initial stages globally, and mobile penetration in G7 and NIE, excluding HK at 34.4% and Japan and 30.3%, was between 10% and 20%. In 2003 each household in ASEAN and BRIC countries still had less than one fixed line, with the average in ASEAN being 28.7% and in BRIC 29.1%, and mobile penetration was still low, averaging 37.9% in ASEAN and 29.1% in BRIC. Over time because of market competition, decline in rates, and gradual increases in per capita income, the T/I ratios will gradually fall to less than 5%, and ASEAN and BRIC countries will cross the income effect threshold. For details see [Tables 6 and 7](#).

The wide variation of T/I ratios and penetration indicates that Hypothesis 3 has proved to be true. Nevertheless, besides the T/I ratio, the deployment rate of fixed and mobile infrastructure most likely influences the mobile penetration. Additionally, when mobile ARPU is close to or lower than fixed line ARPU, mobile service will become affordable relative to fixed line for mass users, and mobile penetration will begin to grow considerably.

5. Results

Developed and developing economies in G7 and NIE are mostly traffic substitution whereas developing economies in ASEAN and BRIC are mostly penetration substitution. FMS patterns in developed and developing economies exhibit significant differences. This article has studied the fixed line and mobile communication growth trends of the four groups of countries and demonstrated that during the study period of 1997 to 2004 the FMS pattern for developed economies such as G7 and NIE countries which have fixed line penetration rate higher than 100% (more than one phone line per household) is mostly traffic substitution. This conforms to Hypothesis 1. For developing economies such as ASEAN and BRIC that have a lower than 100% fixed line penetration rate (less than one phone line per household) the FMS pattern is mostly penetration substitution. This conforms to Hypothesis 2. That is, when disposable income is very limited then telecom penetration will be low. Overall, G7 in the year 1999 and NIE in the year 2000 crossed the 5% income effect threshold, and mobile penetration increased rapidly. ASEAN and BRIC countries, except for fixed lines in Russia, all experienced the income effect. Therefore, any growth of telecom penetration is not easy. This conforms to Hypothesis 3. In addition, this study discovered when observing the four groups of countries that there is a tendency in FMS patterns such that the differences between G7 and NIE countries is slight, and that the basic trends of ASEAN and BRIC countries are essentially the same.

4C convergence will likely change the scope and scale of the telecom industry and influence the development of information economics of a country. Telecom policy regulators have the responsibility to think ahead, facing the trend of the convergence of fixed, mobile, wireless and broadcasting to create a fair, competitive win–win–win environment for the government, operators and subscribers. For ASEAN and BRIC countries, which mainly exhibit penetration substitution on FMS, the tradition of using fixed line network as the model for the basis of a national telecom policy has been changed.

Because most telecom regulators do not publish mobile traffic volume this study was not able to directly use the number of traffic minutes to analyze the FMS patterns. In addition, the 2004 revenue data of some of the countries cannot be obtained. These are the biggest restrictions of this study. The focus of this study is FMS patterns. In the second half of 2004 VoIP emerged and began to move into

the fixed line voice market. In the future, with possible 4C convergence, the relationship of substitution will become more complex. Diversified substitution relationships will be the direction of future research.

6. Discussion

In G7 and NIE countries FMS pattern is the substitution of second fixed lines by mobile, unlike ASEAN and BRIC countries in which first fixed lines are being substituted by mobile. Besides the diminishing price differences between mobile and fixed line services that will accelerate the mobile replacement of fixed line service, the investment patterns of the service providers and government policies can affect this too. Pure fixed line business operators facing traffic substitution may lose some traffic income but may still keep the income from the basic monthly rental fee of the basic line [12]. But fixed line operators facing penetration substitution will lose both the basic monthly rental fees and traffic income to mobile businesses. Full-service telcos who own both fixed line and mobile business could benefit from operating synergy [9]. Telecom businesses, if they take into consideration the industry evolution in their investment planning, should have good opportunities for capturing markets.

