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Full Length Research Paper

Rising productivity of the fixed mobile convergence trend in the telecommunications industry

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This study explores the productivity variation in the telecommunications industry by adopting the slack-based measure in the current period and the SBM-based Malmquist in the cross-periods spanning from 2006 to 2009. The observed global leading 51 telcos (telecommunications companies) are top ranking on the Forbes Global 2000, and divided into three groups of mobile-only, fixed-only, and fixed-mobile patterns. For the catch-up effect, the degree of effort in improving the productivity for the fixed-mobile operation is better than the mobile-only and the fixed-only patterns. With regard to the Malmquist index, the fixed-mobile operation had displayed TFP progress in efficiency more than the other two group patterns. Although the mobile-only pattern presented the progress in productivity, the progress rate was gradually declined. Moreover, by buying back the mobile stockholdings to fully own the fixed-line and mobile operations, these telcos are named 're-mergers,' and most of them have achieved rising productivity for the study period. The findings of this research address a turning point since 2007. The number of fixed-mobile operators that had achieved efficient TE was the most among the three group patterns, and had increased from seven in 2007, to ten in 2008, and fourteen in 2009. In 2009, the observed operators that have achieved efficient TE include the three re-mergers of Telefonica, Royal KPN, and Belgacom. The fixed-line operators who spun-off their mobile branches were called 'de-mergers' and had displayed a regression in productivity. In conclusion, the strategic implications for being merged as a fixed-mobile operation are promising for the integrated synergy to cope with the fixed mobile convergence trend.

Key words: Productivity, catch-up, Malmquist, FMC, FMS.

INTRODUCTION

An important topic covering the telecommunications industry development from the trend of fixed to mobile substitution (FMS) to fixed mobile convergence (FMC) has not been extensively discussed in academia. This study is consistent with the findings from the prior research: "Are the fixed-mobile telcos more comparative? A Cross-country efficiency Study" written by Mao, Hu and Chen (2010) which traces the integrated synergy of FMC. FMC is described as the networks and services of fixed-line and mobile operations, which could be connected and transferred seamlessly to use a single terminal in a different environment (family, work, leisure and moving spaces). The main driving force for FMC comes from FMS which lets subscribers generate seamless communications requirements between fixed-line and mobile services, because the mobile phone is specialized with functions as an individual proprietary device with portable convenience. Through the connection of a worldwide local area network (WLAN), the networks and platforms of telecommunications operators could be integrated and strengthened to form a convergence via IP (internet protocol). The attractive characteristics of FMC for subscribers are a promise for user-centered commitment, and this could be helpful for reducing the subscribers' cost expenditures as well as ensuring customer's loyalty.

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The development evolution of the telecommunications industry from FMS to FMC solidly verifies Luo Guanzhong's famous sayings: "The world, long divided, must reunite; whereas the world, long united, must be divided" as stated in his groundbreaking Chinese novel: 'The Romance of the Three Kingdoms.' The global telecommunications market with facility-based classification in the process of privatization could be divided into three business operations of mobile-only, fixed-only, and fixed-mobile services. By the year 2000, mobile services were in a high-growth stage and considered as a cash cow. Under the industrial top issue of whether the mobile business should be separated from the traditional telecommunications operation, many incumbents decided to split their mobile branch. The background of this study spans the period from the beginning to the end of 2001, and the incumbents continued to split off their mobile branches to become a fixed-only operator. For example, in January, Swisscom spun off Swisscom Mobile. In February, France Telecom split off its mobile branch as Orange SA. Also in February, Telmex separated America Movil (Telcell). In March, KPN spun off KPN Mobile NV. In May, Eircom separated Eircell. In July, old AT&T spun off AT&T Wireless. In October, BT Group separated mmO2. And finally in December, PCCW separated with CSL.

However, since 2004, the aforementioned fixed-only operators continuously merged back their spun-off mobile branches to become a fixed-mobile operator. We know that the business strategies for the fixed-line and mobile services had been separated in the past, but since the second half of 2004, this status had started to change. The fixed-only operators were trying to introduce integrated services in order to prevent the fixed-line voice revenue from declining, as well as to further satisfy the subscribers' seamless access. The spun-off wave of the mobile branch in the telecommunications industry popularly occurred in 2001, but since 2004, France Telecom started to merge back its mobile subsidiary of Orange to own 100% of the shares. Thereafter, Telecom Italia, Royal KPN, Belgacom, Telefonica SA, Swisscom AG, and KT continued to merge back their mobile subsidiaries to own the fixed-line as well as the mobile operations. Hence, the most favorable development of FMC is deemed to be the telcos, who have both fixed-line and mobile services in their offerings that have 100% of the stockholdings (If the mother company holds 100% of the stockholdings of the mobile branch; then the two companies must have an identical Chairman and CEO. But if the mother company only owns partial shares for the mobile branch, then they do not necessarily have the same Chairman and CEO) in order to operate. These telcos are focused on FMC development through M&A activities. Whether the efficiency and productivity of fixed-mobile operators have been improved over the situation before or better than the fixed-only and mobile-only operators could provide reasons to conduct research on this topic. Given the above observation, the purpose of this study is to explore how the comparative productivity in the FMC trend could be deliberately considered by the government's regulators and telcos to make appropriate policy decisions, and by academia for further study.

This paper presents the first study to explore the productivity variation for the global leading telcos spanning over four years, which are top-ranked on the Forbes global 2000 in the telecommunications industry and divided into three facilities-based patterns. The slack-based measure (SBM) model is employed to evaluate the performance of telcos in the current period, and the SBM-based Malmquist approach is used to measure the productivity variation in the cross-periods among the three group patterns. This study adopts four output variables of revenue, EBITDA, EBIT, and net income and three input variables of total assets, debt, and SG&A expenditure (sales, general and administrative expenditures) to measure the productivity index. The related data has been retrieved from the telcos' annual reports on their websites and the companies' equities of the UBS Investment Bank database.

Literature review

Studies of productivity variation are critical in the improvement of governments' regulated policy and management decision-making for enterprises. Since the early 1980s, there has been a growing interest in measuring the efficiency and productivity of the telecommunications sectors. Nadiri and Schankerman (1981) decomposed TFP (total factor productivity) growth into a scale economies component and a technical change component for the US Bell System from 1947 - 1976. The average annual growth rate of TFP was found to be 4.09% and scale economies accounted for a large percentage of TFP growth during the entire post-war period. Majumdar (1995) investigated the effect of the adoption of new switching technology on the carriers' performance in the U.S. telecommunications industry by calculating input-conserving and output-augmenting measures. Majumdar (1998) further applied DEA to illustrate patterns of resource utilization in the US telecommunications industry in 1990, using different output variables in three different models. Sueyohsi (1998) explored the economic assertion of NTT by comparing its performance before and after privatization in 1985. His study indicated an improvement in production-based efficiency but a lack of price-reducing benefit after the privatization of NTT. Madden and Savage (1999) conducted a panel study to examine the telecommunications productivity, technological catch-up and innovation in 74 countries for the period covering 1991 - 1995. They found that TFP growth was highest for the sub-sample of industrialized countries and was negative for countries in Africa and the Western Hemisphere. Giokas and Pentzaropoulos (2000) applied the DEA

approach to investigate the regional productive efficiency of public telecommunications organizations in Greece in 1998. Their studies indicated that out of a total of 36 telecommunications centers, 15 of them were found to be efficient with a maximum score of one.

More recently, production frontier approaches such as the productivity of the Malmquist index have become popular in measuring the performance efficiency in the telecommunications industry. Uri (2000, 2001a, 2001b) applied the DEA and the Malmquist index to measure the TFP growth for 19 local exchange carriers in the United States during the periods from 1988 - 1998. His studies indicated that productivity increased by about 5% per year and the increase in productivity was mainly due to innovation rather than improvements in efficiency. Rushdi (2000) found that the average TFP growth rate of Telstra in Australia during the post-reform period (1980 - 1991) was 10.1%, which was significantly higher than the growth rate of 4.9% during the pre-reform period (1980 - 1991). Lien and Peng (2001) calculated the production efficiency of telecommunications in 24 OECD countries to apply a DEA approach for the period between 1980 and 1995, and confirmed that competition in the telecommunications sector is associated with enhanced production efficiency. Calabrese, Campisi and Mancuso (2002) used the Malmquist index to measure the TFP growth of 13 OECD countries for the period covering 1979 - 1998 and reported that the average TFP growth was 4.78% per annum for the countries under study. Nemoto and Asai (2002) examined the cost structure of local telecommunications services in Japan to provide measurements of productivity growth. Their study revealed that the contributions of technical change to productivity growth are greater than those of scale economies and capital adjustment.

