Report for the GSM Association

The Socio-economic Impact of Allocating Spectrum for Mobile Broadband Servicesin China

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CATR

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0. Executive Summary

This is the report of the study conducted by China Academy of Telecommunication Research (CATR) for the GSM Association (GSMA) to estimate the socio-economic impact of reallocating spectrum for mobile broadband services in China.

0.1 Background and Objectives

Radio spectrum is a valuable natural resource and as limited as other resources such as water, land and minerals, especially with massive increase of demands on radio spectrum as a resource in the radio technology and its application. With increasing scarcity of this resource, the use of radio spectrum needs to be planned in a scientific manner. The importance of the role played by radio spectrum in modern economies has also grown rapidly in the last 20 years or so. The projected economic impact of spectrum based services in China is predicted to be some 4.4 trillion Yuan by the year 2016 – that is 2.41% of GDP (added value).

The resource of radio spectrum is also non-exhaustible, in that when certain radio service is terminated, the radio spectrum it occupies will be released and provided for the use of other radio services. If spectrum cannot be fully utilised, it will also be a kind of resource waste. So is the case of improper use of spectrum. The allocation and release of radio spectrum has become an emerging hot topic. It is now a worldwide trend to recycle and re-allocate radio spectrum. For instance, as we move from analogue television to a digital one, the efficiency of transmission is significantly improved, thus helping to save a certain number of spectrum in the frequency band of 700 MHz as used for broadcasting and television, for purpose of re-use. The dividend that accompanies such re-allocation of spectrum is called “digital dividend” or “spectrum dividend”.

In 2007, the ITU decided to release the spectrum of 698 MHz to 806 MHz. In principle it is up to each and every country to decide its own speed of promoting this programme in accordance with the demands of its domestic mobile communication and the digitalisation of broadcasting and television. According to this plan, the US has auctioned twice, where out of the 800 MHz band, 100 MHz broadband was released to ensure that mobile broadband acquire sufficient spectrum resources. From this, the government also collected some revenue of 19.6 billion USD. Countries like Japan and Australia have also in a gradual manner already released the bandwidth of 100 MHz, which can eventually reach a bandwidth of 200 MHz.

The CATR conducts a study, the main purpose of which is to find a portfolio on spectrum allocation with optimal economic benefits by means of estimating the economic impact of spectrum, and on the basis of such estimate, to offer appropriate recommendations on spectrum allocation and transfer.

0.2 Basic Assumptions

It is difficult to estimate the socio-economic contribution of spectrum. How does spectrum play its role? To which extent? With what marginal efficiency? All these issues are the key points for consideration in our study. In order to clarify the feasibility and accuracy of our study, the hypotheses involved include a few aspects as follows:

- Spectrum is the necessary factor, also an indispensable and irreplaceable one, of production input for whichever agency using it;
- Apart from the IMT sector, no new spectrum resource will be added into other sectors before 2020;
- To increase the robustness of our analysis, we assume that before 2020, all sectors service shall increase by an S-curve;
- The economic benefit of the IMT can be analysed through the three aspects of terminal, network and cloud;
- Before 2020, the annual growth rate of GDP for China will be 7.5%, and the economic structure of China will not change;
- That social as well as economic issues need to be considered, but that mobile broadband has a major role to play in social welfare issues such as combating the digital divide;
- Economic benefits per unit will be the same within each sector, but marginal benefits will decrease in the long run;

- Computable economic benefits are the foundation of our conclusions while others factors, such as security etc, will not be included.

0.3 Different Scenarios

Although the transfer of spectrum between different sectors (e.g. CA, RFT etc.) will incur significant migration costs, overall it is likely to generate better economic benefits in the IMT sector because of the value created through alternative uses, by moving spectrum from low value uses to higher value ones. It is also clear that with the development of new spectrally efficient technologies may allow incumbent spectrum users to improve their services and use less spectrum, thus freeing up valuable bands for new IMT services such as IMT. We need to consider two scenarios below to illustrate this problem.

(a) Spectrum not re-allocated– the baseline scenario, in which spectrum owners in all sectors maintain the status quo.

(b) Spectrum re-allocated to meet increasing IMT demand – a scenario in which spectrum is transferred from other sectors to satisfy IMT demands. In this case, we should consider the costs of alternative uses.

Before 2016, there will be no predicted shortage of spectrum in the IMT sector for their 687 MHz, for this reason the key area for our analysis is the scenario after 2016. We can classify scenario (b) into the circumstances additional spectrum by increments of 300 MHz:

(b1) allocate an additional **300 MHz** to IMT giving a total of 987 MHz；

(b2) allocate an additional **600 MHz** to IMT giving a total of 1287 MHz；

(b3) allocate an additional **900 MHz** to IMT giving a total of 1587 MHz；

(b4) allocate an additional **1200 MHz** to IMT giving a total of 1887 MHz；

(b5) allocate an additional **1500 MHz** to IMT giving a total of 2187 MHz.

0.4 The Economic Value of Spectrum

Economic Benefits

If we assume that all the spectrum demand in the IMT sector can be satisfied and there is no loss to the other services (CA, RFT, SC) in allocating more spectrums to IMT, then we can first of all have an estimate of the economic benefits for the IMT, as can be seen in the following figure

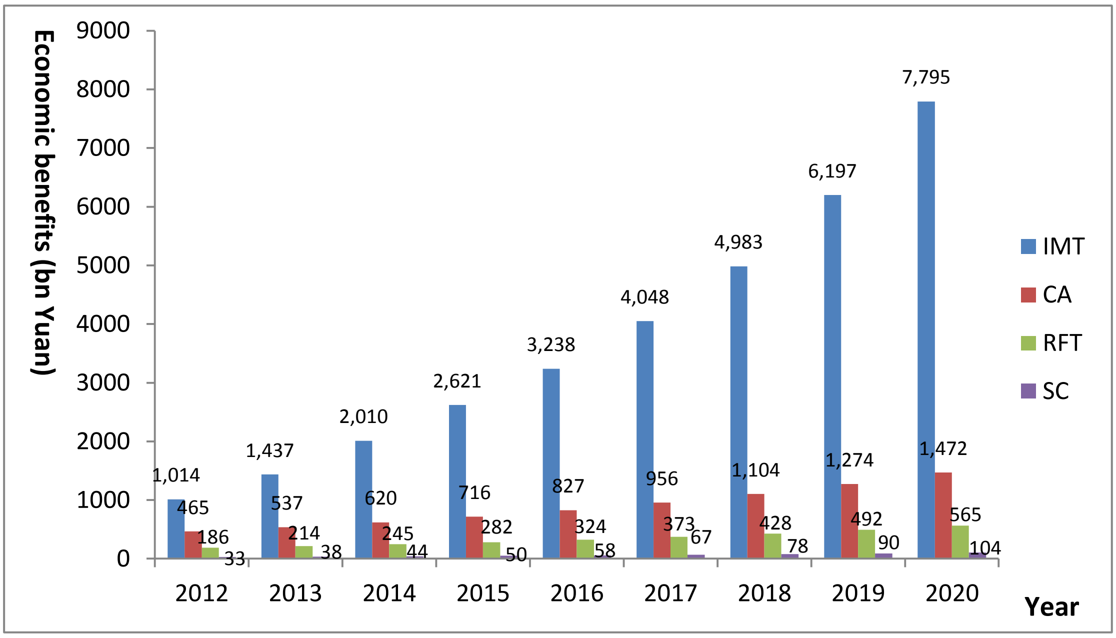

Figure E.1 Economic benefits of each sector

From the above figure it can be seen that, under the assumption that all IMT spectrum needs can be satisfied, the efficiency of using spectrum in the IMT sector exhibits a large increase, In 2012, the contribution of spectrum in the IMT sector to the whole national economy reached 1014 billion Yuan, it will reach 7795 billion Yuan in 2020.

Net Economic Benefits

A comparison of the 6 scenarios above for year 2020 is summarized in the next graph.

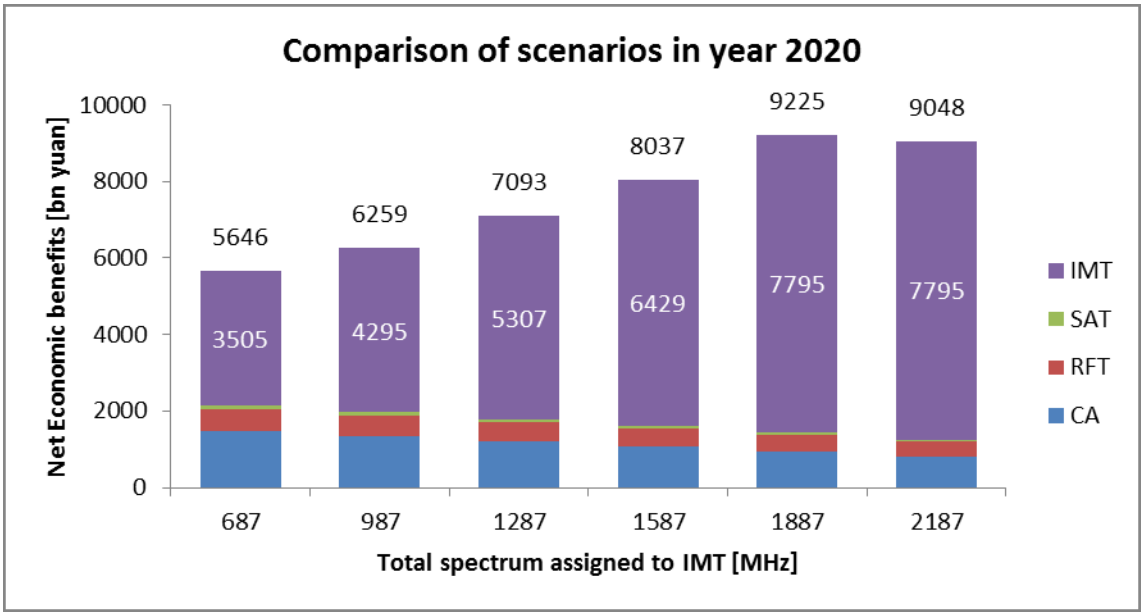

Figure E.2 Net economic benefits of each sector

We can see that the overall economic benefit from the 4 industries in 2020 is maximized when an additional 1200 MHz is allocated for IMT, giving it a total of 1887 MHz. The economic benefit for Chinese economy will be 9.2 trillion Yuan compared to 5.6 trillion Yuan if no extra spectrum is given to IMT. This is an increase of 3.6 trillion Yuan in year 2020 alone. Out of this IMT will contribute to 7.8 trillion Yuan instead of 3.5 trillion Yuan, a 122% increase. The total contribution of civil aviation, broadcast and satellite communication together will be 1.4 trillion Yuan instead of 2.1 trillion Yuan, a 33% decrease.

0.5 The Social Impact of Spectrum

We have analysed quantitatively the contribution of spectrum to economy, while its contribution to society is difficult to quantify. Qualitatively, we can see that spectrum can produce prominent social contribution in the following areas:

- The level of digitalisation in social enterprises will be improved steadily.
- Better social cohesion by providing government services for all with improved communication and faster responses.
- To serve the rural communities in providing access to internet services for education, agriculture and health allowing lives to be improved.

- An estimated 8.7 Million additional jobs can be created if enough spectrum is assigned to IMT.

0.6 Conclusions

- ✓ Spectrum has a prominent contribution to economic growth, albeit with difference varying from one industry to another.

Table E.1. Economic Benefits of Spectrum dependant services

	Economic Benefits in 2012		**Projected Economic Benefits in 2020 under scenario b4**	
Sectors	Value*	Percentage	Value*	Percentage
IMT	1,014	60%	7,795	84%
CA	465	27%	946	10%
RFT	186	11%	434	5%
SC	33	2%	51	1%
Total	**1,698**	100%	**9,226**	100%

*Billion Yuan

- ✓ To allocate more spectrum resources for IMT will produce significant net added economic benefits.

According to our analysis and estimate, with the continuous increase of data traffic, to satisfy the demands of the developing 3G and 4G services, China by estimate will experience a shortage of spectrum after 2016. If we can add 1200 MHz more spectrum into the IMT sector, then for economy, the newly-added benefits will be 7089 billion Yuan over 4 years.

- ✓ To integrate spectrum resources and clean up the spectrum band where supply exceeds demand.

Scarcity of spectrum resources means it needs to be used more efficiently. Because of legacy radio services currently operating on some of the candidate band, often with out of date technology or with an inefficient use of frequency, it is relatively difficult to recycle and adjust some of the candidate band. China should adhere to a planned, step-by-step “exit” arrangement for these services to withdraw from these bands to be used for the further mobile broadband service.

1. Background

CATR has conducted research and addressed the issue of spectrum requirements for mobile broadband services in China. Access to spectrum across China presents a one-off opportunity to boost the development, both in economy and in the wider Chinese society. China Academy of Telecommunication Research (CATR) undertook a rigorous assessment of the socio-economic benefits of spectrum planning in China. This includes the marginal value of spectrum to other services such as broadcasting and satellite communications where appropriate.

1.1 Spectrum Overview

Radio spectrum is an important natural and strategic resource to a nation. In recent years, the field of radio technology is entering into a prosperous era of fast development, with various innovative technologies emerging and being applied commercially in a rapid manner. The enormous economic value of radio frequency becomes a publicly-known fact. The direct contradiction between the have and have-not, abundance and shortage, high- and low-efficiency of use of the spectrum resource between different sectors has become all the more salient. On the one hand, certain units and agencies possess some spectrum band, which is kept idle and unused for long; while on the other hand, some overused spectrum band, with the development of new technology and an increase in the number of users and service load, becomes so crowded that it can no longer meet the needs of further development. This contradiction has to a certain extent constrained the further development of radio-related sectors in China.

The studies for allocating spectrum for the IMT system designed by ITU-R WP5D is used not only as reference for spectrum planning by regulatory bodies across nations around the world, but also as industrial guidance for manufacturers, for purpose of achieving economy of scale and reducing barriers for international roaming by means of global or regional integration. At the moment, the spectrum allocated for mobile communication systems can, in principle, be used for the deployment of any technology in the future, albeit with a consideration of the status quo of service applications on current frequency bands, the issue of interference with services on neighbouring bands, and the strategy of spectrum re-allocation.

In order to avoid interference among services, and to ensure an effective use of the spectrum resources, the ITU has devised radio management policy, so as to offer a planning of using the spectrum of 9 kHz-3000 GHz. Regulatory bodies across nations around the world have correspondingly made radio management policy on their own respectively, to plan service applications on various frequency bands. In the latest version of radio management policy, various spectrum resources have been allocated for the IMT service in order to meet the increasing demands on spectrum.

International Planning on the IMT-related Spectrum

New frequency bands have been allocated for the IMT service at the following three conferences, namely WARC-92, WRC-2000, and WRC-07. Such frequency bands include 450-470 MHz, 698-960 MHz, 1710-2025 MHz, 2110-2200 MHz, 2500-2690 MHz, 2300-2400 MHz, and 3400-3600 MHz, of which 698-960 MHz and 3400-3600 MHz are not global frequency bands, which is annotated in the form of footnote by certain regions.

In order to advance the global or regional integration of spectrum planning and use by mobile communication systems, to reduce inter-system interference, and to provide regulatory bodies all over the world with reference on spectrum allocation for mobile communication systems, ITU-R has carried out research on the planning and use of these spectrum. By the same token, it has drafted some technical recommendation – M.1036, namely “Programme for Spectrum Allocation for the IMT System”.

The Frequency Band of 450-470 MHz

Currently most countries have allocated the frequency band of 450-470 MHz as the main service to mobile and fixed services. Moreover, a certain number of countries have already deployed IMT system on this frequency band. The frequency band of 450-470 MHz, due to its characters of communication, is suitable for providing the deployment of IMT with a large-scale coverage. This is particularly important for certain developing countries or nations in need to provide economic solutions for regions with low population density, or to be used in the early stages of networks-building. In China, it is currently mainly used for certain intercom systems. At the moment, the programme for the frequency band of 450-470 MHz includes nine proposals in total: seven proposals for FDD allocation, one for TDD, and a mixed one for FDD/TDD.

The Frequency Band of 698-960 MHz

After the analogue television is completely migrated into digital, many frequencies in the UHF frequency band will be vacated for use by other systems than the broadcasting and television system. As the UHF frequency band can achieve a wider coverage with better penetrability than in the frequency band of 2-3GHz, fewer base stations will be needed for covering the same area for the IMT at a lower cost. For this reason the UHF frequency band is regarded as valuable spectrum resource by mobile carriers all over the world. The WRC-07 Conference did not manage to allocate the UHF frequency band as a globally harmonized frequency band for the IMT system. Zone 1 (mainly Europe and Africa) allocated 790-862 MHz to IMT, Zone 2 (America) 698-806 MHz, while in Zone 3 (Asia-Pacific), nine countries allocated a spectrum of 108 MHz in total (698-806 MHz) to IMT.