Because broadband xDSL internet connections still rely on tradition phone lines, the newer Wi-Fi, WiMax, 3G Wireless network card, and cable modem all may create substitution for the xDSL internet connection, but the quality of wired communication is still superior to that of the wireless. Furthermore, when cable operators provide triple-play service and increase its penetration, then cable modem to fixed line substitution will be increased.

6.1. VoIP substitution

VoIP (Voice over Internet Protocol) may be divided into IP Domain VoIP (QoS) and best effort level of VoIP (no QoS), and has been introduced by the fixed operators or ISPs into the market. In addition, IP Backhaul and VoIP are also moving into mobile access. Because of the separation of the broadband network into infrastructure and application, VoIP (best effort) has become the most attractive value-added service. Free bandwidth upgrades indirectly help promote VoIP service. It is more than merely transforming the last miles; the core network must also be replaced. The IMS (IP Multimedia Subsystem) vision is one network that supports both mobile and fixed access [13]. It is foreseeable that one flat rate for unlimited calls will be the main voice service for the telcos. Around the world the major traditional telcos first introduced the enterprise of VoIP, then starting from the 2nd half of the year 2004, also introduced VoIP to the general public. American VoIP companies like Vonage (Voice Net Age) in less than two years had more than 1,200,000 subscribers by the end of 2005, and Times Warner's VoIP had 1,100,000 subscribers. Cable TV operators also joined the VoIP battle, bundling with the triple-play service of voice, data and video. The appearance of Skype in the 2nd half of the year 2004 has caused a great deal of change to the global fixed voice market. This study covers only to the end of 2004, but the 2004 revenue data cannot be obtained during the writing of this paper. We should know, however, that the fixed ARPU is not only affected by the mobile service, but also by VoIP during 2004, which is outside the scope of this study.

6.2. *Wireless substitution*

New Wireless technology and services are emerging. The application of wireless is blurring the distinction between fixed line and mobile, and in the future fixed line and mobile platforms may gradually converge over the IP network [14]. The FMWS (Wireless to Fixed and Mobile Substitution) are coming as evidenced by the extensively distributed Metropolis Wireless Local Area Network and the wide spread of hotspots in public places. The combination of Wi-Fi and VoIP with mobility will obviously affect fixed and mobile voice services. The maximum transfer rate of WiMax is 75 Mbit/s and the transmission range is 50 km [15]. It requires fewer base stations and the cost of base station construction is estimated to be lower than the construction of current 3G base stations. Wireless technology is one of many future visions. Others look more at the evolution to IMS networks using an evolution of CDMA (Code Division Multiple Access) and UMTS (Universal Mobile Telecommunications System) technology. Wireless replacing voice and data access are described below:

- (1) Voice substitution: VoIP operators provide the integrated function of Wi-Fi and VoIP handsets and provide subscribers with unlimited VoIP calling at home and outdoors, and this will cause the obvious substitution effect for fixed and mobile voice services.
- (2) Data substitution: WiMax is a new access technology which is expected to replace fixed DSL and mobile 3G data services [15]. If connection can be established using indoor Wi-Fi protocol and then connecting to outdoor WiMax stations via IEEE 802.16, this technology will potentially replace fixed DSL. Mobile WiMax supports the packet transmission ability, and some equipment manufacturers have embedded the WiMax technology in notebook, handset and PDA by implementing the IEEE 802.16e protocol. The Japan mobile operator KDDI has recently tested the video and image transit qualities of mobile WiMax and found that they are clearer than 3G W-CDMA. The maximum downward transit speed is 384 kbit/s for mobile base stations of W-CDMA, but the mobile WiMax has a higher transfer rate at 1 Mbit/s. Nevertheless, if the telcos can maintain their position by offering digitalized movie and music content service on 3G mobile, they can counter the inroad threats made by WiMax, and gradually meet the customers' demand for high-speed bandwidths by using Fiber-Optic network to replace DSL network and thus diminish the threat of being substituted by the technological development of WiMax.