In addition, Lam and Lam (2005) adopted both the growth accounting approach and the Divisia aggregation method to estimate the total factor productivity (TFP) growth of the Hong Kong Telephone Company (HKTC) in Hong Kong. The TFP of HKTC was estimated to be 2.31 - 3.56% per annum between 1964 and 1998. Tsai, Chen and Tseng (2006) applied the DEA approach with a classical radial measure, A&P efficiency measure and efficiency achievement measure, respectively, to compare the efficiency for global telcos. Hu and Chu (2008) applied the Malmquist productivity index to evaluate the efficiency improvement of Asia-Pacific telecommunications firms, indicating that the total factor productivity growth of these telecommunications firms is mainly due to technical innovation instead of from technical efficiency change. Lam and Shiu (2008) applied the DEA approach to measure the productivity performance of China's telecommunications sector at the provincial level. Their study indicated that the efficiency scores of the provinces in the eastern region are significantly higher than those in the central and western regions. Lam and Shiu (2010) further indicates that there is a bi-directional relationship between real gross domestic product (GDP) and telecommunications development for European and high-income countries. Their studies show that countries with competition and privatization in telecommunications have achieved a higher TFP growth than those without competition and privatization.

Only a few articles have studied related issues of fixed mobile substitution (FMS) and fixed mobile convergence (FMC). Mao, Tsai and Chen (2008) studied the issues of FMS patterns of traffic substitution and penetration substitution. Their studies indicated that during 1997 - 2004, for those countries in the G7 an NIE with fixed-line penetration higher than 100%, the FMS is mostly traffic substitution. For those countries with fixed-line penetration lower than 100%, such as in ASEAN and BRIC countries, the FMS is mostly penetration substitution. Chen, Tsai and Mao (2008) explored FMS effects of income, affordable and threshold effects in the developed and developing economies. Their studies indicated that most developing economies have experienced only the income effect, and when the mobile ARPU (average revenue per user) comes close to or drops lower than fixed-line ARPU, the mobile penetration rate begins to increase and the affordable effect is evident. They also proposed that the threshold effect happens only when the mobile penetration rate crosses a critical mass threshold, and then the growth of fixed-line penetration will decline or stop. Bijl and Peitz (2008) discussed the challenges for telecommunications regulation in light of converging services for voice, data, and video from a European perspective. Their studies indicated that the regulatory practice might need a drastic overhaul in order to accept convergence and suggest it may no longer be appropriate to view access regulation depending on country-specific characteristics. With regard to the study of the integrated fixed-mobile operations, Mao, Hu and Chen (2010) adopt the `DEA approach to show that the strategic decision not to spin-off the mobile business from fixed-mobile operations was correct, and indicates that from a long-term perspective, the future for fixed-mobile service carriers is promising. However, the research of Mao, Hu and Chen (2010) haven't proved that the fixed-mobile pattern always plays the best choice in efficiency performance among the three groups' patterns, their empirical results showed that the efficiency of fixed-mobile operation was better than fixed-only and mobile-only patterns in 2002 - 2004, but the mobile-only pattern is better than the fixed-only and fixed-mobile patterns in 2005 - 2007. Nevertheless, this study is extended to the aforementioned research to clearly verify the fixed-mobile operation is superior to the fixed-only and mobile-only patterns irrespective of reaching the numbers of efficient TE and productivity improvement by applying the slack-based measure in the current period and the SBM-based Malmquist in the cross-periods spanning from 2006 - 2009. Hence, it is very important for a single operation of mobile-only and fixed-only telcos to reconsider whether to

adopt a fixed-mobile business model to increase their operations productivity.

TELECOMMUNICATIONS INDUSTRY DEVELOPMENT

De-merge and re-merge background

The global communications market with facility-based classification in the process of privatization could be evolved into the following three group patterns of mobile-only, fixed-only, and fixed-mobile services.

Mobile-only pattern

There are two types of mobile business operators. One is the mobile operation split from the incumbents to become a mobile-only operator. Another is the newly established mobile-only operator. Because the mobile services in the millennium were in the high-growth stage, they tended to be considered as the resources of mainstream revenue. Hence, the mobile branches for some telcos have continually been spun-off from the mother operator to establish a new publicly traded company. Mao, Hu and Chen (2010) indicate that many of these new spun-off mobile companies achieve this through an IPO (initial public offering) to enjoy a higher stock price without the negative burdens of fixed-line voice declining revenues. The following examples are illustrated for reference. In July 1995 Telecom Italia was the earliest telco to separate its mobile branch of TIM (Telecom Italia Mobile) to operate the mobile business. In October 1998 NTT DOCOMO was spun-off from NTT Corporation because the regulator considered preventing NTT to own a monopoly in Japan's telecommunications market. In April 2000, the Chinese regulator commanded China Telecom to split off its mobile department as a new company called China Mobile. Since 2001, many incumbents have split their mobile branch to be called 'de-mergers' under the industrial top issue of whether the mobile business should be separated from the traditional telecommunications operation. Mao, Hu and Chen (2001) show that from the beginning to the end of 2001, the incumbents continued to split off their mobile branches to operate independently as a mobile-only operator. For example, in January, Swisscom spun off Swisscom Mobile. In February, France Telecom split off its mobile branch as Orange SA. Also in February, Telmex separated America Movil (Telcell). In March, KPN spun off KPN Mobile NV. In May, Eircom separated Eircell. In July, old AT&T spun off AT&T Wireless. In October, BT Group separated mmO2. And finally in December, PCCW separated with CSL (Table 1).

Fixed-only pattern

The incumbents sold out all their mobile branches or owned the partial stockholding of a mobile branch to operate only the fixed-line services called as a fixed-only operator. This type of fixed-line pattern is included for famous carriers such as BT, NTT Corporation, and KT are generally referred to as 'de-mergers.' In June 2009, KT merged with KTF as a fixed-mobile operator, and therefore KT was categorized as a fixed-only operator before 2008.

Fixed-mobile pattern

The incumbents didn't split off their mobile branches to own both of the fixed-line and mobile operations, and through an IPO in the open market they can focus their efforts as fixed-mobile operators. This kind of operation pattern has been reported in the leading incumbents in their local markets including SingTel in Singapore, Chunghwa Telecom in Taiwan, and Telstra in Australia.

For coping with the industry evolution trend of fixed mobile convergence, the decision-making factors for the 'de-mergers' of whether to merge back the mobile subsidiary to have fixed-line and mobile operation is an important topic in the telecommunications industry. Mao, Hu and Chen (2010) indicate that most incumbents sold their mobile stockholding to become a simple fixed-line operator in 2001. But after several years of operation, since 2004 the 'de-mergers' began to have a positive action by buying back the remaining shares of a mobile subsidiary to own 100% of the shares. These kinds of 're-mergers' by once again owning the fixed-line and mobile operations are seen in cases for France Telecom, Telecom Italia, KPN, Belgacom Group, Swisscom, and KT.