The Frequency Band of 2300-2400 MHz

As for the particular use of the frequency band of 2300-2400 MHz, there exist great divergences across nations. Some has used this frequency band for alternative applications, thereby impossible to be used for the IMT service. Among them, in Europe, CEPT is using it for aerial remote reconnaissance, radio amateur, SAB/SAP, mobile applications, fixed radio connections, defence system in certain countries, and radio positioning system. Russia uses this frequency band for wireless access system. Canada allocated 2200-2300 MHz and 2360-2400 MHz for government use, while auctioned 2305-2320 MHz and 2345-2360 MHz in February, 2004 for radio communications service. Japan uses it for public services. Currently the countries that consider using this frequency band for the IMT system are mainly in the Asia-Pacific Region, including China, New Zealand, South Korea, India, Vietnam and Singapore. In 2002, China in its planning allocated this frequency band as a supplementary working frequency band to the 3G system in TDD, then in 2009; it allocated 2320-2370 MHz to the TD-SCDMA system for indoor coverage.

The Frequency Band of 3400-3600 MHz

Worldwide, the main services on the frequency band of 3400-3600 MHz include fixed and satellite fixed services. The WRC-07 Conference allocated the frequency band of 3400-3600 MHz for the use of the IMT system, albeit not to be enforced in a uniform manner across the globe. At the moment, internationally this frequency band is still been largely used for satellite fixed service. With technological advance, satellites using this frequency band can move towards high frequency sections such as Ku and Ka band. Nevertheless, in tropical regions such as Africa, due to the serious impact on high frequency sections by rain attenuation, the C frequency band is almost always the only one that can be used, to ensure the high reliability of satellite communication.

1.2 Industry Classification

In our study, the spectrum industry is defined as those sectors that make direct use of the spectrum to supply a radio service, as well as equipment manufacturers and service sectors that supply those sectors. Spectrum sectors might include:

(a) **The Cellular Telecommunications Sector** (include public system for mobile communication, public mobile data network, public mobile radio, wireless broadband);
(b) **The Radio Broadcasting Sector** (include digital audio broadcasting, data broadcasting, television broadcasting);
(c) **The Satcom Sector** (include emergency telecom, satellite television, digital broadcasting, satellite broadband);
(d) **The Transportation Sector** (include aviation, railway, waterway);
(e) **The Meteorology Sector**;
(f) **The National Defence Sector**;
(g) Other Sectors.

Due to the issue of data availability, our research has placed emphasis upon analysing (a), (b), (c) and (d) sectors.

1.3 China's Frequency Planning on IMT

The global market scale of mobile communications has manifested a trend of continuous, rapid growth, while the development of the 3G network evolving into LTE has accelerated its pace. By July, 2012, eighty-two LTE networks around the world have been put into commercial application, while fifty-eight operators had been carrying out experiments on the LTE network. Currently, China's mobile communications network is also at a crucial stage of 3G evolving into LTE. Since 2009, China Mobile has consecutively carried out an experiment on the R&D technology of TD-LTE, a "6+1"scale deployment of network in pilot cities, and an extended scale experiment in ten cities in China, thus laying a solid foundation for the network-building of TD-LTE for large-scale commercial application. It is of vital importance that state agencies on radio administration have appropriately made policies on frequency planning that will benefit and support the development of LTE. As the leading country on TD-LTE, China with its related state agencies should allocate the required frequency resources for TD-LTE, guide and support in a positive way the continuous development of the TD-LTE sector, boost and strengthen the confidence in the prospect of TD-LTE on the part of international telecom operators, and pave the way for the internationalisation of TD-LTE. However FDD is currently the dominant technology in the global market, and used to provide services to many consumers in China. Consideration should be given to the appropriate mix of FDD and TDD spectrum requirements.

As the global mobile communications sector evolves into the next-generation broadband mobile communications, the mobile broadband network plays an increasingly salient, fundamental role in the next-generation information technology. Mobile broadband has become an important component of national broadband strategy all over the world. In order to advance the evolution and development of the next-generation broadband mobile communications, certain major countries have adopted such methods of spectrum transaction and auction, thus having completed the frequency planning towards mobile broadband and issued licenses on the spectrum of mobile broadband.

Facing the status quo of the development of mobile communications in China in recent years, State Radio Regulatory Centre (SRRC) have made great efforts to ensure that the planning and allocation of frequency in China be consistent with the international practice of frequency allocation, while at the same time, China also considers in a full manner the status quo of its own frequency use, so as to coordinate and take into account in a comprehensive manner all demands on the frequency resource by radio services, on the basis of which the demands on the frequency resource by the development of mobile communications can be fundamentally satisfied at this stage.

With reference to an ITU estimate on the IMT frequency demand before 2007, by 2020, the spectrum demand in advanced markets worldwide will be 1720 MHz, while those in developing markets will be 1280 MHz (ITU-R M.2078). For this reason, by 2020, the frequency for mobile communications in China will experience a relatively big shortage. While further providing a scientific planning and rational allocation of the radio spectrum resources among all services, SRRC needs also take into consideration the demands on the frequency resource by radio networks. For instance, in recent years, Chinese mobile operators, while striving to advance the construction of mobile communications networks, have also deployed in an all-round manner WLAN broadband wireless access system on2.4 GHz and 5.8 GHz, which has effectively diverted the rapidly-increasing flow of data service in hot urban regions. In order to effectively meet public needs on high-speed data access, the SRRC at the MIIT plans to offer more frequencies for the WLAN planning in the following spectrum bands: 5150 to 5250 MHz, 5250 to 5350 MHz, and 5470 to 5725 MHz, so as to support the application and development of WLAN.

Apart from this, targeting the situation in China that mobile communications systems experience an increasing shortage of the low-spectrum band resources, in the future SSRC will actively explore the possibility of releasing spectrum band, so as to satisfy at the maximum level the demand on frequency resources by future mobile broadband communications.

1.4 Spectrum Allocation

“China Regulations on the Radio Frequency Allocation” (hereafter referred to RRFA) is the fundamental and framework documentation for the radio frequency allocation, allotment and assignment, which has specific regulations in designated conditions for terrestrial radio, space radio and radio astronomy. According to the latest revised RRFA, the status of the frequency allocation in China is as follows:

Table 1 Spectrum allocation in China [1]

Sector	Spectrum Range	Spectrum Band
International Mobile Telecom (IMT)	800 MHz, 900 MHz ,1800 MHz 2300-2400 MHz , (2500-2960 MHz)	687
Satcom (SC)	137 MHz-500 MHz, 3400-3600 MHz, 3800 MHz-4200 MHz, 4200 MHz-4400 MHz	800
Radio, Film and TV (RFT)	470 MHz-566 MHz, 606 MHz-958 MHz	376[2]
The Civil Meteorological Sector	1.27-1.37GHz, 2.7-3.1GHz 420-435 MHz, 438-450 MHz	-
Civil Aviation	328.6-335.4 MHz, 118-137 MHz 108-118 MHz, 960-1215 MHz 2.7-2.9GHz, 1.25-1.35GHz 1030 MHz, 1090 MHz	680

1.5 **China's Planning on the IMT Spectrum**

Mobile communications spectrum allocation includes three components: spectrum for the second-generation mobile cellular communications system, spectrum for the third-generation mobile communications system, and spectrum for LTE.

The frequency bands in the spectrum for the second-generation mobile cellular communications system are all FDD bands, including GSM and CDMA bands: the former including 885-915/930-960 MHz and 1710-1755/1805-1850 MHz; while the CDMA ones are 825-835/870-880 MHz.

As for the spectrum for the third-generation mobile communications system, according to Circular on the Issue of Spectrum Planning for the Third-Generation Public Mobile Communications System – MIIT [2002]279 by Radio Regulatory

[1]Sectors as the National Defence Sector which we cannot get data of spectrum are not in this table.
[2]The spectrum in RFT sector can be calculated as follow: 47 MHz*8 = 376 MHz (the total spectrum band except radio), and spectrum band of radio is approximate 46 MHz which is lower than 108 MHz.

Bureau at the Ministry of Industrialisation and Information Technology (MIIT), the working frequency bands for the third-generation public mobile communications system include:

(a) Main working frequency bands:

In FDD format: 1920-1980 MHz/2110-2170 MHz;

In TDD format: 1880-1920 MHz/2010-2025 MHz;

(b) Supplementary working frequency bands:

In FDD format: 1755-1785 MHz/1850-1880 MHz;

In TDD format: 2300-2400 MHz, to be co-used with radio positioning services. Both are main services, while the standard on co-use will be promulgated separately.

The LTE frequency band is 2500-2690 MHz, at 190 MHz in total, which is allocated in entirety to the TDD spectrum.

Currently, the total amount of spectrum allocated for IMT is 687 MHz, namely:

FDD: the frequency bands of 825-835 MHz / 870-880 MHz, 885-915 MHz / 930-960 MHz, 1710-1755 MHz / 1805-1850 MHz, 1755-1785 MHz / 1850-1880 MHz, 1920-1980 MHz / 2110-2170 MHz;

TDD: the frequency bands of 1880-1920 MHz, 2010-2025 MHz, and 2300-2400 MHz.

TD-LTE: 2500-2690 MHz.

2. The Total Impact on Economic Growth of Spectrum

As the contribution by spectrum is difficult to break down into different components, it thus becomes difficult to analyse its economic impact. This is particularly the case for China, where market mechanism is not introduced into the allocation of spectrum. For this reason it is not possible to calculate its value though auction or other market mechanisms. In order to render our economic analysis of spectrum as objective and accurate as possible, we have devised a five-layer framework to calculate its value, as shown in the following figure:

2.1 The Main Framework

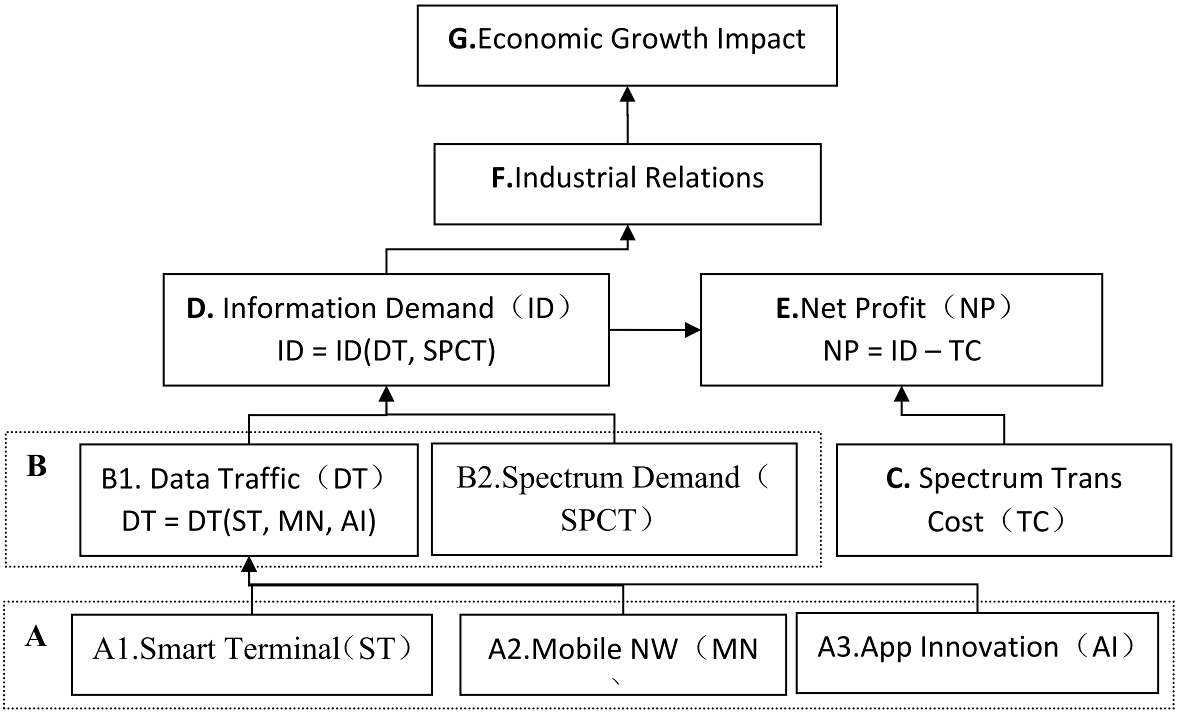

Figure 1 The main framework to estimate economic contribution

From Figure 1 it can be seen that the order of constructing our analytical framework is: A: terminal, network and cloud, then B: data traffic and spectrum demand, C: spectrum transaction cost; D: information demand; F: industrial relation, and G: economic growth. The impact mechanism at each layer works as follows:

（1） A: Terminal, network and cloud (ST, MN, AI) – B: data traffic（DT）: to estimate the future data traffic, through the analysis at the three aspects of terminal, network and application, the indices we have chosen respectively for them are smart terminal (ST), mobile network market scale (MN) and application innovation (AI), at the equation of $\mathrm{DT} = \mathrm{DT}(\mathrm{ST}, \mathrm{MN}, \mathrm{AI})$. For convenience of measurement, the equation is simplified as $\mathrm{DT} = \mathrm{ST}^{a} * \mathrm{MN}^{b} * \mathrm{AI}^{c}$;

（2） B: Data traffic （DT）, spectrum demand（SPCT）– D: Information demand (ID): to estimate future information demand through data traffic and spectrum demand, of which information demand is the function of data traffic and spectrum. We believe that in constructing the two elements for information demand, data traffic (DT) and spectrum demand (SPCT) are both indispensable and irreplaceable. For this reason, the functional relationship between the three elements can be expressed as $\mathrm{ID} = \mathrm{MIN}(\mathrm{DT}, \mathrm{SPCT})$. In this function, there is no substitutability between factors, including DT and SPCT. For details, see annex;

（3） D: Information demand – F: Industrial relations – G: Economic growth: to analyse the increase on economic flow caused by spectrum input, through the analysis of the increase in information demand caused by data traffic and through industrial relations[3].

The economic contribution of spectrum as measured through industrial relations can be divided into three kinds of effect: multiplier effect, feedback effect and spill-over effect.

- ✓ *Multiplier effect.* The change in the level of production caused by the unit of final demand within an industry is the influence of internal demand upon itself for the industry, with its effect to be seen in the industrial capacity of development and self-correction.
- ✓ *Feedback effect.* After the unit of final demand in a certain industry has influenced upon other sectors, this influence will in its turn produce a feedback effect upon the very industry.
- ✓ *Spill-over effect.* The spill-over effect can be defined as the sum of both direct and indirect influence of the unit of final demand in a certain industry upon the output of other sectors. This effect is a single-directional effect, reflecting the industry's impact capacity.

Table 2 Differentiation of the effect of industrial relation

Multiplier Effect	Feedback Effect	Spill-over Effect	Total Effect
1.399	0.061	2.102	3.562

[3]In the industrial system of national economy, when certain industrial sector experiences change, this change will cause changes in other industrial sectors directly related to it through different industrial relations. The changes in the latter will again cause further changes in more sectors directly related to them. The transmission of such influence will gradually diminish. This whole process is the direct industrial relation.

As far as the differentiation of industrial relation is concerned, of the three effects, the spill-over effect is the most prominent, the multiplier one in the second while the feedback effect the least prominent. In particular, every increase of 100 million Yuan in final demand will produce a total impact effect of 356.2 million Yuan, of which the multiplier effect will contribute 139.9 million Yuan, while the feedback effect 6.1 and the spill-over effect 210.2 million Yuan.

2.2 Data Traffic

Currently, the age of the mobile Internet has come, while the transition from the traditional to the mobile Internet is underway. At this moment, to focus on the traffic of the mobile Internet becomes the key element, where to strengthen the estimate and monitoring the traffic of the mobile Internet has become an issue of crucial importance.

2.2.1 Customer Willingness to Pay

To illustrate why the willingness to pay affects data traffic, we can consider a simple supply and demand equilibrium model, characterised by the current price and demand for a given service, and either a constant elasticity or by directly estimating the willingness to pay for the service, which provides the choke price. This is shown in the figure below.