6.3. *Future infrastructure composition*

Because broadband xDSL internet connections still rely on tradition phone lines, the newer Wi-Fi, WiMax, 3G Wireless network card, and cable modem all may create substitution for the xDSL internet connection, but the quality of wired communication is still superior to that of the wireless. Furthermore, when Cable operators provide triple-play service and increase its penetration, then cable modem to fixed line substitution will be increased. But if the fixed line monthly service fee is low enough, fixed line subscribers will still hold onto one phone line probably for 'lifeline' emergency services.

FMS and FMWS (fixed mobile to wireless substitution) will influence the future composition of telecommunication infrastructure networks for every country. Because by means of mobile or wireless access the telecom operators could also meet the universal service of obligation (USO), the regulators

have the responsibility to use policies with the future in mind to guide not only the market opportunities created by the advancement of technology for the operators but also the development of national infrastructure networks. Wireless broadband may take advantage of lower cost and may also combine with IP network to substitute the utilization of voice and Internet access to a certain degree. The possible substitution patterns of FMS and FMWS will be similar to the Chinese proverb about the relationship of the mantis stalking the cicada, unaware of the oriole following behind. The role of the regulator making a policy decision is like a hunter deciding who will live or die in the struggle of telecom evolution. It is foreseeable that the distributed ratio for the composition of the future communication infrastructure will display a significant difference according to the level of per capita GDP per country. Because the G7 and NIE countries have mainly experienced traffic substitution, and their fixed and mobile infrastructure networks are already completed, therefore the allocation ratio of Wireless network is expected to be limited.

It is worth noting that the developing countries have mainly experienced penetration substitution, and if the demand for data besides voice arises in the future, the mobile data bandwidths will be inadequate to meet the demand for data transmission. When this moment arrives, will subscribers go back to using the fixed line IP network thus reviving the stagnant or dropping fixed penetration, or will they turn to new wireless technology? It is expected that the allocation cost for WiMax will be lower compared to the traditional PSTN network, but will the new wireless technology be extensively adopted by the developing countries which are still at a lower rate of fixed penetration? Or, if the allocation ratio for mobile and wireless infrastructure is higher than for fixed network, will that influence the composition of the basic communication infrastructure network and the dynamic for market competition? Please see Fig. 9. Separate data revenue should be used for the study of multi-element substitution. All of the above questions deserve further research.

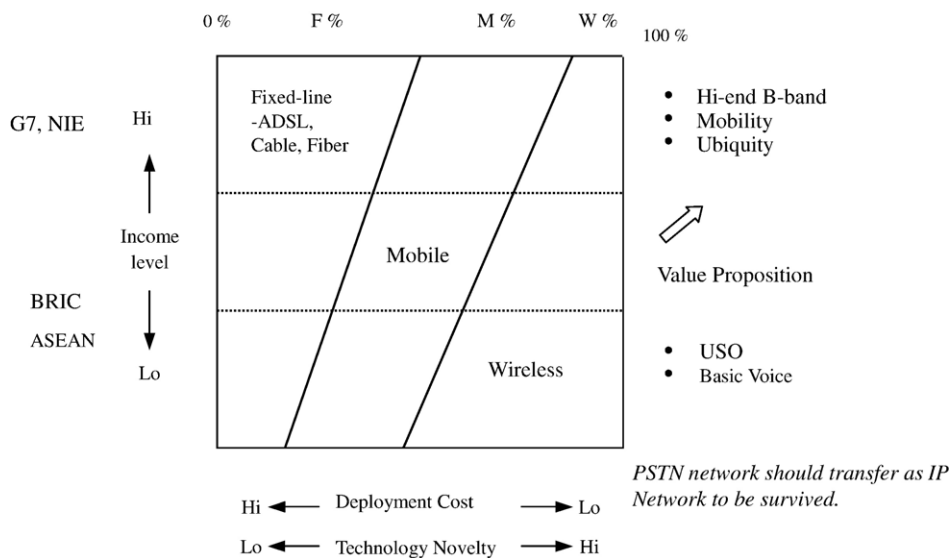


Fig. 9. Future telecommunication infrastructure composition source: Dr. C. K. Mao, Telecom Regulation (APEC Workshop, 2005).