At the end of 2003 France Telecom (FT) first bought back the mobile shares of the spun-off Orange SA in the public market. Thereafter, FT announced an ownership position of owning 99.01% of mobile stockholdings of Orange SA, and in June 2004 further announced to have 100% shares of Orange SA. In July 1995, TIM (Telecom Italia Mobile) was the first company to be separated from the mother company of Telecom Italia, but in June 2005 Telecom Italia merged back TIM as a fixed-mobile operator. In October 2005, KPN bought NTT DOCOMO's remaining interest of 2.16% in KPN Mobile NV to own 100% shares. On December 20, 2006 Swisscom bought back Vodafone's 25% shares in Swisscom Mobile AG to once again have 100% of the shares. In early November 2006, the Belgacom Group acquired 25% of the stockholdings from Vodafone in Belgacom Mobile to have 100% of the shares. In addition, KT's interest in KTF increased from 40.7% in 2004 to 52.2% in 2008. However, in June 2009, KT eventually merged with KTF to own 100% of the shares of KTF in order to meet the FMC trend. In another case for SoftBank Group, through a series of M&A activities and after obtaining a 3G license, SoftBank eventually owned the fixed-line and mobile operations.

Table 1. Fixed-only carriers remerge with the mobile branches

Parent operators	Mobile branch	De-merged time	Shareholdings (%) (May, 2004)	Re-merged time	Shareholdings (%)
France Telecom	Orange SA	February 2001	99.01	June 2004	100
Telecom Italia	TIM	July 1995	56.00	June 2005	100
Royal KPN	KPN Mobile NV	March 2001	97.80	October 2005	100
AT&T (old)	AT&T Wireless	July 2001	-	-	-
New AT&T (SBC)	Cingular Wireless	-	60.00	January 2006	100
BellSouth	Cingular Wireless	-	40.00	-	-
Belgacom	Belgacom Mobile	January 2001	75.00	November 2006	100
Telefonica S. A.	Telefonica Moviles	January 2001	92.44	December 2007	100
Verizon Communications	Verizon Wireless	-	55.00	July 2007	100
Swisscom AG	Swisscom Mobile	January 2001	75.00	December 2007	100
Telmex	Telcell (America Movil)	September 2000	-	-	-
China Telecom	China Mobile	April 2000	-	January 2009	3G License
KT	KTF	-	40.70	June 1, 2009	100
NTT Corporation	NTT DOCOMO	October 1998	61.50	July 2010	63.1

Source: Telcos' Annual Reports and Mao, Hu and Chen (2010).

Moreover, in April 2000, China Telecom was com-manded to spin off its mobile department of China Mobile by Mainland China's regulator, and then focus on fixed-line operations. China Unicom was originally the sole fixed-line and mobile company to introduce 2G services into the China mobile market. In January 2009 the Ministry of Industry and Information in Mainland China issued three sheets of 3G licenses to authorize China Mobile, China Telecom, and China Unicom to introduce 3G services. Since 2009, China Telecom has tried to develop their numbers of 3G subscribers in order to operate as a fixed-mobile operator. For a listing of the changes in the parent operators' ownership of the mobile branches (Table 1).

Businesses development description

The productivity analyses of business development are according to the three kinds of operating characteristics of the industrial development included for a mobile-only pattern, fixed-only pattern, and fixed-mobile pattern.

Mobile-only operation

Mobile-only operators have faced high mobile penetration rates, which are not easy to develop for new subscribers. The telcos usually adopt the ARPU metric to measure each subscriber's contribution to its revenue (total revenue is divided by all subscribers), which is equal to the payment of each subscriber to the operators per month or per year. Fierce competition in the market has resulted in declined ARPU and decreased revenues for mobile operators. This had occurred to the developed economies, even though the subscribers are in improvement but only a limited room for growth. In this paper, the mobile operators in Japan are represented in the mobile-only pattern for further productivity analysis. In 2009, the mobile penetration rate in Japan was 87% for a total of four carriers including DOCOMO, KDDI, SoftBank Mobile and EMOBILE. EMOBILE was a new entrant to provide 3G services since 2008. In 2009, DOCOMO was the leading operator to own an absolute advantage of 51% market share, followed by KDDI who accounted for 29%, SoftBank Mobile who owned a market share of 19%, and the lowest EMOBILE with only 1% market share. The number of mobile subscribers grew slowly as well and the growth rate of the mobile subscribers was limited. In March 2010, the market rate of DOCOMO's FOMA service (equivalent to 3G service) was at 95%, while MOVA users (equivalent to 2G service) was only at 5%.

SoftBank adopted a low pricing strategy that intensified the mobile market competition in Japan.

Table 2. Growth trend of mobile subscribers and ARPU in Japan

Operators/Years	2005	2006	2007	2008	2009
DOCOMO					
Subscribers (000)	48,825	51,144	52,621	53,388	54,601
Revenue (US$m)	40,567	54,900	54,000	51,000	47,100
Total ARPU/Yen for month	7,200	6,910	6,700	6,360	5,710
of which Data ARPU (Yen for month)	1,870	1,880	2,010	2,200	2,380
Data ARPU percentage	26	27	30	35	42
KDDI					
Subscribers (000)	23,132	25,439	28,189	30,339	30,843
Revenue (US$m)	35,200	38,300	41,300	40,100	37,900
Total ARPU/Yen for month	7,170	7,040	6,610	6,260	5,800
of which Data ARPU (Yen for month)	1,740	1,890	2,020	2,130	2,210
Data ARPU percentage	24	27	31	34	38
SoftBank					
Subscribers (000)	15,041	15,210	15,909	18,586	20,633
Revenue (US$m)	26,800	29,200	31,900	30,700	31,800
Total ARPU/Yen for month	6,150	5,890	5,120	4,660	4,070
of which Data ARPU (Yen for month)	1,200	1,350	1,360	1,490	1,740
Data ARPU percentage	20	23	27	32	43

Source: Telcos' Annual Reports.

For reducing the operating costs of network maintenance, SoftBank required all mobile subscribers to have 3G handsets and announced the termination of the 2G businesses as of March 31, 2010. Since SoftBank engaged in the mobile market, the subscribers of DOCOMO and KDDI only displayed minimal growth. For the mobile revenue, DOCOMO and KDDI started to display a downward trend in 2006FY and 2007FY, respectively, but SoftBank showed slight growth. With regard to the total mobile ARPU, DOCOMO, KDDI, and SoftBank showed a declined trend for the period covering 2006-2009, and the figures of total ARPU for DOCOMO and KDDI were very close to each other. SoftBank Mobile was the lowest ARPU among the three telcos, and the declined rate of mobile total ARPU reached 30% in 2009 compared to 2008. For a comparison of the mobile data ARPU to the total ARPU rate, in 2009 the highest rate was SoftBank Mobile at 43%, the next was DOCOMO at 42%, and KDDI had the lowest with 38%. For the growth trend of mobile subscribers, revenue, total ARPU, and data ARPU in Japan for the period 2005 – 2009 (Table 2).

Fixed-only operation

The future development of the fixed-only pattern seemed to be not hopeful due to the declined fixed voice revenue and the current limited growth of broadband value-added revenue. In addition, the fixed-line operators needed to invest mass quantities of money in the establishment of next-generation networks (NGN). BT is taken as a representative example of the fixed-only pattern for further exploring the productivity variation. In October 2001, BT had spun-off the mobile department of Cellnet (mmO2) to be a fixed-only operator. The traditional fixed-line telephone services for BT are composed of telephone calls and lines, while broadband and convergence revenue includes broadband Internet access and convergence services such as VoIP (Voice over Internet Protocol, i.e. Broadband Talk), digital television (Digital TV) and so on.

BT had tried to return back to mobile business operation by introducing integrated fixed-line and mobile services. By switching with Vodafone's mobile network to utilize special Bluetooth phones, this allowed subscribers at home to connect to BT's fixed-line telephone network. In fiscal year 2010 compared to 2007, BT's revenue of fixed-line telephone voice and line rental fees declined year by year, and the reduction rate was about 11%. However, the revenue of broadband services and convergence businesses grew at a rate of 16% in fiscal year 2010 compared to 2007. This only displayed a slight growth since 2008 (Figure 1).