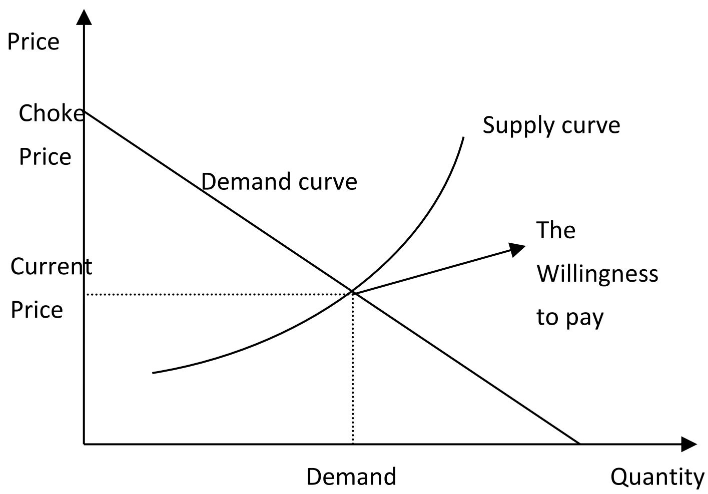

Figure 2 Demand and supply equilibrium of data traffic

The figure above illustrates the supply and demand equilibrium relationship of data traffic, which is decided by supply curve and demand curve. Supply curve is a graph showing the hypothetical supply of a product or service that would be available at different price points. The supply curve usually slopes upward, since higher prices give producers an incentive to supply more in the hope of making greater revenue. In the short run the price-supply trade-off is greater than in the long run. In the short run, an increase in price will usually cause an increase in supply, but the leading producers can only manage a limited increase. In theory, in the most extreme cases, supply can be totally unreactive to price (special cases of very uncompetitive markets), or supply can be infinite at a particular price (e.g. a highly competitive market). Supply and demand is an economic model of price determination in a market. It concludes that in a competitive market, the unit price for a particular good will vary until it settles at a point where the quantity demanded by consumers (at current price) will equal the quantity supplied by producers (at current price), resulting in an economic equilibrium for price and quantity. Also, choke price says the highest price the consumer wants to pay.

2.2.2 **Data Traffic Forecast**

With the further development of the industry, mobile Internet will create new business models. Mobile Internet will maintain a rapid speed, and the network infrastructure and fundamental condition have a big scale. In addition, a large number of mobile smart terminals began to appear, such as tablet PCs which not only undertake the computer function, but more similar to the mobile phone. Social network will greatly increase the demand of consumers which the desktop Internet cannot satisfy. Mobile Internet brought the data traffic of the explosive growth, and data traffic growthis a very good opportunity for operators to hold back ARPU decline, and foreign operators has been making use of this opportunity.

To forecast data traffic before 2020, we have used the following method:

$$\mathrm{DTGI} = \mathrm{WPDI}/(\text{ Unit cost})$$

Of it, DTGI is data traffic growth index; WPDI is the total expenditure of the willingness to pay for data; and Data Unit cost is the willingness to pay for data per unit. In order to calculate WPDI, we have used the future disposable income per capita in China and assumed that the total proportion (denoted as p) of payment for data traffic will increase by an annual rate of 10%.

Where, the growth rate of PCDII is supposed to be 11%, and the formula between PCDII and WPDI is:

$$\mathrm{WPDI} = \mathrm{PCDII} * (1 + \mathrm{p})^{\mathrm{t}}$$

Where, t denotes time. The statement of data traffic could be seen in the table below.

Table 3 Data traffic forecast

Year	PCDII	WPDI	Data Unit cost	DTGI
2012	1.00	1.00	1.00000	1.00
2013	1.11	1.27	0.60391	2.10
2014	1.23	1.61	0.36941	4.36
2015	1.37	2.04	0.22855	8.95
2016	1.52	2.60	0.14845	17.48
2017	1.69	3.19	0.09408	33.95
2018	1.87	3.81	0.05803	65.62
2019	2.08	4.39	0.03476	126.42
2020	2.31	5.07	0.02525	200.77

PCDII: disposable income per capita index, the growth rate is 11%

WPD: The willingness to pay for data

WPDI: The willingness to pay for data index

DTGI: data traffic growth index

Data Unit cost: The willingness to pay for per unit data index

The ARPU of mobile Internet of China is 65.79 Yuan in 2012. Combining the fast growth of data traffic and disposable income of consumer, we forecast that the growth rate of ARPU will be 27% between year 2012 and 2016, and 15% between 2017 through 2020. Using the real condition of mobile Internet in 2012, we can get two indices: consumer willingness to pay for each GB data and future data traffic.

Table 4 Data fee and data traffic

Year	ARPU (Yuan)	Data Unit cost (Yuan/GB)	Data Traffic per user per month (MB)
2012	65.79	300.00	53
2013	83.50	181.17	111

2014	105.98	110.82	231
2015	134.52	68.56	474
2016	170.73	44.54	925
2017	210.13	28.22	1797
2018	250.54	17.41	3474
2019	289.09	10.43	6693
2020	333.56	7.58	10629

Note: ARPU is the index that illustrates the income of an enterprise, and WPDI is a costumer willing to pay for exactly the same data. So, in a equilibrium state of a market, the two indices grow in the same rate. This is also suit to cost/Gb and Data unit cost.

From the above table it can be seen that the growth rate for data traffic is surprisingly high: Data Unit cost of 2012 is 300 Yuan, while this index declines to 7.58 Yuan in 2020; data traffic in 2015 will be 9 times as much as that in 2012; while in 2020, data traffic will be 200times as much as that in 2012, at a compound annual growth rate as high as nearly 100%.

2.3 The Economic Contribution of IMT

Our study analyses the income of various services in the telecom sector, on the basis of which to further distinguish and evaluate whether these services income fall in the economic contribution of radio spectrum in the telecom sector. The service income for the telecom sector mainly includes the following seven categories: fixed local call network, long-distance call network, data communications, mobile communications network, satellite communications network, and radio paging network. Of these, only the service in mobile communications network and that in radio paging network rely completely upon radio spectrum resources in the telecom sector, for which reason, the rate of contribution to GDP by radio spectrum in the telecom sector can be shown as:

$$\frac{\text{Mobile Network Service Income} + \text{Radio Paging Network Income}}{\text{GDP}} \times 100\%$$

Based on the above analyses, as well as the selection and adjustment of data, we can see the result in Figure 3, of the contribution to GDP by spectrum in the telecom sector in the period from 2033 to 2010. Since 2008, the service income of mobile communications network has apparently accelerated its growth rate, while by 2010; the percentage of the contribution of mobile networks to the total service income of all communication services has increased to 69.9%. The rapid development of the mobile communications sector has pushed forward a continuous and steady growth in the telecom sector, while radio spectrum is the fundamental of the development of mobile communications, with an economic value reaching 628.2 billion Yuan in 2010. The economic value of radio spectrum in the telecom sector can be seen most directly and effectively in this aspect.

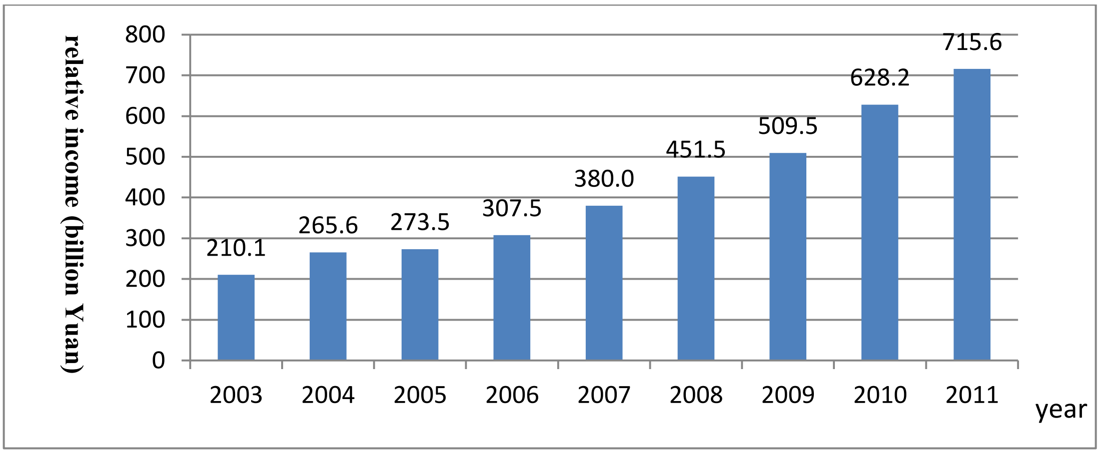

Figure 3 Spectrum contribution to economic growth in telecom

According to the different functions along the industrial chain, the mobile Internet system can be divided into the three parts: terminal, network and application, which is commonly referred to as "terminal, pipe and cloud", the three of which are closely related with functional complementarity, thus building the base for the existence of the mobile Internet. To measure the economic contribution of the mobile Internet, first of all we need to forecast the future growth of the above-mentioned three aspects. Based on the representativeness and availability of data, for the "terminal" part we select smart terminal (ST) as the index, for the "duct" part IMT data traffic cost, while for the "cloud" part software revenue related to the mobile Internet.

To estimate ST, MN and AI: Estimated based on S-Curve method by[4]:

$$y(x) = \frac{1}{A + B * \exp(-C * x)}$$

2.3.1 **Smart Terminals**

In the general structure of the mobile Internet, smart terminals have occupied a crucial place, which is not only due to the fact that currently the mobile Internet is still in its

[4]It is explained in Annex why we have used the S-shape curve.

stage of preliminary development, with the coexistence of other systems and diversity of platforms, but more importantly, such features of mobile terminals as individuality, mobility and integrated functions are in and of themselves the fundamental driving force of the development and innovation in the mobile Internet. Therefore, a study of the mobile Internet cannot possibly disregard terminals and pay attention only to the service and business of the mobile Internet. Apart from this, the soft- and hardware of terminals are also one of the most important parts of the research on the mobile Internet. Mobile smart terminals are developing rapidly all over the world. In 2010, 1.6 billion mobile terminals were sold worldwide[5], at an increase of 31.8% from 2009; the sale of smart phones increased by 72.1% from 2009, accounting for 19% of the total sale of mobile terminals worldwide. In the fourth quarter of 2010, the shipment quantity of mobile smart terminals, smart phone and pad exceeded that of PC. Smart mobile phone will continue to push forward the changes in technological cycles, while its industrial scale will be further expanded.

Using the S-curve and on the basis of related parameter estimated by the growth trend in the past years, we have forecasted the shipment quantity of smart terminals in the nine-year period from 2012 to 2020. Also we have assumed that in 2020, the price of smart terminals will be half of their current price (to decrease by exponential rate). By our analysis, in 2020, the shipment quantity of smart terminals in 2020 will be 13 times as much as that in 2011, reaching 1502 million.

Table 5 Shipment quantity and total value of smart terminals

Year	Shipment Quantity (Million)	Price (Yuan)
2012	220.24	1787.11
2013	365.54	1719.48
2014	555.89	1641.51
2015	726.29	1553.22
2016	860.54	1454.59
2017	980.78	1345.63
2018	1110.93	1226.35
2019	1282.07	1096.73
2020	1502.11	956.79

[5]Because we aim to measure the spectrum contribution, the number below takes into account only the terminals sold in China. Those are manufactured in China are not included.

Combining our forecast of the shipment quantity and the corresponding price of smart terminals, we can estimate the total value of smart terminals in 2020. As can be seen in the following figure, in 2020, the total value of smart terminals will reach 1437 billion Yuan.

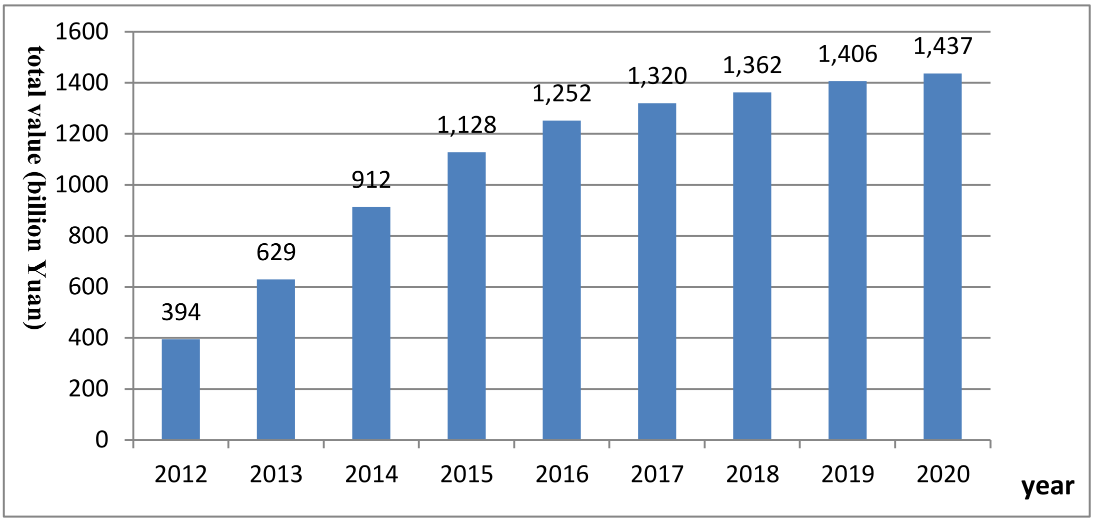

Figure 4 The total value of smart terminals

2.3.2 **IMT Data Traffic Revenue**

The market scale of the mobile Internet mainly includes three parts: the data traffic revenue, mobile application and service revenue, mobile shopping and wireless advertisement revenue.

The network infrastructure platform for the mobile Internet covers all kinds of base station equipment accessing the Internet and mobile terminals, including the mobile communications network, Wi-Fi, and Wimax. The growth trend of data traffic revenue on this platform is what concerns us most. We have first of all used historical data, population, subscription rate and penetration rate to estimate the future IMT data traffic revenue, as can be seen in the following Table.

First, the forecast of population follows the formula below, in which the growth trend is on the basis of the real situation after 1980.

$$y(x) = \frac{1}{A + B * \exp(-C * x)}$$

Second, subscription growth rate is assumed to be 30%. Penetration rate is the proportion of subscription and population. The results could be seen in the table below.

Table 6 IMT data traffic revenue[6] (billion Yuan per year)

Year	IMT Data Traffic Revenue
2012	150.00
2013	247.50
2014	408.38
2015	673.82
2016	1111.80
2017	1778.88
2018	2757.27
2019	4135.90
2020	6203.85

2.3.3 Mobile Application Services

From the perspective of current development, the preference for application service is similar to the fixed Internet, where there is a higher use rate of mobile phone search, video, game, reading and mobile SNS. Nevertheless, while it inherits from the fixed Internet, the mobile Internet, with its own features of development, has sparked innovation in such aspects as the type of service, content of application and habit of use. The following figure shows the growth trend of mobile application and service of the Internet from 2012 to 2020.

[6] IMT data traffic revenue include the revenue from network equipment sold in China, As the same reason mentioned above, we don't consider international sales.

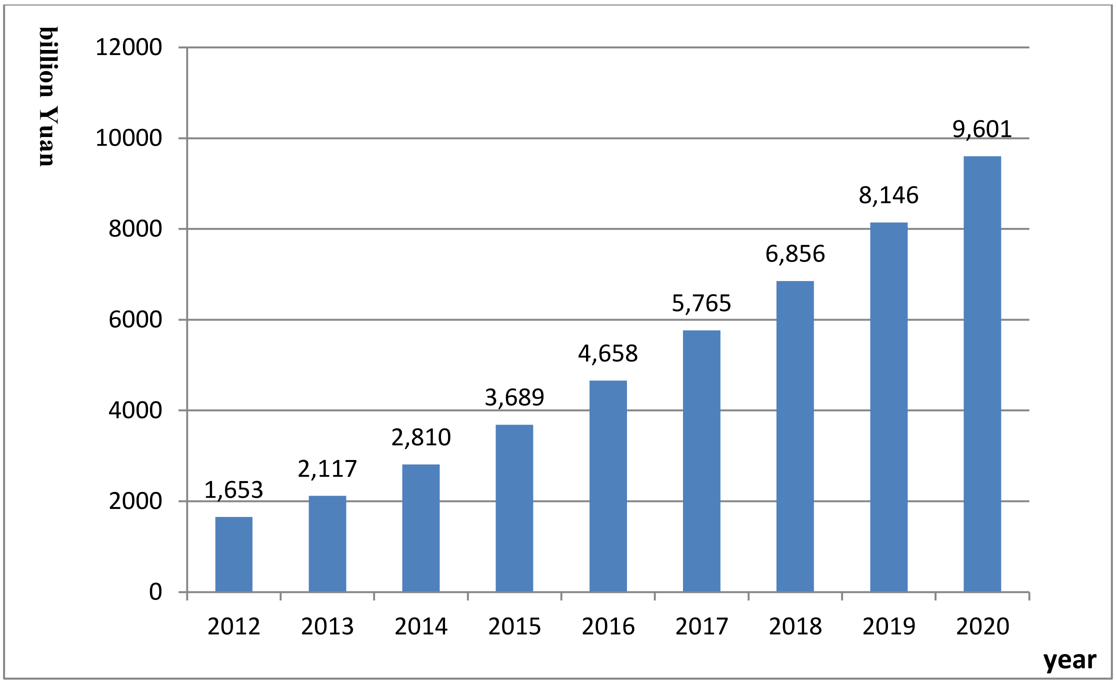

Figure 5 Software and service revenue

2.3.4 The Economic Contribution of IMT

Both historical and international experiences have testified that the mobile Internet can contribute to economic growth. Of course, this is not just due to the need of production input to build networks and sell mobile phones, but more importantly, due to the fact that the mobile Internet can advance the spread of information, improve productivity and efficiency, and enable individuals to explore new market and services in the whole economy. A study led by the Mobile Trade Group from the GSMA, Deloitte and Cisco made an observation of the development of ninety-six markets in developed and developing countries from 2008 to 2011. It was found that in any country, if there were 10% of the population who switched from 2G to 3G networks, then in this period the GDP per capita in this country would increase 0.15 percentage points on average. Apart from this, this study also independently observed fourteen countries from 2005 to 2010 and it was found that when the use of mobile data in these countries doubled, the GDP per capita in these countries increased by 0.5 percentage point on average. Also, the countries with more frequent use of the 3G network, such as Russia, South Korea and the UK, at least one percentage point in the increase of GDP per capita in these countries was contributed by the mobile Internet.