Appendix A. Referred regulators websites

Countries	Regulator websites
Brazil	www.anatel.gov.br
Canada	www.ic.gc.ca
China	www.mii.gov.cn
Finland	www.mintc.fi
France	www.anfr.fr
Germany	www.regtp.de
H.K	www.ofta.gov.hk
India	www.trai.gov.in
Indonesia	www.depub.go.id
Italy	www.comunicazioni.it
Japan	www.soumu.go.jp
Malaysia	www.mcmc.gov.my
Philippines	www.dotmain.gov.ph
Russia	www.minsvyaz.ru
S. Korea	www.kcc.go.kr
Singapore	www.ida.gov.sg
Taiwan, R.O.C	www.dgt.gov.tw
Thailand	www.mict.go.th
U.K	www.ofcom.org.uk
U.S.A	www.fcc.gov

Appendix B. Fixed domestic exchanged lines (unit: 000)

Countries/year	1997	1998	1999	2000	2001	2002	2003	2004
U.S.A	172,452	179,822	183,521	187,002	190,994	186,232	181,600	180,102
Canada	18,660	19,294	20,051	20,840	21,126	20,622	20,664	20,068
Japan	65,735	67,488	70,530	61,960	61,330	60,770	60,575	59,610
Germany	45,200	46,530	48,210	50,220	52,450	53,780	54,250	54,550
France	33,700	34,099	33,888	34,081	34,084	34,124	33,905	33,910
Italy	25,698	25,986	26,502	27,300	27,353	27,142	28,500	26,596
U.K	31,879	32,829	34,021	35,047	35,660	34,517	34,121	33,700
H.K	3647	3729	3846	3946	3926	3842	3820	3780
Singapore	1685	1778	1851	1936	1948	1934	1897	1863
Taiwan	10,862	11,500	12,044	12,642	12,858	13,099	13,355	13,530
S. Korea	20,422	20,089	20,518	21,932	22,725	23,257	22,877	22,800
Malaysia	4223	4384	4423	4628	4710	4670	4572	4448
Thailand	4827	5038	5216	5591	6049	6566	6305	6478
Philippines	4500	5300	5987	6909	6939	6914	6693	6473
Indonesia	4982	5572	6080	6662	7219	7750	8479	9989
Brazil	17,039	19,987	24,985	30,926	37,430	38,800	39,200	37,188
China	70,310	87,421	108,715	144,829	180,368	214,420	263,000	316,000
India	17,802	21,594	26,511	32,436	38,536	41,420	48,917	50,385
Russia	28,250	29,246	30,949	32,070	33,278	35,500	36,993	39,196

Appendix C. Mobile subscribers year by year (unit: 000)

Countries/year	1997	1998	1999	2000	2001	2002	2003	2004
U.S.A	55,312	69,209	86,047	109,478	128,375	140,767	158,722	175,000
Canada	4266	5365	6911	8727	10,862	11,861	13,222	14,984
Japan	38,254	47,308	56,846	63,883	72,797	79,082	85,381	90,187
Germany	8276	13,913	23,446	48,202	55,126	59,128	64,800	71,316
France	5817	11,210	21,434	29,052	36,997	38,585	41,683	43,831
Italy	11,738	20,489	30,296	42,246	51,246	53,003	55,918	57,171
U.K	8841	14,878	27,185	43,452	46,283	49,677	52,984	61,241
H.K	2230	3174	4275	5234	5702	6219	7194	8158
Singapore	849	1095	1631	2747	2992	3313	3578	3861
Taiwan	1492	4727	11,541	17,874	21,633	23,905	25,090	21,528
S. Korea	6879	14,019	23,443	26,816	29,046	32,342	33,592	35,050
Malaysia	2000	2150	2717	5122	7385	9053	11,124	14,611
Thailand	1977	2204	2339	3056	7550	16,117	22,825	27,625
Philippines	1344	1734	2850	6454	12,159	15,201	21,860	32,936
Indonesia	916	1066	2221	3687	6415	11,340	17,888	30,081
Brazil	4550	7368	15,033	23,188	28,746	34,881	46,373	65,606
China	13,233	23,863	43,296	85,260	144,820	206,620	269,953	334,824
India	882	1195	1400	1884	3557	6431	12,687	26,155
Russia	485	747	1371	3263	7750	17,609	36,890	74,350