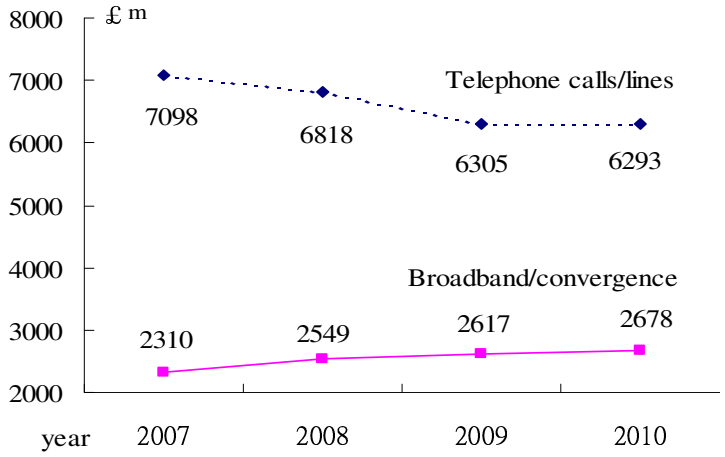

Figure 1. BT's broadband and telephone revenue trend. Source: BT's annual report.

Fixed-mobile operation

The Fixed-Mobile operators could more effectively leverage the synergies of various resources versus mobile-only and fixed-only operators due to the economies of scale. Based on the human resources of the stores, channel integration, and marketing promotion could be integrated for both the fixed and mobile service, and then reduce the administrative expenditure and operation costs. In addition, the fixed-mobile operators could bundle various services of the fixed voice broadband internet, digital TV and mobile services to attract the subscribers and assure their loyalty. In addition, the value-added services through customer-orientation ways could also support three kinds of platforms including broadband, digital TV and mobile services. The IP (internet protocol) network convergence of fixed-line and mobile networks could expand to the scale of the existing subscribers' base. For FMC examples, the contents of Yahoo! Japan that includes shopping, music, auctions, video and other digital content could be mutually supported between fixed-line and mobile networks. Mao, Hu and Chen (2010) indicate that the fixed-line and mobile subscribers of TDC (Tele Denmark Communications) share an identical phone number, a single bill, and a single voice mail. When the subscriber has a call, it will first connect to the mobile phone, and if the mobile handset is off then it will be transferred to the fixed-line phone at home. If nobody answers the call, the caller will be transferred to voicemail and he will be prompted to leave a message. Therefore, the productivity assessment for fixed-mobile pattern is assumed to be better than the fixed-only pattern.

In response to the FMC industry trend, some fixed-only operators merged back their mobile subsidiaries to reduce the number of fixed-only operators and increased the number of fixed-mobile operators. For this study covering a total of fifty-one leading telcos, the numbers of fixed-mobile operators grew from 25 in 2006 to 33 in 2009, and the rate for the fixed-mobile operators to the total observed 51 operators was from 49% in 2006 to 65% in 2009. Mobile-only operators maintained a number of 14 fixed-mobile operators for the period 2006 - 2008, but increased the numbers to 15 in 2009 due to America Mobile merging with Telecommuniciones de Puerto Rico and Oceanic Digital Jamaica Limited to own the 1.6 million fixed-line subscribers in the Caribbean region. The number of fixed-only operators was reduced year by year from 12 in 2002, nine in 2007 and seven in 2008, the remaining five in 2009 were among the observed 51 operators (Appendix 1).

RESEARCH FRAMEWORK

Data and measure

In this study, the 51 leading telcos are top-ranked on the Forbes global 2000 and are classified into three-business patterns for the periods covering 2006 - 2009. The 51 observed leading telcos are the DMUs (decision making units), which assess efficiency and productivity variation by adopting a slack-based measure model and the SBM-based Malmquist approach. There is public disclosure of company information because all the telcos are listed companies in the stock exchange centers of New York, Tokyo, and Hong Kong. In addition, the annual reports of the observed companies are available on their websites (Appendix 1). This study applies three input variables and four output variables to measure the efficiency and productivity variation. The input variables are composed of total assets, debts, and SG&A expenditures and the

output variables are composed of revenue, EBITDA, EBIT, and net income. Differing from past research, this study does not adopt the number of employees as an input variable. This is because the differential salary levels for worldwide operators might not reflect the true productivity variation of a telco when connected with the financial performance index.

In order to deeply explore the development of FMC with the combination of input and output viewpoints, this study evaluates the productivity variation of three group patterns by adopting a slack-based measure (SBM) to evaluate the performance of the current period and the SBM-based Malmquist approach to measure the productivity variation for the cross-periods. The motivations of this study arose from thinking about the following three questions:

(1) By adopting the global leading telcos for the observed samples, the numbers of fixed-mobile operators needed to achieve efficient technical efficiency whether they have increased than two other patterns of mobile-only and fixed-only. And whether the integrated synergy of FMC trend has been improved spanning from 2006 - 2009?
(2) Facing high mobile penetration rate and decreased ARPU for the mobile operators in the developed economies, does the growth trend of productivity variation explain the phenomenon of being in a saturated stage?
(3) Since 2004, some carriers have merged back their spun-off mobile subsidiaries as called 're-mergers'. After four years experience running both fixed-line and mobile operations, do these re-mergers demonstrate rising productivity?

METHODOLOGY

The DEA approach (Charnes et al., 1978) belongs to an application of linear programming (LP). The purpose is to measure the relative effectiveness and efficiency of units with the same organizational objectives by measuring the relationship between multiple inputs and outputs. Expanded DEA models were subsequently established. From a methodological point of view, however, these traditional DEA techniques fail to achieve our purpose in examining the telcos for the following reasons:
(1) Traditional DEA models directly assign 'input-oriented' or 'output-oriented' models that may lack objectivity in terms of reflecting the real input/output conditions for each telcos. In other words, non-radial measures, instead of radial measures, which deal directly with the input excesses and the output shortfalls of the telcos, should be a main concern when seeking to achieve more realistic results.
(2) While forming an efficient frontier to determine the efficiency score for each telcos, the results could be biased due to extreme values. For example, a small-sized telcos may have to refer to the input/output allocation experiences of some super large-sized telcos, which cannot be achieved in reality. This technical problem should be taken care of in this study since the assets of the largest telcos are more than ten times as large as those of the smallest telcos.

To overcome this problem, several authors (Zhu, 1996; Tone, 2001; Tone, 2002; Chen, 2003) had developed non-radial measures of efficiency and super-efficiency. The procedures of the most widely used evaluation model are as follows: First, we employ a Slack-Based Measure (SBM) Model (Tone, 2001) to evaluate the performance of operators in the current period. Next, we use the SBM-based Malmquist approach, which is proposed by Tone (2005) to measure the efficiency variation in the cross-periods among these operators.

Non-oriented SBM Model

The non-oriented SBM model (Tone, 2001) evaluates the efficiency of a target operator by solving the following fractional program:

$$Min \quad \eta_o = \left(1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{io}\right) \Big/ \left(1 + \frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{ro}\right)$$

$$s.t.$$

$$x_{io} = \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^-, \quad i = 1,\ldots,m,$$

$$y_{ro} = \sum_{j=1}^{n} y_{ij}\lambda_j - s_r^+, \quad r = 1,\ldots,s,$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$\lambda_j \geq 0, \; s_i^- \geq 0, \; s_r^+ \geq 0. \tag{1}$$

Here, n is the number of operators, x_{ij} and y_{rj} are the level of the *ith* input and *rth* output, respectively at the *jth* operator, and λ_j is the weight of the *jth* operator. An operator is called 'SBM efficient' if and only if $\eta_o^* = 1$. The value of λ_j indicates whether the *jth* operators serve as an example for the target operators to follow. (1) Requires that the sum of the weights must be equal to one. This suggests that the constructed best practice frontier exhibits variable returns to scale technology, i.e., the frontier permits increasing, constant, and decreasing returns to scale. Hence, the efficiency score obtained from (1) reflects the *oth* operator current scale of operation and is referred to as 'pure' technical efficiency, representing the ability of management in transforming inputs to produce outputs. The fractional program can be transformed into LPs (Tone, 2001).

Non-oriented slack-based Malmquist Index

The purpose of the Malmquist index (*MI*) is to evaluate the efficiency variation when a DMU measures the performance between two time periods. This is defined as the product of 'Catch-up' and 'Frontier-shift' terms. The catch-up term is related to the degree of effort that the DMU attained for improving its efficiency, while the frontier-shift term reflects the change in the efficient frontiers surrounding the DMU between the two time periods t_1 and t_2.