In 2020, smart terminals revenue, data traffic revenue, and mobile application value give a total of 17242 bn Yuan of product revenue. As detailed in Annex B, the input parameter of our Input-Output model is the Final Demand

Table 7 IMT Model inputs (billion Yuan per year)

Year	Smart Terminals	Data Traffic Revenue	Mobile Applications Services	Final Demand
2012	394	150	1653	362
2013	629	247	2117	501
2014	912	408	2810	695
2015	1128	673	3689	920
2016	1252	1111	4658	1167
2017	1320	1778	5765	1460
2018	1362	2757	6856	1796
2019	1405	4135	8146	2229
2020	1437	6203	9601	2798

Based on the input-output method, the IMT product value is calculated. In order to see the impact of IMT on GDP, which is an added value of the whole economy, added value of IMT should be calculated (Net Added Value of IMT = Product value of IMT * added value rate of IMT). From Chinese Input-Output table, added value of IMT is 33%. Net Added Value of IMT to 2020 is listed below.

Table 8 IMT Model outputs (billion Yuan per year)

IMT Product Value	Net Value Added
1014	335
1437	474
2010	663
2621	865
3237	1068
4047	1336
4983	1644
6197	2045
7795	2572

The rate of contribution to the general national economy by the IMT sector can be seen in the following figure.

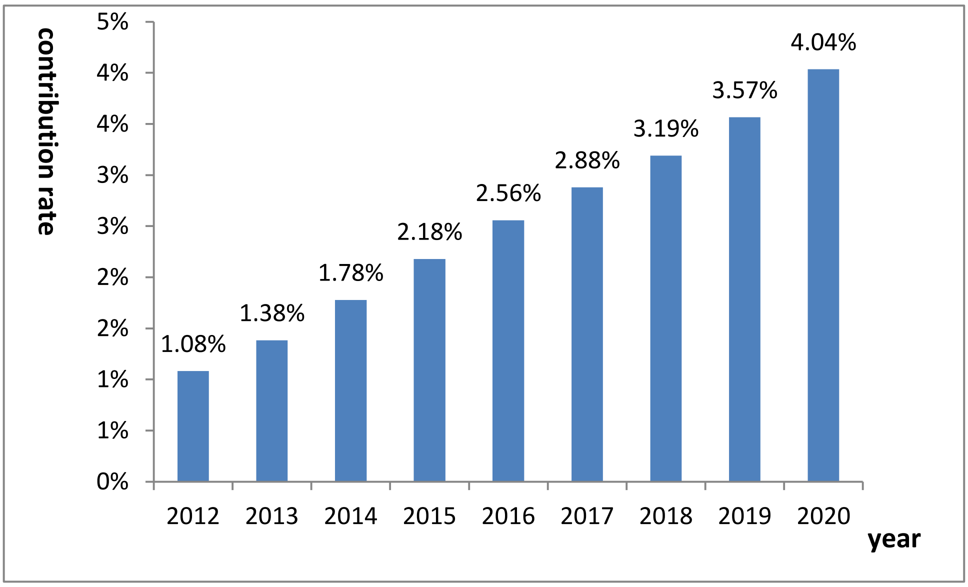

Figure 6 The contribution rate of IMT

From this figure it can be seen that the rate of economic contribution by the IMT will rise from 1% of GDP growth in 2012 to 4% in 2020, such a significant increase in both speed and scale that is rarely seen in other sectors.

2.4 The Economic Impact of Other Sectors

The only way to solve the problem of shortage of the spectrum resources is to increase the overall supply and efficiency of the use of spectrum. Based on the accuracy and availability of data, our analysis of the economic impact of other sectors are mainly focused on radio, film and television (RFT), civil aviation (CA) and satellite communication (SC).

2.4.1 The Radio, Film and Television (RFT) Sector

Recycling broadcasting and television spectrum for re-allocation is the general trend taken across the world. In 2007, the ITU decided to release the 698 to 806 MHz. In principle it is up to each and every country to decide its own pace of promoting this programme in accordance with the demands of their domestic mobile communication and the digitalisation of broadcasting and television. According to this plan, the US has auctioned twice, where out of the 800 MHz band, 100 MHz broadband was released to ensure that mobile broadband acquire sufficient spectrum resources. From this, the government also collected some revenue of 19.6 billion USD. Countries like Japan and Australia also in a gradual manner have already released the bandwidth of 100 MHz, which can eventually reach a bandwidth of 200 MHz.

Advertisement revenue is the most direct manifestation of the economic value of radio technology being applied to the radio broadcasting sector, for which reason the advertisement revenue of broadcasting can be used to calculate the contribution to GDP by radio spectrum in the radio broadcasting sector. Figure 7 gives the rate of the contribution to GDP by radio spectrum in the radio broadcasting sector in the period from 2003 to 2010.

$$\frac{\text{Advertisement Revenue}}{\text{GDP}} \times 100\%$$

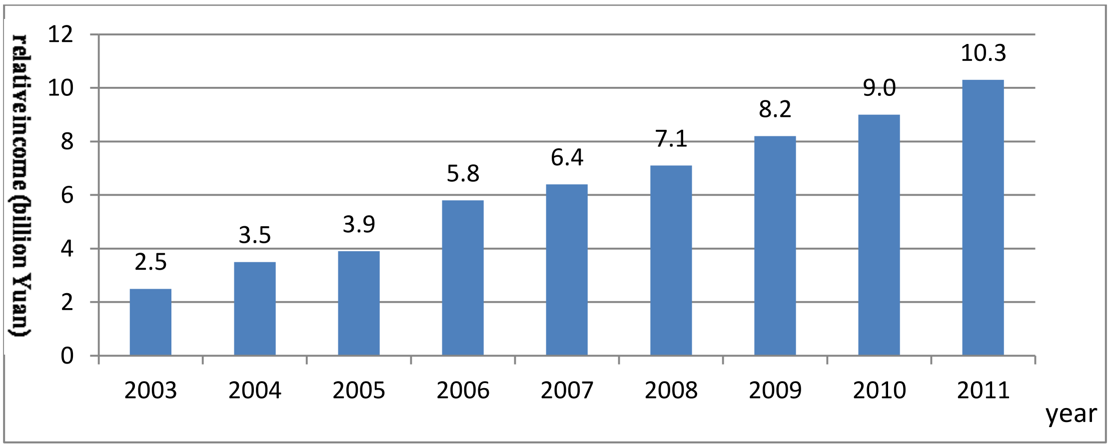

Figure 7 Spectrum contributions to economic growth in broadcasting

From Figure 7, it can be seen that from 2003 to 2010, the contribution to GDP by radio spectrum in the radio broadcasting sector shows a trend of ascending. In 2008, due to the effect of the Beijing Olympics, the revenue in radio broadcasting experienced a relatively large increase, at a rate that even surpassed that of the GDP growth in that year. From this it can be seen that the technology in radio broadcasting is relatively mature and it is a traditional sector with relatively stable scale of development, in spite of which with the support of radio spectrum technology it maintains a strong industrial vibrancy.

To evaluate and estimate the economic benefits of broadcasting and television, we have selected advertisement revenue as the index in the following equation.

Advertisement Revenue Growth:

$$AR = \frac{1}{A + B * \exp(-C * x)}$$

Spectrum Resources: 376 MHz。

The result can be seen in the following table:

Table 9 Advertisement revenue in the RFT sector

Year	A.D. Revenue (Yuan, Billion)	Growth Rate (%)
2012	122.77	10.61%
2013	141.08	14.91%
2014	162.12	14.91%
2015	186.30	14.91%
2016	214.08	14.91%
2017	246.00	14.91%
2018	282.69	14.91%
2019	324.84	14.91%
2020	373.28	14.91%

According the same method used to calculate the economic contribution by IMT, we have calculated the added value economic contribution by the RFT sector, as can be seen in the following table:

Table 10 Added value of the RFT sector

Year	Added Value	Contribution Rate
2012	185.91	0.19%
2013	213.63	0.20%
2014	245.49	0.21%
2015	282.10	0.23%
2016	324.17	0.24%
2017	372.51	0.26%
2018	428.06	0.27%
2019	491.90	0.29%
2020	565.26	0.31%

2.4.2 The Civil Aviation (CA) Sector

With the rapid development of the civil aviation sector all over the world, new radio technology, services and equipment have been increasingly applied to the civil aviation sector, especially in such aspects as communications, navigation, surveillance and metrology. It plays an important role in improving flight security and advancing its steady, coordinated and sustainable development. With the rapid development of the civil aviation sector in China and a continuous increase in the number of civil aircrafts, airports, airway and regulatory sectors, there is a tremendous increase in the demand of frequencies for aviation communications by airports. Currently the radio spectrum for aviation in China has almost covered all spectrum bands from long wave to microwave. In *Classification Table of Radio Frequency in China*, the radio spectrum specially reserved for aviation occupies fifty-four sub-spectrum band, where the radio frequency resources in civil aviation is mainly concentrated on VHF communication and navigation frequency.

In order to evaluate and estimate the economic benefits of civil aviation, we have selected prime operating revenue as the index in the following equation:

Prime Operating Revenue:

$$\mathrm{POR} = \frac{1}{\mathrm{A} + \mathrm{B} * \exp(-\mathrm{C} * \mathrm{x})}$$

Spectrum Resources: 680 MHz。

The data structure can be seen in the following table:

Table 11 Prime operating revenue in the CA sector

Year	P.O.R. (Yuan, Billion)	Growth Rate (%)
2012	458.37	19.15%
2013	529.36	15.49%
2014	611.35	15.49%
2015	706.04	15.49%
2016	815.39	15.49%
2017	941.69	15.49%
2018	1087.54	15.49%
2019	1255.98	15.49%

2020	1450.51	15.49%

According the same method used to calculate the added value economic contribution by IMT, we have calculated the economic contribution by the CA sector, as can be seen in the following table:

Table 12 Economic benefits of the CA sector

Year	Added Value	Contribution Rate
2012	465.11	0.47%
2013	537.15	0.50%
2014	620.35	0.54%
2015	716.43	0.58%
2016	827.40	0.62%
2017	955.55	0.66%
2018	1103.55	0.71%
2019	1274.47	0.75%
2020	1471.87	0.81%

2.4.3 The Satcom (SC) Sector

The mobile satellite communications system can be divided into Maritime Mobile Satellite System (MMSS), Aviation Mobile Satellite System (AMSS) and Land Mobile Satellite System (LASS). The MMSS is mainly used for improving the rescue at sea, the efficiency and management of using watercrafts, and improving maritime communication service and radio positioning capacity. The AMSS is mainly used for providing voice and data communication to cabin crew and passengers between aircrafts and the ground service. The LMSS is mainly used for providing communication to running vehicles. The spectrum range allocated for MMSS is 235 MHz to 71 GHz, while the lower limit of the working frequency is determined by the aerial gain available to small-aperture antenna suitable for mobile earth station. For instance, if the required aerial gain is 3dB, then for an antenna with an effective aperture of 1m, the lower limit of frequency will be 200 MHz. The upper limit of the working frequency is subject of the influence of multiple factors. For those above 1GHz, rain attenuation (as raindrops can diminish the signal intensity) and molecular absorption will increase with higher frequency. As for system requiring a high level of reliability, the best spectrum range will be 200 MHz to 10 GHz. Apart from the factor of communication, we should also consider other factors, such as the level of development of the technology, the requirement of reliability, and the recycling of frequency.

The mobile industry is not seeking bands above 5 GHz for wide area mobile services. There have been some suggestions in the ITU process to seek bands above 5 GHz for Wifi type applications.

In order to evaluate and estimate the economic benefits of the Satcom sector, we have selected Satcom revenue as the index in the following equation:

Satcom Revenue:

$$\mathrm{SR} = \frac{1}{\mathrm{A} + \mathrm{B} * \exp(-\mathrm{C} * \mathrm{x})}$$

Spectrum Resources: 800 MHz[7]。

According the same method used to calculate the economic contribution by IMT, we have calculated the economic contribution by the SC sector, as can be seen in the following table:

Table 13 Satcom revenue and added value

Year	Satcom Revenue (Yuan, Billion)	Growth Rate	Contribution Rate
2012	32.59	15.57%	0.06%
2013	37.67	15.57%	0.06%
2014	43.53	15.57%	0.07%
2015	50.31	15.57%	0.07%
2016	58.14	15.57%	0.08%
2017	67.19	15.57%	0.08%
2018	77.65	15.57%	0.09%
2019	89.74	15.57%	0.09%
2020	103.72	15.57%	0.09%

[7]The spectrum of 800 MHz is referred to which between 400 MHz and 5 GHz.

3. The Economic Benefits of Spectrum

Although the spectrum is an important natural and strategic resource, the economic contribution by spectrum does not exist independently and its economic impact is possible only after it is combined with other productive input. However, due to the limited availability of data, it is impossible to calculate the marginal contribution of spectrum. As a substitute, we can see the important role of spectrum indirectly through the economic benefits of those sectors using spectrum and their contribution to the whole national economy.

3.1 Spectrum Demand and Supply in China

Currently, the total spectrum resource possessed by the IMT sector in China is 687 MHz (800 MHz, 900 MHz, 1800 MHz, 2.3-2.4GHz, 2.5-2.96GHz – although a large portion of this was only made available recently and with some restrictions in some bands). Because of the international nature of the IMT industry and the need for low cost, mass produced devices, it is important that the bands selected for consideration in China match up with what is under consideration in current the ITU/WRC global harmonisation process.

The main international main bands under discussion are:

- ✓ An extra 100 MHz below 694 MHz as suggested by the US and others;
- ✓ 1300 – 1525 MHz (excluding 1400-1427 MHz) – 198 MHz (known as “L band”);
- ✓ 2.7 – 2.9 GHz (used in many countries for ground based radar at airports);
- ✓ 3.4-3.6 GHz (identified in many countries, including China, for IMT but not widely implemented). The band was awarded in some countries for WiMax but there was limited deployment. Used for fixed satellite services (FSS)[8]under the current international regulations.
- ✓ 3.6-3.8 GHz used for FSS also. The EU has identified this for IMT/mobile broadband type services.
- ✓ 3.8– 4.2 GHz also FSS.

[8] Fixed point to point communications between two earth stations relayed via a satellite. Especially useful for setting up communication links with remote areas. Not intended for broadcasting services, but used to carry content to local TV distribution networks..

In China, the most plausible spectrum band who can be cleared for IMT usage can be shown in the figure below.

Candidate bands	Bandwidth	Currently occupied by
470-806 MHz	108 MHz	RFT (terrestrial TV)
1000-1300 MHz	300 MHz	Mainly CA (civil aviation)
1300-1700 MHz	173 MHz	
2025-2700 MHz	~100 MHz	Mainly IMT already, but possibly 100 MHz more can be identified
3400-3600 MHz	200 MHz	FSS (Satcom)
3800-4200 MHz	400 MHz	FSS (Satcom)
4200-4400 MHz	200 MHz	FSS (Satcom)

Table 14 IMT "candidate" frequency bands in China

The figure above shows the current use of IMT "candidate" frequency bands in China, which adds up to about 1500 MHz. According to our forecast, in the year 2020, the total spectrum demand of the IMT sector will be 1864 MHz (ie a shortfall of 1177 assuming 687 MHz is currently available).