Appendix D. Fixed telephony service revenue (US\$ mn)

Countries/year	1997	1998	1999	2000	2001	2002	2003
U.S.A	198,000	210,000	220,010	230,762	227,113	210,820	205,863
Canada	8772	9051	8553	9207	8536	8231	8110
Japan	45,527	42,649	51,264	50,753	44,689	43,100	42,078
Germany	25,778	26,027	23,063	19,358	19,107	21,226	26,292
France	17,141	16,421	16,024	13,423	12,833	13,194	12,930
Italy	17,006	20,903	19,700	15,978	15,438	15,400	15,843
U.K	18,586	20,241	20,458	18,788	16,957	17,612	18,361
Average	47,259	49,328	51,296	51,181	49,239	47,083	47,068
H.K	3166	3564	3,400	3183	2,902	2,744	2,428
Singapore	1741	1428	1312	1041	934	926	894
Taiwan	3969	4455	3899	4087	3278	2615	2859
S. Korea	5858	3736	7166	7467	6411	6498	6354
Average	3683	3296	3944	3945	3381	3196	3134
Malaysia	2082	1592	1519	1588	1663	1692	2316
Thailand	2038	1528	1984	1966	1812	1676	1609
Philippines	1198	1025	1055	932	804	764	744
Indonesia	2110	715	1085	1163	1055	1133	1239
Average	1857	1215	1411	1412	1333	1316	1477

Appendix D (continued)

Countries/year	1997	1998	1999	2000	2001	2002	2003
Brazil	10,894	12,641	10,122	12,339	11,886	18,614	18,688
China	13,595	17,742	18,996	17,558	19,763	22,545	23,800
India	5046	5210	5140	5483	5665	5701	6135
Russia	1600	1700	1844	1946	2047	2334	2490
Average	7784	9323	9025	9331	9840	12,299	12,778

Appendix E. Mobile communication revenue (US\$ mn)

Countries/year	1997	1998	1999	2000	2001	2002	2003
U.S.A	33,000	36,775	48,000	62,000	74,687	81,521	89,857
Canada	2356	2950	3070	3604	3852	4593	5932
Japan	33,233	35,664	46,012	55,985	68,913	85,158	91,210
Germany	9879	10,570	13,979	19,188	20,256	22,278	28,236
France	3680	4495	6019	7146	9175	11,015	15,451
Italy	6630	8832	9593	10,106	12,411	14,386	17,865
U.K	5244	6406	8587	9697	11,449	13,582	17,377
Average	13,432	15,099	19,323	23,961	28,678	33,219	37,990
H.K	2634	2442	2509	2934	3173	3251	3478
Singapore	741	777	769	872	1006	1163	1213
Taiwan	1190	3374	3626	4971	5056	5338	5744
S. Korea	5182	4693	7758	10,571	10,618	12,172	13,534
Average	2437	2821	3666	4837	4963	5481	5992
Malaysia	1262	991	1183	1640	2121	2444	2526
Thailand	883	714	804	1049	1426	2095	2967
Philippines	397	362	484	722	1096	1335	1762
Indonesia	295	220	535	819	770	1381	2220
Average	709	572	751	1057	1353	1814	2369
Brazil	3043	5937	5928	7541	6542	6130	7078
China	5641	7307	9255	15,224	18,742	24,867	26,333
India	–	510	795	1039	1338	1354	1784
Russia	200	461	856	1329	1896	2957	4308
Average	2221	3554	4209	6283	7130	8827	9876

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