The "Malmquist index (*MI*)" is now obtained as a product of Catch-up and Frontier-shift.

$$\text{Malmquist index} = (\text{Catch-up}) \times (\text{Frontier-shift}) \tag{2}$$

The index represents the Total Factor Productivity (TFP) of the operator, in that it reflects progress or no progress in efficiency of

the DMU along with the progress or regress of the frontier technology. We employ the following notation for the efficiency score of the operator measured by the frontier technology t_2.

$$\delta^{t_2}((x_o, y_o)^{t_1}) \tag{3}$$

Using this notation, the 'catch-up' effect can be expressed as:

$$\text{Catch up} = \frac{\delta^{t_2}((x_o, y_o)^{t_2})}{\delta^{t_1}((x_o, y_o)^{t_1})} \tag{4}$$

The frontier-shift effect is described as

$$\text{Frontier-shift} = \left[\frac{\delta^{t_1}((x_o, y_o)^{t_1})}{\delta^{t_2}((x_o, y_o)^{t_1})} \times \frac{\delta^{t_1}((x_o, y_o)^{t_2})}{\delta^{t_2}((x_o, y_o)^{t_2})} \right]^{1/2}. \tag{5}$$

From the product of Equations (5) and (6), we obtain the following formula for the computation of *MI*.

$$\text{MI} = \left[\frac{\delta^{t_1}((x_o, y_o)^{t_2})}{\delta^{t_1}((x_o, y_o)^{t_1})} \times \frac{\delta^{t_2}((x_o, y_o)^{t_2})}{\delta^{t_2}((x_o, y_o)^{t_1})} \right]^{1/2}. \tag{6}$$

This last expression gives another interpretation of *MI* (i.e., the geometric means of the two efficiency ratios): one version is that the efficiency change is measured by the period t_1 technology and the other is that the efficiency change is measured by the period t_2 technology.

As can be seen from these formulae, the *MI* consists of four terms: $\delta^{t_1}((x_o, y_o)^{t_1})$, $\delta^{t_2}((x_o, y_o)^{t_2})$, $\delta^{t_1}((x_o, y_o)^{t_2})$, and $\delta^{t_2}((x_o, y_o)^{t_1})$. The first two are related with the measurements within the same time period, while the last two are for intertemporal comparison. Here, *MI* >1 indicates progress in the TFP of the target operator from period t_1 to t_2, while *MI* = 1 and *MI* < 1 respectively indicate the status quo and decay in TFP.

The Non-Oriented SBM and the Non-Oriented Super-SBM Models used for computing $\delta^{t_2}((x_o, y_o)^{t_1})$ are represented by the following fractional programs.

Non-oriented SBM

$$\delta^{t_2}((x_o, y_o)^{t_1}) = Min \left(1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{io}^{t_1}\right) \Big/ \left(1 + \frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{ro}^{t_1}\right)$$

$$s.t.$$

$$x_{io}^{t_1} = \sum_{j=1}^{n} x_{ij}^{t_2}\lambda_j + s_i^-, \quad i = 1,\ldots,m,$$

$$y_{ro}^{t_1} = \sum_{j=1}^{n} y_{ij}^{t_2}\lambda_j - s_r^+, \quad r = 1,\ldots,s,$$

$$\sum_{j=1}^{n} \lambda_j = 1,$$

$$\lambda_j \geq 0, \; s_i^- \geq 0, \; s_r^+ \geq 0. \tag{7}$$

Non-Oriented Super-SBM

$$\delta^{t_2}((x_o, y_o)^{t_1}) = Min \left(\frac{1}{m}\sum_{i=1}^{m} \overline{x}_i / x_{io}^{t_1}\right) \Big/ \left(\frac{1}{s}\sum_{r=1}^{s} \overline{y}_r / y_{ro}^{t_1}\right)$$

$$s.t.$$

$$\overline{x} \geq \sum_{j=1}^{n} x_{ij}^{t_2}\lambda_j, \quad i = 1,\ldots,m,$$

$$\overline{y} \leq \sum_{j=1}^{n} y_{ij}^{t_2}\lambda_j, \quad r = 1,\ldots,s,$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\overline{x} \geq x_o^{t_1}, \overline{y} \leq y_o^{t_1}, \lambda_j \geq 0. \tag{8}$$

The fractional program can be transformed into LPs (Tone, 2002)

RESULTS

Technical efficiency analysis

The empirical results show that the operators who can achieve efficient TE (technical efficiency equal to one) are in sum equal to eight for the observed fifty-one operators during the period 2006 - 2009. There are five mobile-only operators who have achieved efficient TE for the continued four years including China Mobile, NTT DOCOMO, VimpelCom, and Taiwan Mobile. There are three fixed-mobile operators who have achieved efficient TE for a consecutive four years including Saudi Telecom, SoftBank Group, and Turk Telecom. Only one of the carriers, NTT DOCOMO, for fixed-only pattern has achieved efficient TE for a continuous four years (Table 3).

The numbers of mobile-only operators to achieve efficient TE for the continued four years are better than that of fixed-mobile and fixed-only patterns. However, an efficient TE for the numbers of fixed-Mobile operators is incrementally increased year by year and more than that of the mobile-only and the fixed-only patterns since 2007. As a key turning point since 2007, the number of fixed-mobile patterns from six in 2006 improved to seven in 2007, and with significant growth from ten in 2008 to fourteen in 2009. Therefore, the technical efficiency for the integrated performance of a FMC is gradually to benefit the fixed-mobile operation.

For the numbers of mobile-only operators to achieve an efficient TE from seven in 2006 (the highest among the three patterns) but it dropped to six in 2007, and then increased to eight in 2008, but still maintained eight in 2009 which have not been seen to be increased. The empirical results proved that the gradual saturation of the mobile market resulted in a limited growth of strength. The fixed-only patterns to achieve an efficient TE are the least among the three patterns. There were two in 2006

Table 3. Efficient TE numbers of three group patterns over 2006-2009.

Operators/Years	2006	2007	2008	2009
Mobile-only	China Mobile NTT DOCOMO KDDI VimpelCom Taiwan Mobile Turkcell Reliance Communi.	China Mobile NTT DOCOMO KDDI VimpelCom Taiwan Mobile Millicom Intl. Cellular -	China Mobile NTT DOCOMO KDDI VimpelCom Taiwan Mobile Turkcell, MTN Group America Movil	China Mobile NTT DOCOMO KDDI VimpelCom Taiwan Mobile Turkcell, MTN Group Millicom Intl. Cellular
Efficient Operators no.	7	6	8	8
Fixed-only	NTT Corporation BT Group	NTT Corporation BT Group	NTT Corporation	NTT Corporation
Efficient Operators no.	2	2	1	1
Fixed-Mobile	SoftBank Group Telekom Indonesia Turk Telecom Saudi Telecom (STC) Telkom SA Chunghwa Telecom	SoftBank Group Telekom Indonesia Turk Telecom Saudi Telecom (STC) Deutsche Telekom - Bharti Airtel PLDT Philippines	SoftBank Group Telekom Indonesia Turk Telecom Telefonica China Unicom Chunghwa Telecom Bharti Airtel PLDT Philippines Rogers Communications Telecom Egypt	SoftBank Group Telekom Indonesia Turk Telecom Telefonica, Royal KPN Deutsche Telekom Chunghwa Telecom Bharti Airtel, Belgacom PLDT Philippines Rogers Communications Telecom Egypt America Movil, KT
Efficient Operators no.	6	7	10	14

Source: This Study.

and 2007 but this dropped to only one number in 2008 and 2009 due to no mobile arm was on hand to reduce the technical efficiency. In Japan's telecommunications market, to achieve an efficient TE, the telcos that were comprised of the fixed-line operator of NTT, the mobile operators of DOCOMO and KDDI, and the fixed-mobile operators of SoftBank for the period 2006 - 2009. Although DOCOMO and KDDI displayed a declined revenue trend but they had tried to reduce their related input costs and expenditures to result in an efficient (Table 3).