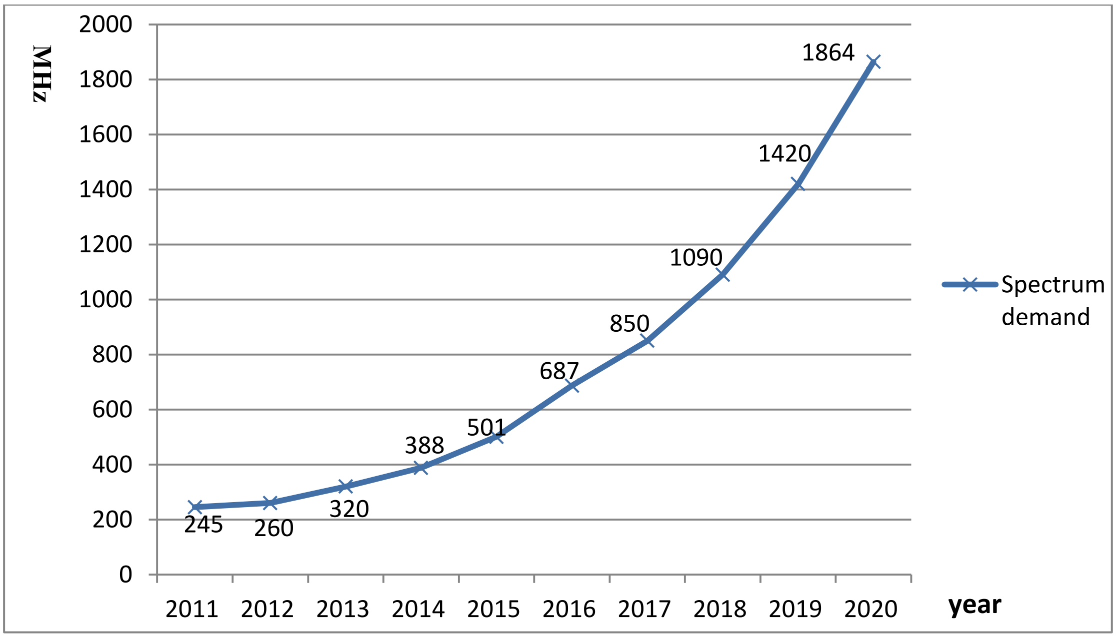

Figure 8 Spectrum demand and supply in IMT of China

3.2 Scenarios for alternative use of released spectrum

At the time being, we cannot give the priority of the “candidate” frequency bands, as this may relate to other questions of feasibility. It will also relate to the costs incurred by the other incumbent services (broadcasting, CA, FSS etc.) due to losing some of their spectrum. Traditionally affected services would either migrate to higher frequency bands and or make use of more spectrally efficient technologies. (such as moving from analogue to digital).

So in order to be able to estimate the economic benefits for each industry in our following scenarios, we assumed that spectrum necessary to IMT will be taken proportionally from the available bandwidth from each of these candidate bands. Ideally one would need to optimise this, rather than take just spectrum proportionally. For example in figure 9, one can see that in 2020 the economic impact of satellite is very low compared to the other services (some 104 for SC vs 7795 for IMT). Yet SC has 800 MHz of spectrum. That would imply that the economic value generated by SC (per MHz) would be around 30 times less than IMT, in the year 2020. Please refer to Annex H for more detail on the economic value per MHz of each service.

Although the transfer of spectrum between different sectors (e.g. CA, RFT etc.) will incur significant costs, overall it is likely to generate better economic benefits overall for China. This is consistent with modern economic theory that suggests scarce resources should flow from low value uses to higher value ones, to maximise economic efficiency. . We need to consider two scenarios below to illustrate this problem.

(a) Spectrum not re-allocated – the baseline scenario, in which spectrum owners in all sectors maintain the status quo, IMT will only have 687 MHz currently identified.

(b) Spectrum re-allocated to meet IMT demand – a scenario in which spectrum is transferred from other sectors to satisfy IMT demands. In this case, we should consider the costs of alternative uses.

Before 2016, there will be no shortage of spectrum in the IMT sector, for this reason the key area for our analysis is the scenario after 2016. We can classify scenario (b) into the following few circumstances[9]:

(b1) allocate an additional **300 MHz** to IMT giving a total of 987 MHz;

(b2) allocate an additional **600 MHz** to IMT giving a total of 1287 MHz;

(b3) allocate an additional **900 MHz** to IMT giving a total of 1587 MHz;

(b4) allocate an additional **1200 MHz** to IMT giving a total of 1887 MHz;

(b5) allocate an additional **1500 MHz** to IMT giving a total of 2187 MHz.

Under different scenarios, we analyse several economic indices below, including economic benefits, net economic benefits and value addition. Economic benefits illustrate the total contribution of spectrum of different sectors. Net economic benefits equal economic benefits minus opportunity cost which shows the biggest revenue of alternative use. Those indices have the relationship below:

$$\text{Net Economic Benefits} = \text{Economic Benefits} - \text{Opportinity Costs}$$

$$\text{Value Addition} = \sum(\text{Net Economic Benefits} \times \text{Discount Rate})$$

3.3 Economic Benefits

If we assume that all the spectrum demand in the IMT sector can be satisfied and there is no loss to the other services (CA, RFT, SC) in allocating more spectrum to IMT, then we can first of all have an estimate of the economic benefits for the IMT, as can be seen in the following figure

[9]Scenario b has four specific assumptions. Relative distribution of the spectrum.is as our context above, that is, for example, 108 MHz from RFT, 178 MHz from other six frequency bands under average distribution.

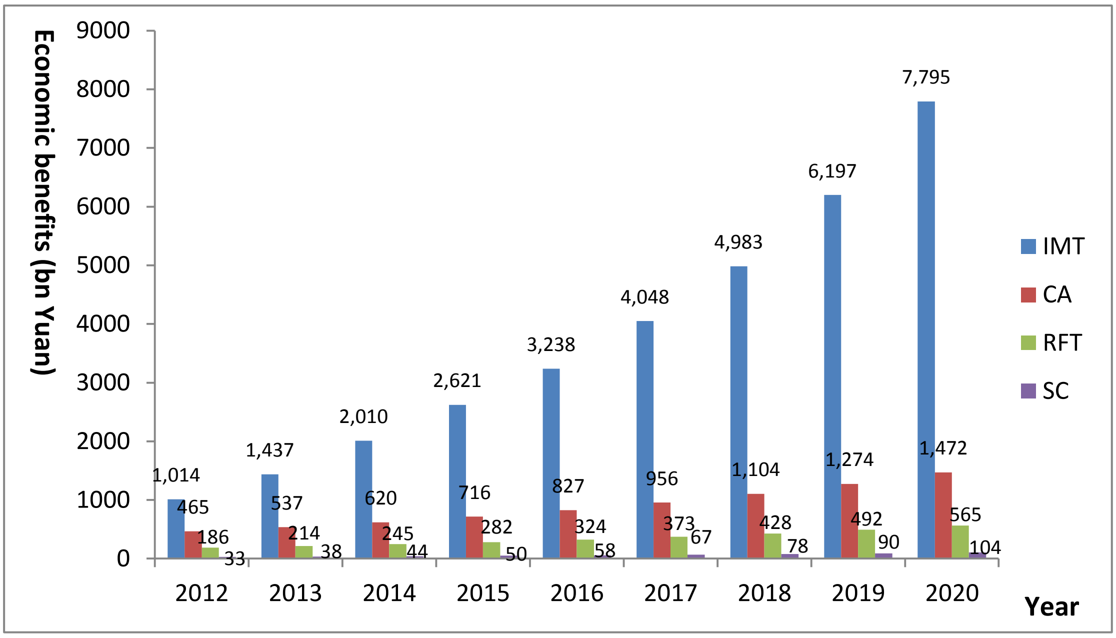

Figure 9 Economic benefits of each sector

From the above figure it can be seen that, under the assumption that all IMT spectrum needs can be satisfied, the efficiency of using spectrum in the IMT sector exhibits a large increase, In 2012, the contribution of spectrum in the IMT sector to the whole national economy reached 1014 billion Yuan, it will reach 7795 billion Yuan in 2020.

3.4 **Net Economic Benefits**

In order to analyse the impact of spectrum re-allocation on national economy, we will analyse Scenario (a) and (b) from the perspective of total volume of net economic benefits. We have used the cost-benefit method. The benefit includes all benefits generated when spectrum from different bands has been input into the IMT sector; while the cost is the maximum benefit these same frequencies can produce in other sectors.

If we assume that spectrum is an indispensable resource for the sectors using spectrum, then in Scenario (a) – the status quo, the economic benefits for the total of the4 industries can be seen in the following figure (economic benefits under spectrum shortage only can rely on neutral technological progress, see Annex for details):

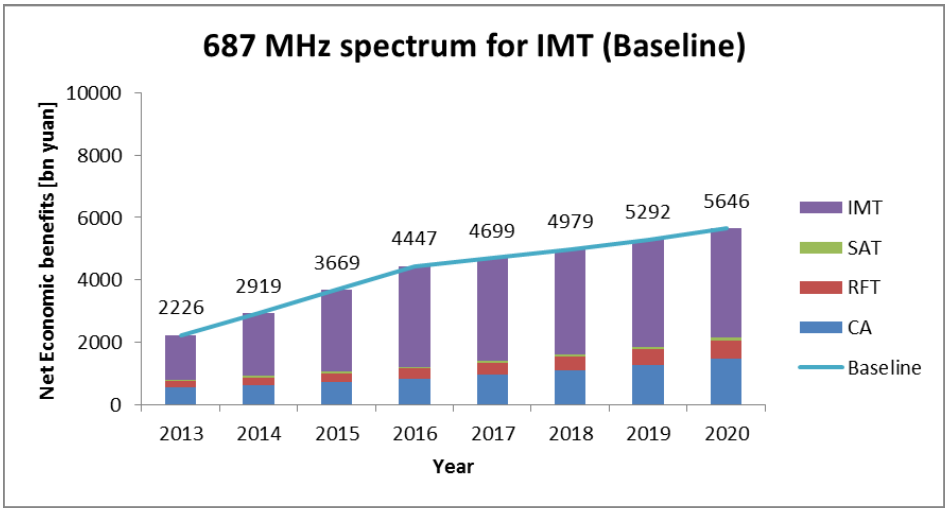

Figure 10 Economic benefits of IMT [Scenario (a)]

We can see from this graph that whereas the 3 other industries grow close to the optimum as calculated in graph 9, economic benefits from IMT is restricted to be approximately flat starting from 2016, because of the shortage of spectrum. Under this scenario, in 2020, IMT economic benefits is 3.5 Trillion Yuan whereas the total of Satellite, Broadcasting and Civil aviation is approximately 2.1 trillion Yuan.

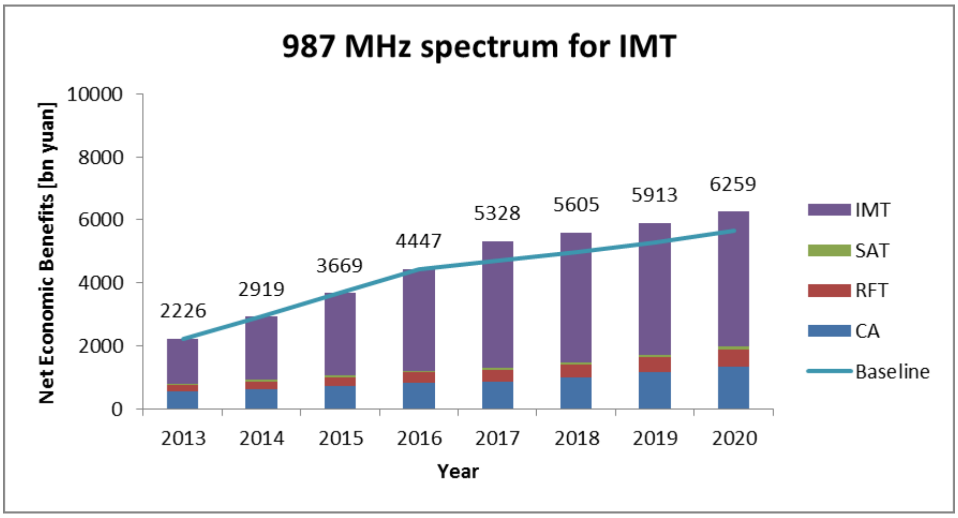

Figure 11 Economic benefits of IMT [Scenario (b1)]

In Scenario (b1), we assume we would add an additional 300 MHz by 2016, giving a total of 987 MHz in IMT. Compared to the baseline value, which is the result from scenario (a) above, the total economic benefits of IMT increased to 4.3 trillion Yuan in 2020, the other 3 industries gives a total of approximately 2.0 trillion. The total economic benefits of the four industries increased by 11% in 2020 alone. From

2017-2020, the total economic benefits of the 4 industries will contribute to an additional 2.5 trillion Yuan for the Chinese economy over the 4 years.

We repeat the same analysis in scenarios of additional 300 MHz increments for IMT, the results for each scenario can be seen below.

In Scenario (b2), we assume we would add an additional 600 MHz into IMT:

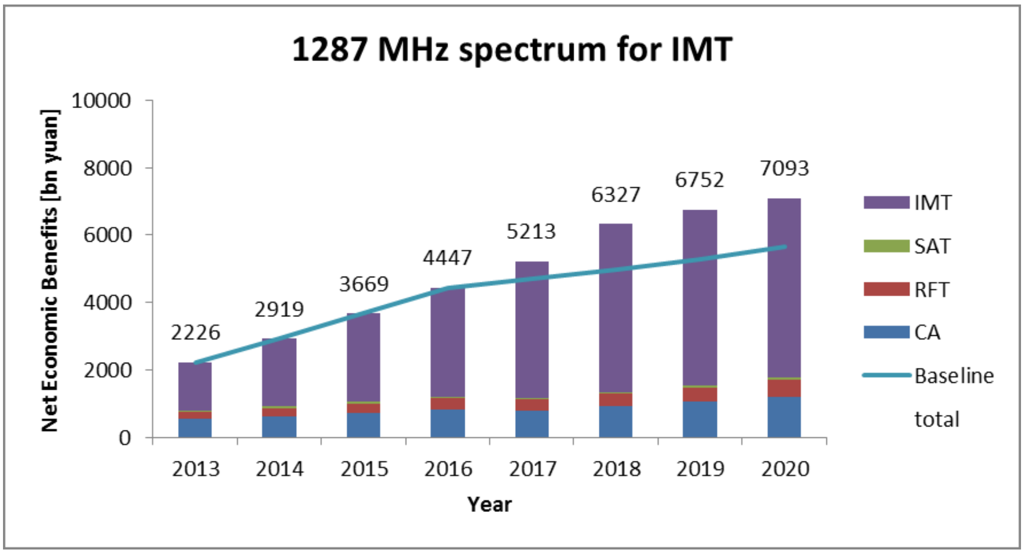

Figure 12 Economic benefits of IMT [Scenario (b2)]

In 2020, the total of the 4 industries represent 7.1 trillion Yuan, that's 1.4 trillion Yuan premium over scenario (a) in year 2020.

In Scenario (b3), we assume we would add an additional 900 MHz into IMT. The premium over scenario (a) is 2.4 Trillion Yuan.

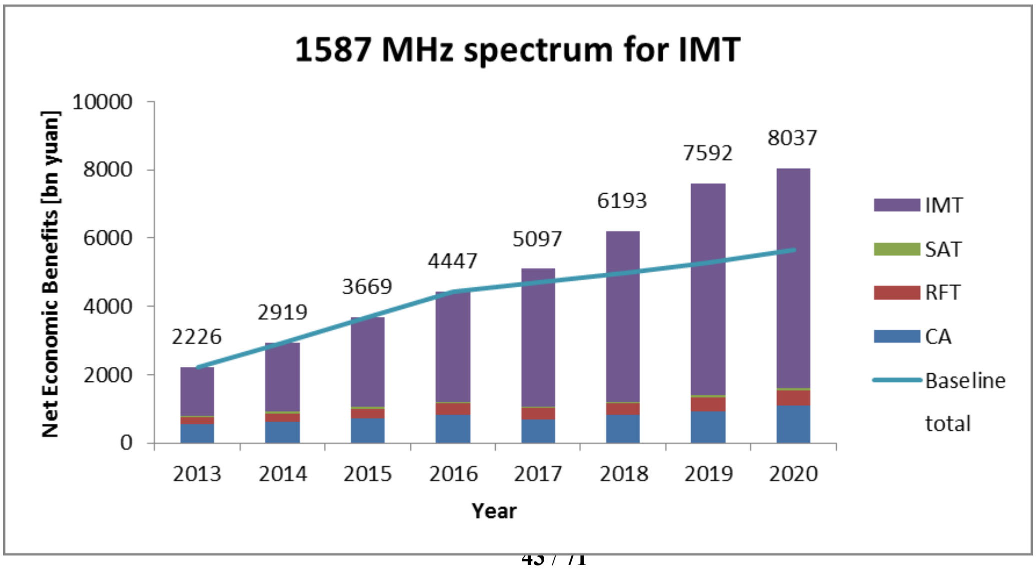

Figure 13 Economic benefits of IMT [Scenario (b3)]

In Scenario (b4), we assume we would add an additional 1200 MHz into IMT. This represents an additional 3.6 trillion Yuan to the Chinese economy in year 2020 alone.

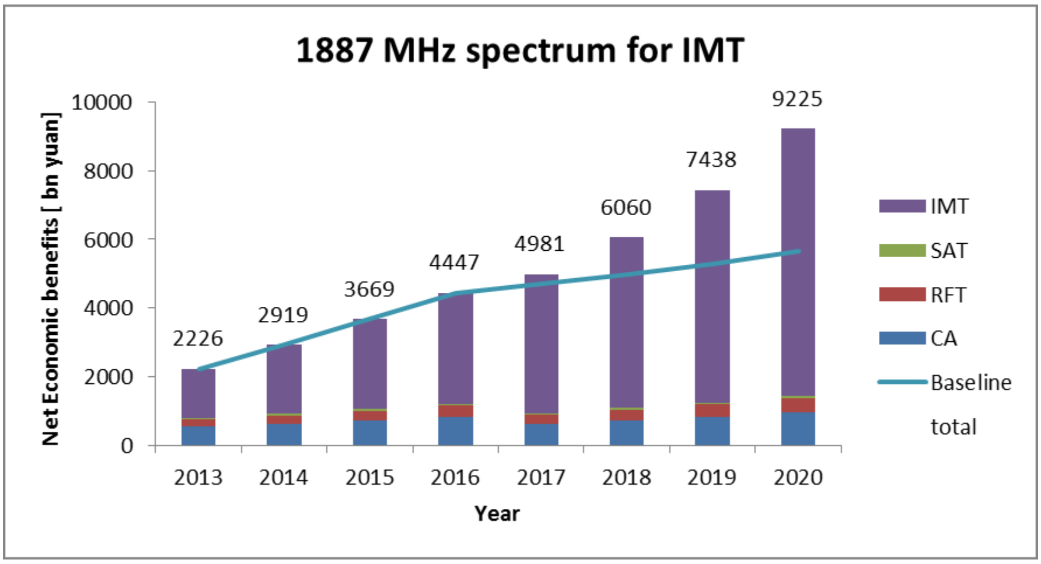

Figure 14 Economic benefits of IMT [Scenario (b4)]

In Scenario (b5), we assume we would add an additional 1500 MHz into IMT. We can see here the total economic benefits is lower than the previous scenario, this is because the IMT economic benefits stays the same as in (b4) as IMT has already the needed spectrum (until 2020), but the constraint on the spectrum for the other 3 industries make the total benefits sub-optimal.

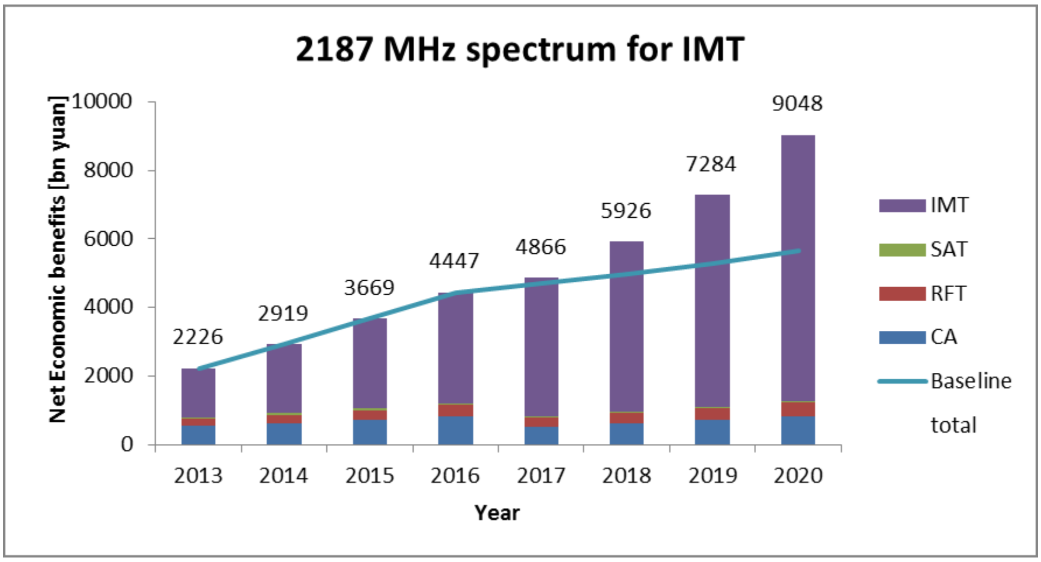

Figure 15 Economic benefits of IMT [Scenario (b5)]

A comparison of the 6 scenarios above for year 2020 is summarized in the next graph.

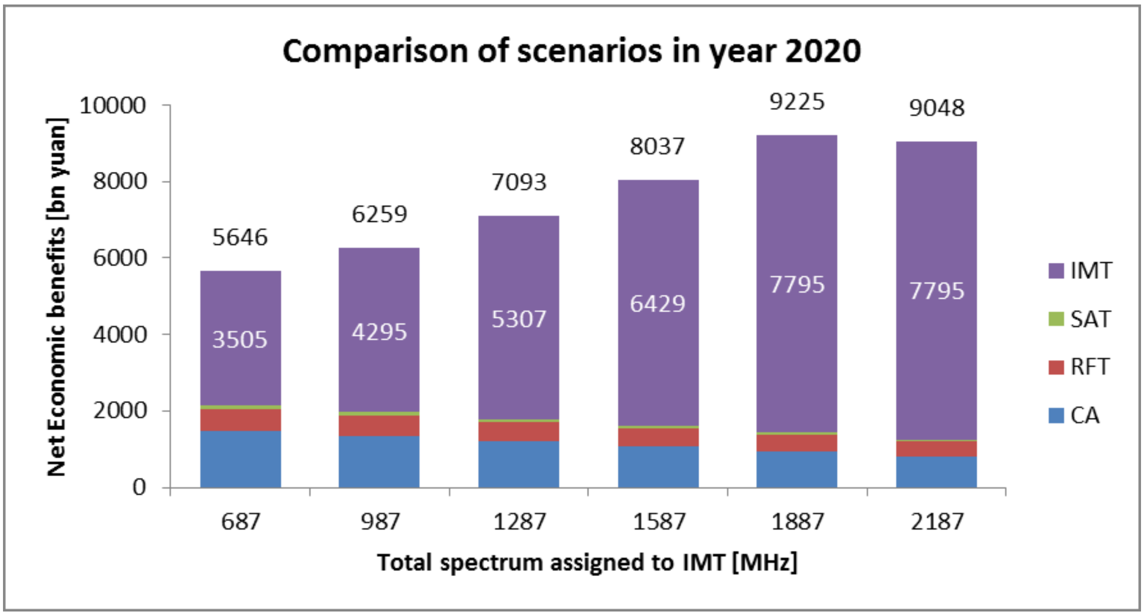

Figure 16 Economic benefits of each sector in 2020

We can see that the overall economic benefit from the 4 industries in 2020 is maximized when an additional 1200 MHz is allocated for IMT, giving it a total of 1887 MHz. The economic benefit for Chinese economy will be 9.2 trillion Yuan compared to 5.6 trillion Yuan if no extra spectrum is given to IMT. This is an increase of 3.6 trillion Yuan in year 2020 alone. Out of this IMT will contribute to 7.8 trillion Yuan instead of 3.5 trillion Yuan, a 122% increase. The total contribution of civil aviation, broadcast and satellite communication together will be 1.4 trillion Yuan instead of 2.1 trillion Yuan, a 33% decrease.

The total added economic benefits over 4 years can be seen in the following table.

Table 15 Value addition from 2016 to 2020 of economic benefits (billion Yuan)

Scenario	Increase compared to scenario (a)
(a)687 MHz	N.A.
(b1)987 MHz	2,490
(b2)1287 MHz	4,769
(b3)1587 MHz	6,304
(b4)1887 MHz	7,089
(b5)2187 MHz	6,509

From this table it can be seen that from 2016 to 2020, assigning additional spectrum into the IMT sector could yield an additional 7.1 trillion Yuan for the Chinese economy. The additional spectrum needed to maximise this benefit is the scenario of 1887 MHz.

Under scenario (a) and (b), the total spectrum of IMT will amount to 687 MHz, 987 MHz, 1287 MHz, 1587 MHz and 1887 MHz, respectively. While considering the economic costs of other sectors, total economic benefits will be 5646, 6259, 7093, 8037 and 9225 billion Yuan.

Contribution to GDP

Economic benefit of spectrum will be 4447 billion Yuan in 2016. Using a Value added ratio of 0.33, the Net Value Added is 1467 billion Yuan. The proportion of spectrum benefit to GDP is then 2.41%. The above scenarios, based on the input-output model, the economic impact of spectrum is shown in the following table.

Table 16 Value added under the two scenarios (billion Yuan)

Scenario	Economic benefit	Net Value Added
(a)	5646	1863
(b1)300 MHz	6259	2065
(b2)600 MHz	7093	2340
(b3)900 MHz	8037	2652
(b4)1200 MHz	9225	3044

Note：Net Value added = Economic benefit * value added ratio (0.33)

From Tab. 15, economic benefits of spectrum are 5646, 6259, 7093, 9037 and 9225 billion Yuan. Net Value Added will be 1863, 2065, 2340, 2980 and 3044 billion Yuan. Assuming the GDP of 2020 is 69355 billion Yuan (2011 price), the Net Value added of spectrum to GDP will be 2.69%, 2.98%, 3.37%, 3.82% and 4.39%, respectively. Comparing scenario (b4) to scenario (a), the re-allocation of spectrum will induce an increment of 1181 billion Yuan or 1.7% of GDP in 2020.

4. The Social Benefits of Spectrum

With the spectrum resource being widely used all over the world under the new generation of information technology, it has not only profoundly influenced our economic structure and efficiency, but also, our social culture and spiritual civilisation as it is the representative of an advanced production force. It has been widely applied in innovating upon social management and public service, thus becoming the new vehicle of improving social welfare. Radio application has penetrated in such aspects as national economy, social life and national defence. It can help to improve the living standard and make our life more convenient and efficient. Currently, the areas to which radio spectrum is applied include mobile communications, broadcasting and television, satellite communications, transportation and logistics, meteorology and national defence. With further development and application of the spectrum resource, we have experienced a rapid development in the next-generation mobile communications, the Internet of Things, broadband communication and cloud computing, on the basis of which “smart Earth”, “wireless city”, “e-community” and “smart home” have been built, all these capable of significantly changing our way of work, interaction and life.

4.1 A steady improvement of the digitalisation of social enterprise

Social enterprise is concerned with the improvement of people’s welfare, as well as an important guarantee of social harmony and stability. The wide application of radio IMT to social enterprise can continuously improve the level of digitalisation in such areas as education, medical care and health, employment and social security. It can help with education, the improvement of medical care, and a universal coverage of social security. It can promote equal access to basic public services. For instance, the electronic health record system can integrate medical records and share records through reliable portals, with which hospitals can accurately and smoothly transfer patients to other medical outpatient departments or hospitals, while patients can also keep their own medical records updated at all times. On the basis of this, doctors can make accurate diagnosis and treatment by referring to the complete medical history of patients.

4.2 An all-round deepening of digitalised applications in urban public services

An all-round application of radio IMT to government and public administration can help to deepen the application of e-governance, improve the capacity of public services and innovate upon the mode of social management. Through using such technologies as sensing, transmitting, smart computing and treatment, an information system of early warning of disaster, security and prevention, and transportation management can be built and improved, so as to improve the digital level of urban public management and the administration of public security, as well as to strengthen the comprehensive carrying capacity of urban areas. For instance, the new public service system can integrate data and processes unto one integrated platform, data and processes that are originally administered separately in such functional departments as civil affairs, social security, police and taxation. A uniform process can be established to offer an integrated administration of system and data, which will provide greater convenience and a highly-efficient “one-stop” service to the public. Through sensors that can be installed everywhere, it can help to collect real-time information on traffic and assist the monitoring and controlling of road traffic.

4.3 To serve the modernisation of rural communities

The IMT can play an important role in restructuring agricultural development and improving the quality of life among rural residents. It can also consolidate the rural information infrastructure, promote the R&D and application of IMT in agriculture, advance the development, integration and comprehensive use of agriculture-related information resources, provide service to large-scale, sophisticated agricultural production, and reduce the digital gap between rural and urban areas. It also provides access to internet services for education and health allowing lives in remote area to be improved.

4.4 Allocation of more spectrum bands to IMT could result in more new jobs

China will be able to look forward to a substantial economic benefits should it choose to allocate more spectrum bands to mobile. Measured in terms of job creation, this would be vastly more productive than allocating these bands to other sectors.

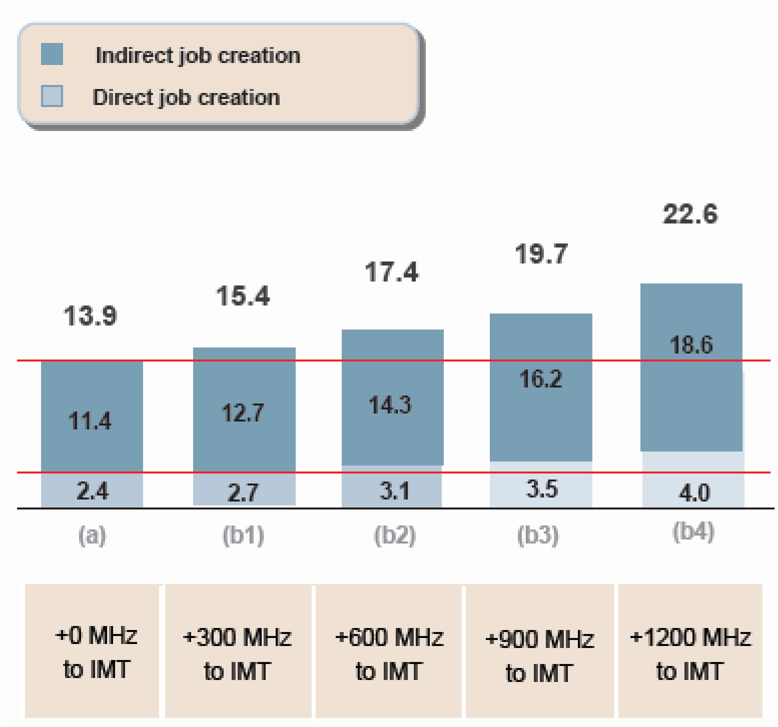

Figure 17 Job creation of spectrum in 2020 (million)

New business activities, divided between new operations within existing companies and wholly new enterprises, are expected to be created before 2020 as a result of allocating more spectrum bands to IMT. These new enterprises would be in a range of activities, from those directly concerned with the Internet, such as website design and ICT maintenance, to those enabled by faster, cheaper access, such as e-job services, online specialty stores and online outsourcing. We assume the labour force in 2020 would be 0.7 billion in China, and labour productivity of spectrum sectors will be 290,000 and 99,000 in other sectors. This would lead to the creation of about 13.9 million, 15.4 million, 17.4 million, 19.7 million and 22.6 million jobs in 2020 under scenarios (a), (b1), (b2), (b3), (b4) respectively – a significant proportion of them in indirect effect, where direct job creation will be 11.4 million and 18.6 million under scenario (a) and (b4) respectively. Compared to scenario (a), incremental job creation is 8.7 million under scenario (b4) – of which direct increment is 1.6 million and indirect increment is 7.2 million. This is a conservative estimate, since it excludes jobs likely to be created as a result of improved productivity in the new firms.

5. Conclusions

5.1 Spectrum has a prominent contribution to economic growth

Spectrum has a prominent contribution to economic growth, albeit with significant variation from one industry to another. Take the IMT sector as an example. In 2012, the economic contribution of spectrum is 1,014 billion Yuan, while in the same period, the contribution by civil aviation, broadcasting and television, and satellite communication is only 465, 186 and 33 billion Yuan respectively.

Table 17 Economic Benefits of Spectrum dependant services

	Economic Benefits in 2012		**Projected Economic Benefits in 2020 with 1887 MHz for IMT**	
Sectors	Value*	Percentage	Value*	Percentage
IMT	1014	60%	7795	84%
CA	465	27%	946	10%
RFT	186	11%	434	5%
SC	33	2%	51	1%
Total	**1698**	100%	**9226**	100%

*Billion Yuan

5.2 More spectrum resources for the IMT sector contribute to growth

According to our analysis and estimate, with the continuous increase of data traffic, to satisfy the demands of the developing 3G and 4G services, China by estimate will experience shortage of spectrum after 2016. Assigning additional spectrum into the IMT sector could yield an additional 7.1 trillion Yuan for the Chinese economy. The additional spectrum needed to maximise this benefit is the scenario of 1887 MHz.

5.3 Consolidation of spectrum resources is vital

Scarcity of spectrum resources means it needs to be used more efficiently. Because of legacy radio services currently operating on some of the candidate band, often with out of date technology or with an inefficient use of frequency, it is relatively difficult to recycle and adjust some of the candidate band. China should adhere to a planned, step-by-step “exit” arrangement for these services to withdraw from these bands to be used for the further mobile broadband service.