For the average Technical Efficiency (Mean TE) analysis, the TE scores of the mobile-only pattern are the highest among the three group patterns for the period 2006-2009, which grew from 0.737 in 2006 to 0.739 in 2007, and this further improved to 0.781 in 2008 and 0.822 in 2009, respectively (with a maximum score of 1). The mean TE score for the fixed-mobile pattern is the second, and it showed a gradual growth trend from 0.619 in 2006 to 0.646 in 2007, and furthermore to 0.693 in 2008 and 0.711 in 2009. The mean TE for the fixed-only pattern is the worst among the three patterns from 0.617 in 2006, and then met a slight decline at 0.580 in 2007 and continued to decline at 0.529 in 2008, but it grew slightly to 0.624 in 2009. Nevertheless, the differences among the three group patterns for the mean TE were insignificant according to the Kruskal-Wallis test by adopting statistical significance at the 0.05 level for the period ranging from 2006 to 2009. However, the difference was in gradually widening for the period from 2006 - 2008, but the differences among the three group patterns in 2009 were gradually minimized than in 2008. The non-parametric statistical analysis for the difference among the three group patterns are analyzed in Table 4.

Cross-period efficiency analysis

This section uses the model described in the businesses development description Section to analyze the performance of efficiency variations for the period ranging from 2006 to 2009. The results of the cross-period efficiency analysis are shown in Table 5. The catch-up and frontier-shift effects, spanning from 2006 to 2009, can be

Table 4. Non-parametric statistical analysis of patterns.

Patterns/Years	2006	2007	2008	2009
Mobile-only (mean TE)	0.737	0.739	0.781	0.822
Fixed-only (mean TE)	0.617	0.580	0.529	0.624
Fixed-Mobile (mean TE)	0.619	0.646	0.693	0.711
Kruskal-Wallis Test (p-value)	0.475	0.371	0.146	0.274

Note: * Statistically significant at 0.05 level.

calculated by means of the four equations described earlier. The product of the catch-up and frontier-shift is the Malmquist Index (*MI*). If *MI* > 1, this indicates an improvement in efficiency which means that the productivity of a specific telco increases over the previous year; if *MI* < 1, this indicates a reduction in efficiency which indicates that the productivity of a specific telco decreases over the previous year.

With regard to the catch-up effect, the degree of effort in improving the efficiency for the fixed-mobile pattern is the best among the three patterns with average scores of 1.184, which is superior to the mobile-only of 1.100 and fixed-only of 0.973 spanning from 2006 to 2009. The catch-up score for the fixed-mobile pattern is 1.056 in 2007 over the previous year 2006 (2006 to 2007), which is lower than that of the mobile-only score of 1.066. But the catch-up effect for the fixed-mobile pattern grew rapidly at 1.292 (2007 to 2008) and at 1.217 (2008 to 2009), which are higher than that of the mobile-only pattern of 1.111 (2007 to 2008) and 1.123 (2008 to 2009), respectively.

Since 2007, the fixed-mobile pattern had displayed the catch-up effect to display a higher degree of effort in improving the efficiency. Even though the catch-up effect for the mobile-only pattern indicated an improvement in efficiency, but the growth rate was limited to verify the gradually saturated market for the mobile-only operation. In addition, the catch-up score for the fixed-only pattern is 1.017 which displays an improvement in efficiency in 2007 over the previous year of 2006 (2006 to 2007), but since 2007 has not shown any improvement in efficiency because the catch-up scores are lower than 1 (2007 to 2008: 0.986, 2008 to 2009: 0.920). For the details please see Table 5.

With regard to the frontier-shift effect, the average scores for the three patterns are all lower than one (mobile-only: 0.999, fixed-only: 0.972, fixed-mobile: 0.991) reflecting not any change in the efficient frontiers spanning from 2006 to 2009. The frontier-shift effect for the three groups pattern are only in 2007 over the previous year of 2006 (2006 to 2007) this indicates the change in efficiency improvement (mobile-only: 1.084, fixed-only: 1.115, and fixed-mobile: 1.039) (Table 5).

With regard to the Malmquist index (*MI*), it represents total factor productivity (TFP) of the operator to reflect progress or a regress in efficiency. The average *MI* score for the fixed-mobile pattern is 1.165, which is higher than that of the mobile-only of 1.101 and the fixed-only of 0.944 over the study period. It reflects the progress in improvement of productivity for the fixed-mobile pattern, which is better than the mobile-only pattern. In addition, the *MI* score of the fixed-mobile pattern indicates the least at 1.075 (2006 to 2007), but since 2007, it displays a significant improvement at 1.292 (2007 to 2008) and 1.139 (2008 to 2009) are superior to the mobile-only pattern of 1.080 (2007 to 2008) and 1.062 (2008 to 2009), respectively. Even though the *MI* scores of the mobile-only pattern are all larger than one, but the *MI* declined from 1.162 (2006 to 2007) to 1.080 (2007 to 2008), and to 1.062 (2008 to 2009) displaying a continued reduction in the efficiency improvement of productivity. However, the fixed-only operation displayed a reduction in efficiency since 2008, and the *MI* score is shown at 0.788 (2007 to 2008) and 0.939 (2008 to 2009), respectively (Table 5).

Re-mergers efficiency analysis

After a series of M&A activities in the telecom industry since 2004, the mobile spun-off companies was owned again by the ‘de-mergers’ to be called as ‘re-mergers.’ The technical efficiency (TE) represents the abilities of management in transforming inputs to produce outputs. In 2009, companies that have achieved efficient TE (with a maximum score equal to 1) include the three re-mergers of Telefonica, Royal KPN, and Belgacom. Telefonica upgraded from 0.707 in 2006 to 0.903 in 2007, and achieved its efficient TE in 2008 and 2009. Royal KPN upgraded its TE scores from 0.586 in 2006 to 0.651 in 2007 and to 0.760 in 2008, and then achieved its efficient TE in 2009. Belgacom started to decline from 0.769 in 2006 to 0.671 in 2007, and thereafter was upgraded to 0.761 in 2008 and achieved the efficient TE in 2009 (Figure 2a). However, SoftBank Group is not a re-merger, but after the M&A activities as a fixed-mobile operator. After acquiring Vodafone Japan in March 2006, SoftBank adequately deployed the FMS integrated performance, and continued to maintain the efficient TE for four years spanning from 2006 to 2009. It provided

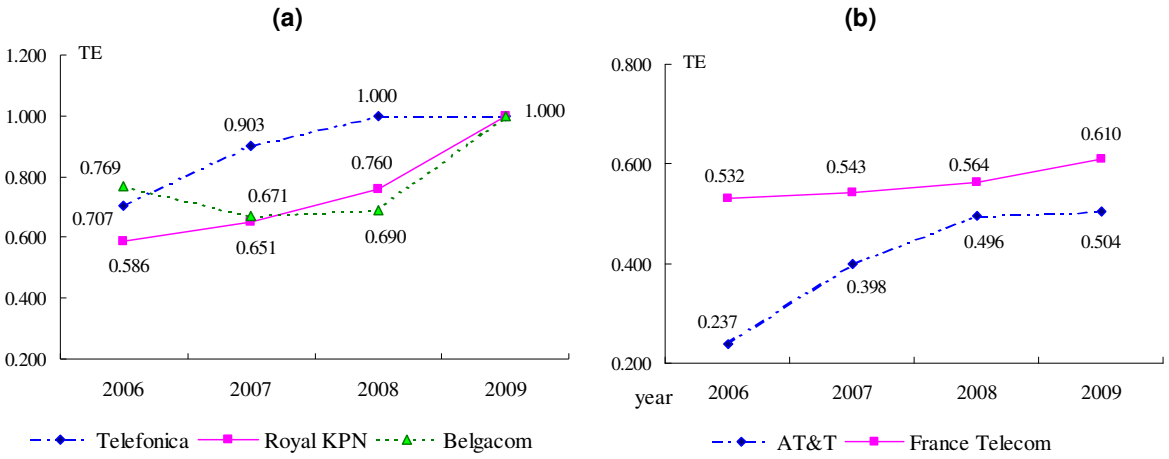

Figure 2. (a). Re-mergers TE obviously upgraded; Re-mergers TE significantly improved. (b) Re-mergers TE upgraded but not efficient; Re-mergers TE improved but not efficient. Source: This study.

evidence for the fixed-mobile telcos to fully actualize the integrated performance to cope with the industry trend of FMC.

As for the re-mergers of new AT&T (SBC) and France Telecom, the TE score had upgraded in a little improvement for the integrated performance of FMC but they had not achieved an efficient TE. The TE scores of France Telecom are higher than those of AT&T spanning from 2006 to 2009 (Figure 2b). The TE scores of the re-mergers haven't been upgraded including Telecom Italia, Verizon Communications, and Swisscom, the integrated TE performance has never been seen during the study period.

Conclusion

This study is different from the prior research by Mao, Hu and Chen (2010), which reveals that the effect of fixed mobile convergence has displayed a rising productivity for an integrated performance spanning from 2006 to 2009. The empirical result also shows that the numbers of fixed-mobile telcos achieving efficient TE have increased year over year. As a turning point since 2007, the numbers of fixed-mobile operators that have achieved efficient TE were the most among the three group patterns, and they have increased from seven in 2007, to ten in 2008, and fourteen in 2009. However, in 2006, the number of mobile- only operators that achieved efficient TE was the most at seven, but reduced to six since 2007 and thereafter improved at eight in 2008 and 2009, respectively. This is because of fierce market competition and the reduced rates urged the mobile ARPU to decline. In 2009, NTT Co. was the sole observed fixed-only operator, which achieved efficient TE, and this was the lowest number among the three groups' patterns. The fixed-only operator of BT had achieved an efficient TE in 2006 and in 2007 but showed a turndown trend of TE scores at 0.792 in 2008 and 0.781 in 2009. Other than being influenced by the declined fixed-line voice revenue, the broadband value-added revenue had not seen significant growth for the fixed-only operation.

Most of the re-mergers in the improvement of technical efficiency had been obvious for the study period. After a series of M&A activities focusing on FMC, the 're-mergers' were not efficient in the prior study stage. Nevertheless, in 2009 the 're-mergers' have achieved an efficient TE score of 1 included Telefonica, Royal KPN, and Belgacom, while in 2008 Telefonica had achieved an efficient TE. SoftBank had achieved an efficient TE for the period ranging from 2006 - 2009, which is a fixed-mobile operator but not a re-merger. It was shown that the four fixed-mobile operators had fully benefited from the integrated performance of FMC. As for AT&T and France Telecom, the TE scores have upgraded year-by-year to report an efficiency improvement but still have not reached an efficient TE under the study period. In addition, the TE scores for Telecom Italia, Verizon Communications and Swisscom have never been upgraded for the periods of 2006 - 2009, and an integrated performance for the three re-mergers have not been achieved and are subject to future consistent verification.

For the catch-up effect, the average scores of the fixed-mobile pattern were all greater than one for cross-period analysis (2006 to 2007: 1.056, 2007 to 2008: 1.292, 2008 to 2009: 1.217). Moreover, the average score of the catch-up effect for fixed-mobile operations was 1.184, which is greater than the mobile-only score of 1.100 and the fixed-only score of 0.973 for the period covering 2006 - 2009. It indicates that the degree of effort in improving the productivity for the fixed-mobile pattern is better than the mobile-only and the fixed-only patterns, while the score of the fixed-only is lower than 1 means that there is

Table 5. Malmquist cross-period efficiency analysis

Patterns	Catch-up				Frontier-shift				Malmquist Index			
	2006 to 2007	2007 to 2008	2008 to 2009	Average	2006 to 2007	2007 to 2008	2008 to 2009	Average	2006 to 2007	2007 to 2008	2008 to 2009	Average
Mobile-only	1.066	1.111	1.123	1.100	1.084	0.975	0.944	0.999	1.162	1.080	1.062	1.101
Fixed-only	1.017	0.920	0.986	0.973	1.115	0.867	0.950	0.972	1.138	0.788	0.936	0.944
Fixed-mobile	1.056	1.292	1.217	1.184	1.039	0.991	0.945	0.991	1.075	1.292	1.139	1.165

Source: This study.

no improvement in efficiency. For the Frontier-shift effect, except for a score in 2007 that over the prior year of 2006 was greater than one, the others were lower than 1 for the cross-period analysis. Moreover, the average frontier-shift scores for the three groups' patterns were all lower than one. This reflects the change in the Frontiers-shift as being inefficient. With regard to the Malmquist index (*MI)*, the average *MI* score was 1.165 for the fixed-mobile pattern being higher than the mobile-only of 1.101 and the fixed-only of 0.944. The empirical results show that the fixed-mobile pattern had displayed a TFP progress in efficiency more than the other two group patterns for the study periods. Since 2007, the fixed-mobile pattern reveals a rising productivity of *MI* to reveal an integrated synergy of fixed mobile convergence.

The group differences for the average TE scores among the three patterns were insignificant. The average technical efficiency (Mean TE) of a mobile-only pattern was the highest among three group patterns during the study period. A fixed-mobile pattern was the next, but showed a growing trend for average technical efficiency. The fixed-only pattern in the average technical efficiency was the worst among the three group patterns. By adopting a non-parametric statistical analysis based on the Kruskal-Wallis test at a 0.05 significance level, the empirical results show that the group difference was insignificant among the three group patterns for the study period. However, the group differences for the two cross-periods of the year 2007 compared to 2006, and the year 2008 compared to 2007 were gradually widening, but in 2009 compared to the previous year of 2008 the group difference was narrowing.

In conclusion, this empirical result reveals that the productivity variation in improvement for the fixed-mobile pattern is better than for a single business operation of mobile-only and fixed-only, and the mobile-only pattern is superior to the fixed-only pattern. From the viewpoint of resources synergy, the fixed-mobile operators that simultaneously own fixed-line, broadband, digital TV, and mobile services could leverage the enterprises' resources to achieve an improvement in productivity. Although the mobile-only pattern represents the progress in productivity but the progress rate has gradually declined because the mobile operators are encountering market saturation. In addition, the regression in productivity variation for the fixed-only operations has occurred due to fixed-line voice loss, the broadband flat rate, broadband convergence limited revenue and the need of mass investment of NGN infrastructure but with no mobile service in their hands. Facing the industry trends from FMS to FMC, the boundaries of fixed-line and mobile services have been gradually ambiguous. In retrospect, the decision for the incumbents not to spin-off the mobile business from the original fixed-line and mobile ope-rations proved to be correct. The contribution to this study in the field of telecommunications research is to prove that the fixed-only operators had started to strive as a fixed-mobile operation based on the FMC trend since 2004. This was achieved via making accurate decisions for forward-looking business strategies by applying the developed approaches of slack-based measures and the SBM-based Malmquist productivity index.

Policy implications

With the establishment of NGN (Next Generation Networks) to introduce all-IP broadband networks, the 4C's (computer, consumer electronic, communication, and content) applications worldwide are created to provide subscribers with more diversified services. In addition to the convergence of fixed-line and mobile net-works and services, with regard to telecommunications, content, cable, broadcasting and other related industries, there is an anticipation to be further integrated. How to create innovative business models to provide multi-service applications is a serious issue for the telcos to cope with. While the rate for 3G data revenue versus the overall 3G revenue has been increased, the fixed-line business has tried to improve the broadband con-vergence (value-added) services to enhance the

overall revenue for making up the loss of a fixed-line voice service. Therefore, the future development for a fixed-mobile operation is promising for the productivity improvement from a long-term viewpoint. Furthermore, the telcos should play a role in transition from the past carriers, positioning not only the telecommunications network infrastructure owner, but also investing in more network-related businesses to support the need for future lifestyle-related multimedia content services. It will be helpful for increasing the service qualities of broadband convergence and mobile value-added services to enhance the telcos' future competitiveness.

One of suggestions for the regulators is to change the asymmetric regulated policies under the fair competitive mechanism. For example, SoftBank was originally an ISP operator. In May 2004, through M&A activities they were able to acquire Japan's second largest fixed-line operator, Japan Telecom. SoftBank obtained a 3G license and in March 2006 they merged with Vodafone Japan and renamed the service as SoftBank Mobile. Thereafter, the SoftBank Group became a fixed-mobile operator.