ANNEX

Annex A: Views on the economic impact of radio broadband

A.1 The investment in mobile broadband has a prominent amplifying effect upon the GDP growth

According to an estimate by leading American economists in 2009[10], if in the next 24 months, the investment in mobile broadband is increased by 17.4 billion USD, then, it will bring along an increase in GDP by 126.3 to 184.1 billion USD, an amount equivalent to roughly 0.9% to 1.3% of the total GDP in the US. In other words, out of the investment in mobile broadband, every USD has a multiplier effect of seven to ten times on the GDP growth, an effect that at the same time is derived from both direct and indirect impact of the investment in mobile broadband on national economic growth.

The direct impact includes the revenue from new application and services available to more Americans due to the construction of new base stations, and the extension and improvement of existing wireless networks. Within two to three years, the direct impact can contribute 0.23% to 0.3% to the GDP growth.

The indirect impact is similar to the building of a railway, which cannot only directly create employment and income for railway workers, but also provide new business opportunities for enterprises. As radio broadband provides a more powerful capacity of web-surfing to users (surfing on the Internet, office at home, online correspondence education and public security, to name just a few), it can increase the income of those enterprises that use mobile broadband and reduce the relevant cost of business development. As indicated by certain estimate, the indirect impact can contribute roughly 0.65% to 0.98% to the GDP growth.

10 http://www.wimaxforum.org/sites/wimaxforum.org/files/documentation/2009/mobile_wimax_overview_and_performance.pdf

Table AA.1 The contribution to the GDP growth by the investment in Mobile Broadband

	6 months	12months	24months
Direct contribution to GDP			
Investment in the infrastructure of mobile broadband	4.4 billion USD	8.7 billion USD	17.4 billion USD
Accumulated increase in GDP by conservative estimate	0.06%	0.11%	0.23%
Accumulated increase in GDP by appropriate estimate	0.07%	0.15%	0.30%
Indirect contribution to GDP			
Accumulated increase in GDP by conservative estimate	0.21%	0.43%	0.65%
Accumulated increase in GDP by appropriate estimate	0.32%	0.65%	0.98%
Total contribution to GDP			
Accumulated increase in GDP by conservative estimate	0.27%	0.54%	0.88%
Accumulated increase in GDP by appropriate estimate	0.40%	0.80%	1.28%

A.2 Using the spectrum of digital dividend on mobile broadband has a prominent contribution to the GDP growth

To use a certain proportion of the spectrum of "digital dividend" during the transition from analogue to digital broadcasting will bring along enormous economic benefits, promote innovation, create employment, and improve the productivity and competitiveness.

According to a report by the GSMA[11], in Europe, if the 72 MHz spectrum (790 to 862 MHz) as currently planned by WRC (World Radio Conference) were to be allocated to European operators with a maximisation of its economic value, then in the next ten years, this would contribute to the annual growth of GDP by 0.6%.

[11] Digital Dividend for Mobile: Bringing Broadband to All, GSMA.

A joint research by the GSMA and the Boston Consulting Group (BCG) has also found that if Asia-Pacific nations were to allocate the 108 MHz spectrum (698 to 806 MHz) to mobile broadband, as well as to deploy broadband between 2014 and 2015, then in the period from 2014 to 2020, this would contribute 68.4, 68.1, 22.6 and 17.5 billion USD to the GDP growth in South Korea, India, Indonesia and Malaysia respectively, a contribution that, if calculated by net present value, accounts for 6.8%, 2.8%, 2.9% and 3% of the national GDP in 2010 for these countries. The GDP of the whole Asia-Pacific region will increase by 658 billion USD. For the same period of time, the broadcasting service using this spectrum band will only contribute 71 billion USD to the GDP growth, less than one ninth of the contribution by mobile broadband.

Spectrum-related sectors cannot only create new industrial opportunities, but also unprecedented opportunities for traditional sectors. Moreover, they can become the platform to carry an innovation economy and knowledge economy for the future. For this reason, national governments all over the world have formulated relevant strategic plans and made multiple policies to support the development of related sectors. Research in different aspects has found that spectrum can contribute to the GDP growth and restructuring of economic development in the following two ways: one, by direct contribution, including the investment in network and equipment, as well as a pulling effect of investment in both upper- and lower-stream network equipments, applications and content service; while two, by indirect contribution, which mainly refers to the fact that a sound mobile Internet will benefit more the attraction of FDI and the improvement in productivity in other sectors. As far as an estimate of contribution is concerned, on global average, every US dollar to be invested in mobile broadband network will contribute seven to ten dollars to the GDP growth, thus with a prominent multiplier effect. This is particularly the case when we apply the spectrum of “digital dividend” to mobile broadband service, which will bring along enormous economic benefits, promote innovation, create employment, and improve the productivity and competitiveness.

Annex B: How to measure contribution?

Let us first define Direct Consumption Coefficient (DCC):

$$a_{ij} = \frac{Q_{ij}}{Q_i}$$

The basic assumptions of the model and the calculations involved are reviewed here first. The input-output model requires that the economy in question be divided into sectors. Each sector produces goods or services except for the **final sector**, which only consumes goods and services. A production vector **Q** lists the output of each sector. A final demand vector (or bill of final demands) **D** lists the values of the goods and services demanded on other productive sectors by the final sector. As the sectors strive to produce enough goods to meet the final demand vector, they make intermediate demands for the products of each sector. These intermediate demands are described by the **consumption matrix.** This matrix is constructed as follows. The description of the economy begins with a collection of data called an **input-output table** for an economy. This table lists the value of the goods produced by each sector and how much of that output is used by each sector. For purposes of this example the data from the forty-two sectors has been collected into just three: agriculture, manufacturing, and services. Of course, the final sector is also included.

Table AB.1 An input-output table model

	Agriculture	Manufacturing	Services	Final Sector
Agriculture	Q_{11}	Q_{12}	Q_{13}	F_1
Manufacturing	Q_{21}	Q_{22}	Q_{23}	F_2
Services	Q_{31}	Q_{32}	Q_{33}	F_3
Total Gross Output	Q_1	Q_2	Q_3	

The table is straightforward; for example, the agriculture sector spendsQ_1 for the inputs it needs. These inputs are divided among the sectors as follows: Q_{11} of the agricultural output is consumed by the agriculture sector itself, and Q_{21} of the manufacturing output is consumed by the agriculture sector, and so on and so forth. To create the consumption matrix from the table, we can divide each column of the 3×3 table by the total Gross Output for that sector. The result is Table 2, which can be seen below.

The matrix with entries taken from this table is the consumption matrix *A*for the economy.

$$A_{ij} = \frac{Q_{ij}}{Q_i}$$

For an economy, the final demand vector **D**is the column of the table associated with the final sector:

$$D = \begin{bmatrix} F_1 \\ F_2 \\ F_3 \end{bmatrix}$$

The equilibrium levels of production for each sector may now be calculated. These equilibrium levels are the production levels which will just meet the intermediate demands of the sectors of the economy plus the final demands of each sector. If **Q**is the desired production vector, **x** must satisfy

$$\mathbf{Q} = A\mathbf{Q} + \mathbf{D}$$

This equation may be solved for **x** to find that

$$\mathbf{Q} = (I - A)^{-1}\,\mathbf{D}$$

where*I* is the identity matrix. Considering variation, we have

$$\Delta\mathbf{Q} = (I - A)^{-1}\,\Delta\mathbf{D}$$

Annex C: The production function of spectrum

In production function ID(DT, SPCT), we use a Leontief production function which is a production function that implies the factors of production will be used in fixed (technologically pre-determined) proportions, as there is no substitutability between factors. It represents a limiting case of the constant elasticity of substitution production function. The function is of the form

$$q = \mathrm{TECH} \times \mathrm{Min}\left(\frac{z_1}{a}, \frac{z_2}{b}\right)$$

where q is the quantity of output produced, z1 and z2 are the utilised quantities of input 1 and input 2 respectively, and a and b are technologically determined constants. Need to pay attention; parameter TECH is very important which stands for neutral technological progress. TECH is assumed to be 2%, that is, the contribution of technological progress to every sector is the same, even there is no additional spectrum input. In this function, spectrum cannot be substituted by other factors, that is, production will cease if spectrum shortage appears.

Annex D: The Granger Cause Test

The application value of the radio spectrum resources for all industrial sectors has not received so much attention as it should. For this reason, how to effectively measure the value contribution of radio spectrum, so as to enable it to play a better role, becomes an issue to which state agencies on radio administration come to pay increasing attention. Radio spectrum as an intangible asset with enormous economic externality can only be quantitatively analysed, for purpose of calculating its economic value, in such spectrum-commercialised sectors as public mobile communications and radio broadcasting. To calculate the contribution to GDP by radio spectrum in the telecom sector and the radio broadcasting sector, let us consider the function Y = F(X，C), of which Y is the GDP; C other elements that contribute to GDP growth than the telecom sector; X the contribution to GDP by radio spectrum in the telecom sector and the radio broadcasting sector. In order to avoid the possibility of a false regression in our study, we have tested in the first place the hypothesis of whether spectrum is the cause of economic growth. And the result is:

Result: Spectrum is the Granger Cause of Economic Growth

Table AB.2 The Granger cause test

. gcausegdp spectrum, lags(1)	
Granger causality test	Sample: 2004 to 2011
H0: spectrum does not Granger-cause gdp	
F(1, 5) = 0.72	Prob> F = 0.4345
chi2(1) = 1.15	Prob> chi2 = 0.2828

The Granger test shows that the input into spectrum resources is indeed an important variable that influences economic growth, with prominent effect.

```
Progress:gcausegdp spectrum, lags(1)
Granger causality test                    Sample: 2004 to 2011
obs = 8
H0: spectrum does not Granger-cause gdp
F( 1, 5) =    0.72
Prob> F =    0.4345
chi2(1) =    1.15      (asymptotic)
Prob> chi2 = 0.2828      (asymptotic)
. estatic
```

```
-----------------------------------------------------------------------------
       Model |    Obsll(null)   ll(model)     df          AIC         BIC
-------------+---------------------------------------------------------------
           . |      8   -84.21572   -66.72109      3      139.4422    139.6805
-----------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note

. gcausegdpspectrum,lags(2)
Granger causality test                          Sample: 2005 to 2011
obs = 7
H0: spectrum does not Granger-cause gdp
F( 2, 2) =    14.78
Prob> F =    0.0634
chi2(2) = 103.45      (asymptotic)
Prob> chi2 = 0.0000      (asymptotic)
. estatic
-----------------------------------------------------------------------------
       Model |    Obsll(null)   ll(model)     df          AIC         BIC
-------------+---------------------------------------------------------------
           . |      7   -73.19225   -49.0538       5      108.1076    107.8371
-----------------------------------------------------------------------------
               Note: N=Obs used in calculating BIC; see [R] BIC note
```

Annex E: Why S-shape curve?

This part explains why we use S-shape curve to forecast our data**.**

According to related policies and technological standards, we have chosen the S-shaped curve as the basic formula for our forecast. The reason can be explained from a combined effect of stimulating and hindering factors.

（relatively low medium relatively high very high）

Stimulating factors	3G, 4G	Traffic fee adjustment	Mobile marketing	Rich appl. content	SP capacity enhanced	App. store	Terminal diversity	User recognition
2010	relatively low	medium	relatively low	medium	medium	relatively low	medium	medium
2011	medium	medium	relatively low	medium	medium	relatively low	relatively high	medium
2012	relatively high	relatively high	medium	medium	relatively high	medium	relatively high	relatively high
2013	relatively high	relatively high	relatively high	relatively high	relatively high	relatively high	relatively high	relatively high
2014	relatively high	relatively high	relatively high	relatively high	relatively high	relatively high	very high	very high
2015	relatively high	very high	relatively high	relatively high	relatively high	relatively high	very high	very high
2016	very high	very high	relatively high	relatively high	relatively high	relatively high	very high	very high
2017	very high	very high	relatively high	relatively high	relatively high	relatively high	very high	very high
2018	very high	relatively high	very high	very high	relatively high	very high	relatively high	relatively high
2019	relatively high	relatively high	very high	very high	very high	very high	relatively high	relatively high
2020	relatively high	medium	very high	relatively high	very high	very high	medium	medium

Note:

3G, 4G: with the spread of 3G, emergence of 4G, since the start of scale commercial application of the 3G network in 2009, operators have increased efforts to build the 3G networks. Although such networks have not taken shape yet in 2010, nevertheless with the breakthrough in the R&D of the TD-LTE format, operators will increase efforts to build the 4G networks on the basis of existing 3G ones, where it is likely that the market scale will experience a new rapid growth. At the same time, the improvement in bandwidth has also laid a solid foundation for the html5 technology, thus contributing to the mature development of the mobile Internet.

Traffic fee adjustment: a relatively high traffic fee at the moment is a constraint on users using the mobile Internet. An improvement in the basic bandwidth shall surely lead to a reduction in traffic fee. For users, in the future, a monthly payment for traffic will be the key to the emergence of the mobile Internet.

Mobile marketing: at this stage, due to the limits in such basic capacities as network and terminals, advertisers are not very keen on mobile marketing, where the advertisement revenue of the mobile Internet only takes up a small proportion. This problem shall continue for another one year or two. However, in the future, mobile marketing will become part of the revenue of mobile applications.

Rich application content: the content of application on the mobile Internet has become increasingly diverse, where developed platforms can attract content providers and application developers. With an increase in the number and genre of applications, this shall meet the needs of users of the mobile Internet to a greater extent. At the same time, this shall attract more users to access the mobile Internet. The emergence of application stores in recent two years shall reduce the process for users to access applications.

SP capacity enhanced: SP manufacturers has their representation increased in the mobile Internet, where more SP manufacturers have turned to developing platforms, thus bypassing operators to get into direct contact with users. This shall reduce the cost for users to access application and content.

The emergence and development of application stores: operators, end manufacturers, the third party manufacturers, and even such Internet tycoons as Amazon and Taobao, have entered the market of application store. The rapid emergence of the market of application store renders it a key factor to driving forward the development of the mobile Internet in the next one to two years.

Terminal diversification: on the one hand, smart phones will maintain its relatively high speed of growth, while on the other hand, with the emergence of new terminals such as pad and e-books, the mobile Internet shall move from smart phones to terminals with more diversification, including handheld device and vehicle navigation. At the same time, the terminal price is also decreasing. The penetration rate of the mobile Internet terminals among users is increasing year by year.

User recognition: by 2010, the number of netizens on the mobile Internet reached 300 million. There is a rapid rise of low traffic application such as weibo (twitter) and LBS. On the other hand, such content applications as mobile phone reading, game and music, will continue to contribute to the increase in the number of users of the mobile Internet. By our forecast, after 2012, the further improvement of the basic networks and terminals will speed up the growth rate of users of the mobile Internet.

Hindering factors	Limit of basic networks	Constraint of profit model	Relatively high traffic fee	Limited payment options
2010				
2011				
2012				
2013				
2014				
2015				
2016				
2017				
2018				
2019				
2010				

Note:

Limit of basic networks: the 3G service has already been commercialised, albeit with a relatively low speed in building the 3G networks. We should prioritise the first-tier cities and it will take some time to move user demands from voice service to data service. Moreover, it also takes time to build the 4G networks. For this reason, it will take at least one to two years for the basic networks to be improved to a greater extent.

Constraint of profit model for manufacturers: operators still maintain strict control of the whole industrial chain of the mobile Internet through their pipeline advantage and they are the main recipients of profit. At this stage, although a certain number of SP manufacturers have their own operating platform, the profit model is still quite undiversified. The new profit model of mobile advertisement still experiences big problems and it will need some more time to promote these new models.

Relatively high traffic fee: operators need to build their own content, consulting and service system, so as to retain users on their own platforms when in the future data traffic shall be included in monthly payment. For this reason, within a short while operators will still need some time to lay out their services. Before this is completed, it is highly unlikely for the traffic fee to be included in monthly payment.

Limited payment options: the development of the mobile Internet has attracted many more manufacturers to enter the market. More SP are looking for easier ways of payment. At this stage, the payment options are still unsatisfactory according to certain user experiences. With the increasing attention by operators to mobile payment and the emergence of the third payment manufacturers, there will be certain breakthrough in mobile payment.

Annex F: An Analysis of the Economic Contribution of Spectrum

Spectrum as an important driving force to economic growth plays a role that is indispensable. Through analysing the effects and transmitting mechanisms of spectrum, we can delineate the logic relationship between sectors and economic growth, so as to provide a theoretical base for research and analysis. Drawing on the past research and literature both inside and outside China, we can offer a structured analysis of the input-output model. We can analyse the Leontief inverse matrix into the following forms:

Where the final demand is given, in accordance with the traditional input-output model, for the output department X_i, there exists the following relationship,

$$X_i = \frac{1}{1-a_{ii}} Y_i + \left(b_{ii} - \frac{1}{1-a_{ii}} \right) Y_i + Y_j \sum_{j,j \neq i}^{n} b_{ij}$$

The meaning of the Leontief inverse matrix is that one unit of change in the production of a certain sector can lead to a combination of both direct and indirect changes in other industrial sectors. For this reason, we can define the three constitutive elements in the above formula:

Multiplier effect. The change in the level of production caused by the unit of final demand within an industry is the influence of internal demand upon itself for the industry, with its effect to be seen in the industrial capacity of development and self-correction. In particular, it can be expressed as $M_i = \frac{1}{1-a_{ii}}$.