However, the NTT Corporation wanted to bundle fixed-line and mobile business promotions, and they still reported to the regulator of Japan's Ministry of Internal Affairs and Communications (MIC) to acquire the government's agreement. Following the technology advances, the boundaries of fixed-line and mobile businesses were not so separated as before. The second suggestion of this study is that the regulators should consider the possibilities of authorizing a single license regardless of their being fixed-line, mobile, WIMAX or other services if the new entrants would like to provide any service to subscribers.

We see many fixed-only operators who merge back their mobile subsidiaries, but the mobile-only operators rarely merge with a fixed-line operator. Currently America Mobile in Mexico owns fixed-line subscribers in the Caribbean area through a series of M&A activities. In addition, Taiwan Mobile Co. announced a merger with Taiwan Fixed-line Network Co., and Far EasTone also claimed to merge with its fixed-line invested company-New Century InfoComm in Taiwan. As the numbers of mobile-only operators achieving efficient TE have not increased in 2009 as compared to 2008, the average cross-period efficiency scores for the productivity measurement of a catch-up effect and Malmquist Index are all lower than those of fixed-mobile operations. In addition, the cross-periods efficiency scores for a mobile-only pattern show only limited growth to verify the mobile service in a saturation status to establish a contribution of this study in the field of telecommunications research. For coping with the development trends of the FMC, the concept that the mobile-only operators need to own fixed-line operations deserves reconsideration for the mobile-only operators. At the same time, this study provides topics for future follow-up exploration. As for the input variables of SG&A, the data of some telcos in 2005 cannot be found. Therefore, this study is unable to track back to the year of 2005 for the productivity variation after a series of re-merged activities since 2004. This allows room for improvement in this article as well as opportunities for future research.

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Appendix 1. Productivity Efficiency for the period covering 2006-2009.

Forbes ranking	Telcos ranking	DMU/year	2006		2007		2008		2009		Websites
			patterns	TE Score	patterns	TE Score	patterns	TE Score	patterns	TE Score	
38	4	China Mobile	1	1.000	1	1.000	1	1.000	1	1.000	www.chinamobileltd.com
41	6	NTT DOCOMO	1	1.000	1	1.000	1	1.000	1	1.000	www.nttdocomo.com
46	7	Vodafone Group	1	0.401	1	0.283	1	0.245	1	0.347	www.vodafone.com
172	13	KDDI	1	1.000	1	1.000	1	1.000	1	1.000	www.kddi.com
349	23	MTN Group	1	0.501	1	0.477	1	1.000	1	1.000	www.m-cell.co.za
445	26	Zain Group	1	0.385	1	0.346	1	0.532	1	0.607	www.zain.com
497	30	VimpelCom	1	1.000	1	1.000	1	1.000	1	1.000	www.vimpelcom.com
683	40	Turkcell	1	1.000	1	0.937	1	1.000	1	1.000	www.turkcell.com.tr
742	43	Reliance Communications	1	1.000	1	0.463	1	0.428	1	0.535	www.rcom.co.in
986	44	Orascom Telecom	1	0.486	1	0.566	1	0.480	1	0.444	www.orascomtelecom.com
1084	46	Millicom Intl. Cellular	1	0.382	1	1.000	1	0.558	1	1.000	www.millicom.com
1310	48	Adv Info Service (AIS)	1	0.535	1	0.570	1	0.695	1	0.747	www.ais.co.th
1398	49	Taiwan Mobile	1	1.000	1	1.000	1	1.000	1	1.000	www.taiwanmobile.com
131	10	America Movil	1	0.624	1	0.697	1	1.000	3	1.000	www.americamovil.com
41	5	NTT Co.	2	1.000	2	1.000	2	1.000	2	1.000	www.ntt.co.jp
309	21	Telmex	2	0.524	2	0.698	2	0.794	2	0.720	www.telmex.com.mx
523	32	Qwest Communications	2	0.243	2	0.234	2	0.235	2	0.245	www.qwest.com
528	33	KT	2	0.451	2	0.276	2	0.288	3	1.000	www.kt.co.kr
586	36	BT Group	2	1.000	2	1.000	2	0.792	2	0.781	www.bt.com
668	39	CenturyTel (Embarq)	2	0.335	2	0.371	2	0.378	2	0.376	www.centurytel.com
473	28	China Telecom	2	0.434	2	0.481	2	0.213	3	0.433	www.chinatelecom-h.com
13	1	AT&T	3	0.237	3	0.398	3	0.496	3	0.504	www.sbc.com
32	2	Telefonica	2	0.707	3	0.903	3	1.000	3	1.000	www.telefonica.com
37	3	Verizon Communications	2	0.649	2	0.494	3	0.679	3	0.467	www.verizon.com
56	8	France Telecom	3	0.532	3	0.543	3	0.564	3	0.610	www.francetelecom.com
108	9	Telecom Italia	3	0.379	3	0.356	3	0.350	3	0.323	www.telecomitalia.it
144	11	Deutsche Telekom	3	0.414	3	1.000	3	0.309	3	1.000	www.telekom.de
145	12	China Unicom	3	0.448	3	0.459	3	1.000	3	0.271	www.chinaunicom.com.hk
190	14	Telstra	3	0.572	3	0.659	3	0.734	3	0.907	www.telstra.com
205	15	Royal KPN	3	0.586	3	0.651	3	0.760	3	1.000	www.kpn.com
208	16	TeliaSonera Group	3	0.292	3	0.232	3	0.326	3	0.372	www.teliasonera.com
239	17	BCE	3	0.548	3	0.111	3	0.708	3	0.633	www.bce.ca
261	18	Saudi Telecom (STC)	3	1.000	3	1.000	3	0.492	3	0.443	www.stc.com.sa
273	19	Telenor	3	0.452	3	0.304	3	0.384	3	0.345	www.telenor.no
287	20	SoftBank	3	1.000	3	1.000	3	1.000	3	1.000	www.softbank.co.jp

Appendix 1. Contd.

310	22	SingTel	3	0.411	3	0.379	3	0.448	3	0.424	www.singtel.com.sg
352	24	Swisscom	2	0.672	2	0.523	3	0.682	3	0.684	www.swisscom.com
396	25	Rogers Communications	3	0.549	3	0.731	3	1.000	3	1.000	www.rogers.com
471	27	Bharti Airtel	3	0.899	3	1.000	3	1.000	3	1.000	www.airtel.in
487	29	Telus Canada	3	0.570	3	0.588	3	0.682	3	0.588	www.telus.com
511	31	Chunghwa Telecom	3	1.000	3	0.795	3	1.000	3	1.000	www.cht.com.tw
538	34	Portugal Telecom	3	0.610	3	0.573	3	0.811	3	0.604	www.telecom.pt
562	35	Belgacom	2	0.769	3	0.671	3	0.690	3	1.000	www.belgacom.be
658	37	Tele Norte Leste (Telenor)	3	0.452	3	0.304	3	0.384	3	0.345	www.teleno.no
666	38	Turk Telekom	3	1.000	3	1.000	3	1.000	3	1.000	www.turktelekom.com.tr
684	41	Telekom Indonesia	3	1.000	3	1.000	3	1.000	3	1.000	www.telkom.co.id
727	42	OTE S. A(Greece)	3	0.458	3	0.508	3	0.613	3	0.618	www.ote.gr
1080	45	PLDT Philippines	3	0.803	3	1.000	3	1.000	3	1.000	www.pldt.com.ph
1265	47	Telecom Austria	3	0.446	3	0.385	3	0.127	3	0.414	www.telekom.at
1424	50	Telecom Egypt	3	0.430	3	0.631	3	1.000	3	1.000	www.telecomegypt.com.eg
1460	51	Telkom SA	3	1.000	3	0.912	3	0.542	3	0.484	www.telkom.co.za

Note: pattern 1: Mobile-only, Patterns 2: Fixed-only, Patterns 3: Fixed-Mobile.