Feedback effect. After the unit of final demand in certain industry has influenced upon other industries, this influence will in its turn produce a feedback effect upon the very industry. In particular, it can be expressed as $Q_i = b_{ii} - \frac{1}{1-a_{ii}}$.

Spill-over effect. The spill-over effect can be defined as the sum of both direct and indirect influence of the unit of final demand in a certain industry upon the output of other sectors. This effect is a single-directional effect, reflecting the industry's impact capacity. In particular, it can be expressed as $F_i = \sum_{i,j \neq i}^{n} b_{ij}$.

The correspondence between direct contribution, indirect contribution and the abovementioned three effects can be seen in the following table:

Table AF.1 ***The correspondence between direct contribution, indirect contribution and the three effects***

Direct contribution	Indirect contribution
Multiplier effect	Feedback effect + spill-over effect

Annex G: Sensitivity analysis on Smart Terminals, the IMT Market Scale and Software

Using the S-curve and on the basis of related parameter estimated by the growth trend in the past years, we have forecasted the shipment quantity of smart terminals in the nine-year period from 2012 to 2020. Also according to three different growth rates we have provided a corresponding forecast of three scenarios - low, medium and high, respectively.

Table AG.1 Shipment Quantity and Total Value of Smart Terminals

Year	Shipment Quantity(Million)			Price	Total Value(Yuan, Billon)		
	Lower Def	Mid Def	Higher Def	(Yuan)	Lower Def	Mid Def	Higher Def
2007	2.00	2.00	2.00	1970.34	3.94	3.94	3.94
2008	6.01	6.01	6.01	1954.36	11.74	11.74	11.74
2009	15.02	15.02	15.02	1928.04	28.95	28.95	28.95
2010	41.05	41.05	41.05	1891.40	77.63	77.63	77.63
2011	118.13	118.13	118.13	1844.42	217.88	217.88	217.88
2012	219.00	220.24	221.00	1787.11	391.38	393.60	394.95
2013	358.00	365.54	378.00	1719.48	615.57	628.54	649.96
2014	530.00	555.89	580.00	1641.51	870.00	912.50	952.08
2015	660.00	726.29	760.00	1553.22	1025.12	1128.08	1180.44
2016	790.00	860.54	920.00	1454.59	1149.13	1251.74	1338.22
2017	900.00	980.78	1090.00	1345.63	1211.07	1319.77	1466.74
2018	1020.00	1110.93	1260.00	1226.35	1250.87	1362.39	1545.20
2019	1180.00	1282.07	1460.00	1096.73	1294.14	1406.08	1601.23
2020	1360.00	1502.11	1680.00	956.79	1301.23	1437.20	1607.40

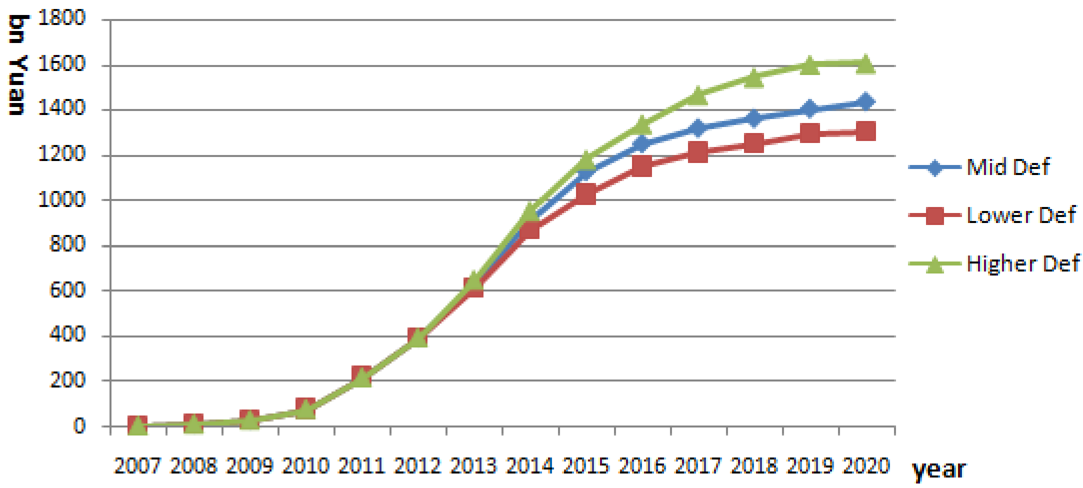

Figure AG.1 The total value of smart terminals

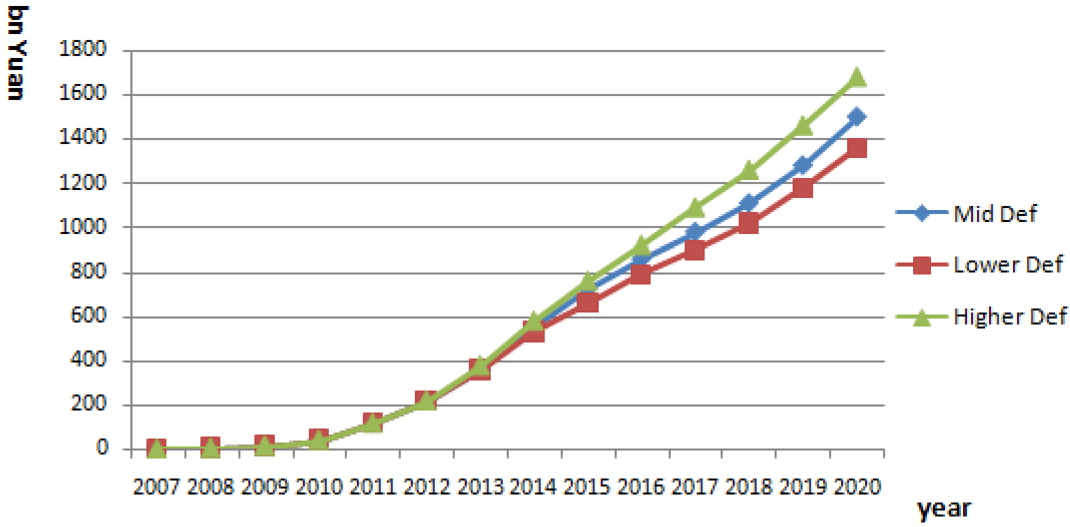

Figure AG.2 Shipment quantity of smart terminals

The IMT data traffic revenue is calculated on the market scale under the three hypothetical circumstances, subscription, population and penetration rate, of which the result can be seen in the following table:

Table AF.2 IMT Data Traffic Revenue

Year	IMT Market Scale			Subscription (Billion)	Population (Billion)	Penetration Rate
	Lower Def	Mid Def	Higher Def			
2007	11.60	11.60	11.60	0.04	1.32	2.65%
2008	20.10	20.10	20.10	0.10	1.33	7.57%
2009	37.78	37.78	37.78	0.21	1.33	15.37%
2010	66.12	66.12	66.12	0.29	1.34	21.51%
2011	80.11	80.11	80.11	0.43	1.35	31.86%
2012	150.00	150.00	150.00	0.49	1.36	36.11%
2013	240.00	247.50	255.00	0.56	1.36	41.31%
2014	384.00	408.38	433.50	0.65	1.37	47.25%
2015	614.40	673.82	736.95	0.75	1.38	54.06%
2016	983.04	1111.80	1252.82	0.86	1.39	61.84%
2017	1572.86	1778.88	2067.14	0.99	1.39	70.75%
2018	2437.94	2757.27	3307.43	1.13	1.40	80.94%
2019	3656.91	4135.90	5126.52	1.30	1.41	92.60%
2020	5485.36	6203.85	7946.10	1.50	1.41	105.94%

Mobile software and application:

Table AG.3 Software Revenue

Year	Software Revenue(Yuan, Billon)			Growth Rate (%)		
	Lower Def	Mid Def	Higher Def	Lower Def	Mid Def	Higher Def
2007	516.50	516.50	516.50	15.95%	15.95%	15.95%
2008	633.14	633.14	633.14	22.58%	22.58%	22.58%
2009	839.48	839.48	839.48	32.59%	32.59%	32.59%
2010	1107.62	1107.62	1107.62	31.94%	31.94%	31.94%
2011	1383.22	1383.22	1383.22	24.88%	24.88%	24.88%
2012	1603.52	1653.11	1752.30	15.93%	19.51%	26.68%
2013	2032.69	2117.39	2265.61	26.76%	28.09%	29.29%
2014	2585.32	2810.13	3034.94	27.19%	32.72%	33.96%
2015	3393.85	3688.97	4020.98	31.27%	31.27%	32.49%
2016	4238.90	4658.13	5123.94	24.90%	26.27%	27.43%
2017	5246.55	5765.45	6399.64	23.77%	23.77%	24.90%
2018	6238.87	6855.90	7678.61	18.91%	18.91%	19.98%
2019	7331.09	8145.65	9204.58	17.51%	18.81%	19.87%
2020	8641.07	9601.19	11041.37	17.87%	17.87%	19.96%

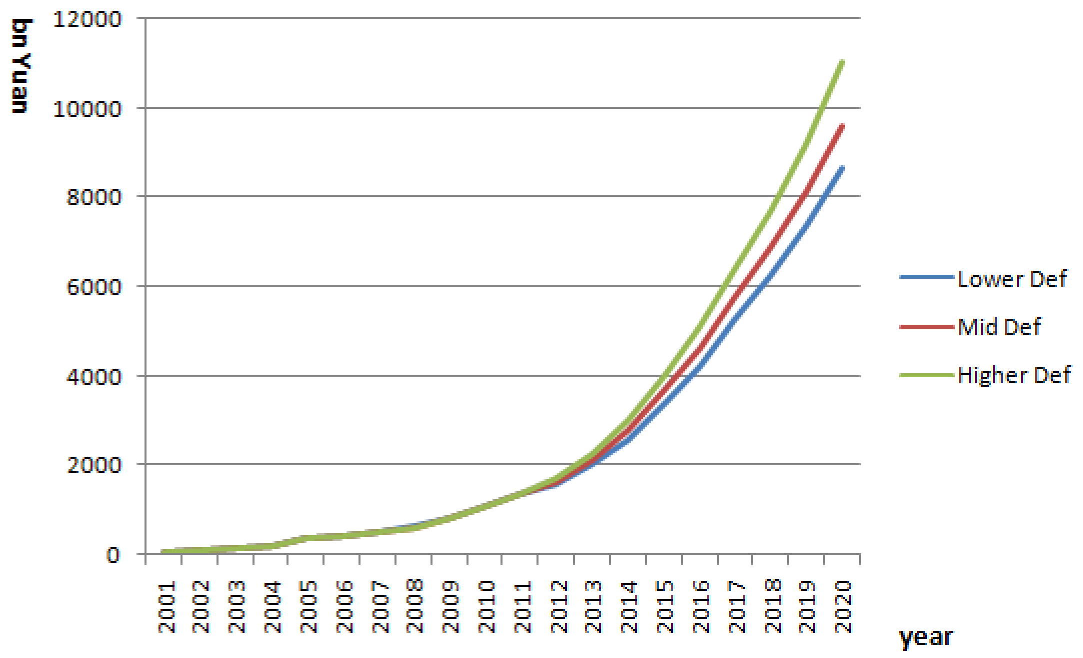

Figure AG.3 Software Revenue

Economic contribution under different definitions:

Table AG.4 The economic Contribution of IMT

Year	SGO (Yuan, Billion)	Contribution Rate Lower Def	Mid Def	Higher Def
2012	98613.59	2.97%	3.02%	3.13%
2013	106502.68	3.84%	3.97%	4.18%
2014	115022.89	4.81%	5.14%	5.46%
2015	124224.73	5.68%	6.21%	6.66%
2016	134162.70	6.46%	7.10%	7.75%
2017	144895.72	7.25%	7.98%	8.93%
2018	156487.38	8.02%	8.85%	10.09%
2019	169006.37	8.93%	9.91%	11.50%
2020	182526.88	10.07%	11.24%	13.32%

Note: SGO = Social Gross Output[12], GDP=Gross Domestic Product[13]. 2001 price.

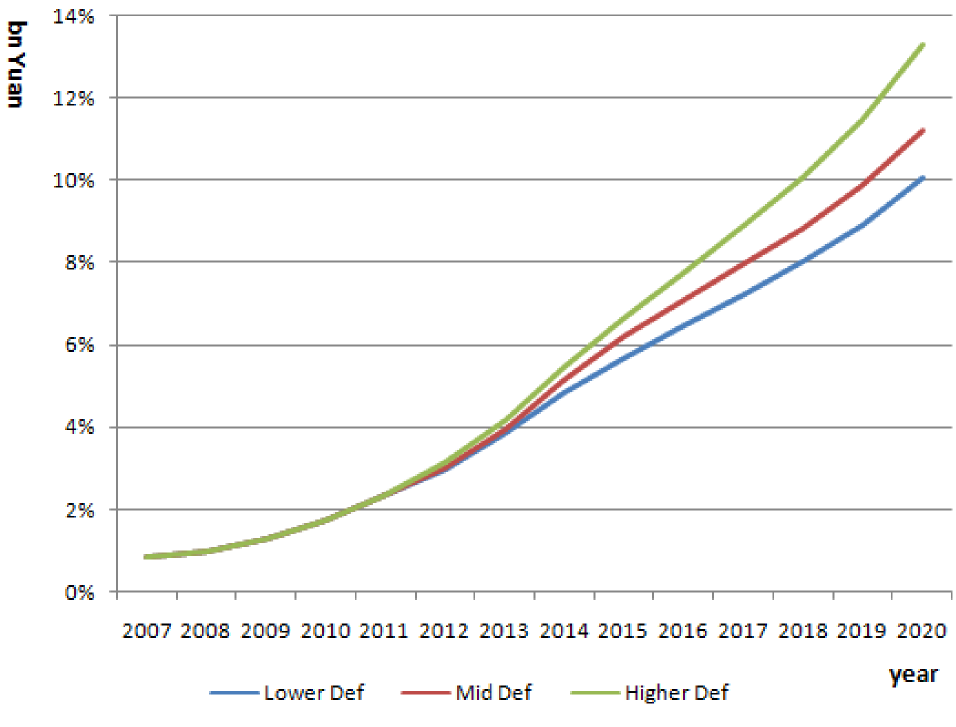

Figure *AG.4* Contribution Rate

[12]Social Gross Output (S.G.O.): All the products made by a society over a given period of time (usually a year). In its natural and material form, it is made up of means of production and articles of consumption; in its value form it is made up of the value of the material used in social production which must be compensated (wear and tear of machines and equipment, production buildings and structures, raw and other materials, etc.) and of the newly created value which goes for consumption by the population and extended reproduction.

[13]SGO to GDP: GDP = SGO * convert multiplier.

Economic contribution per MHz under different definitions:

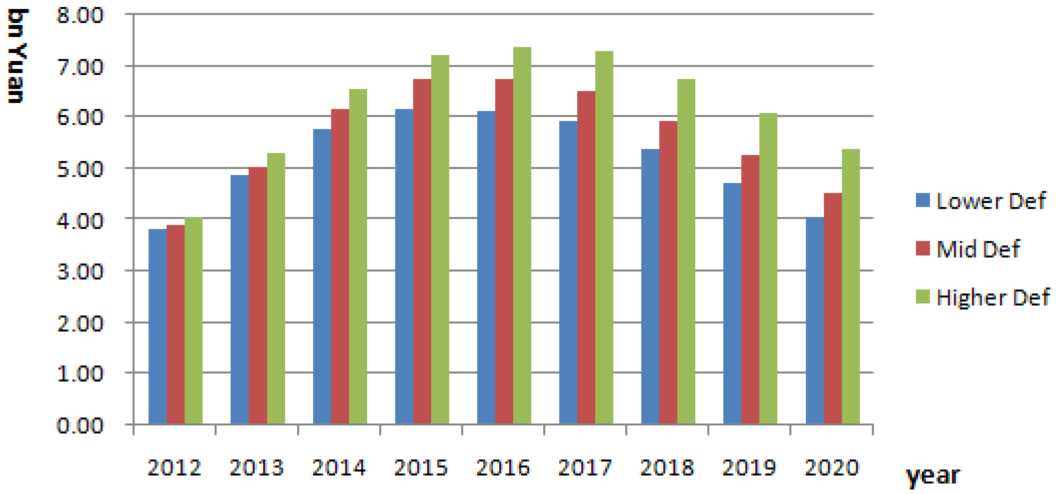

Figure AG.5 Economic benefits of IMT per MHz

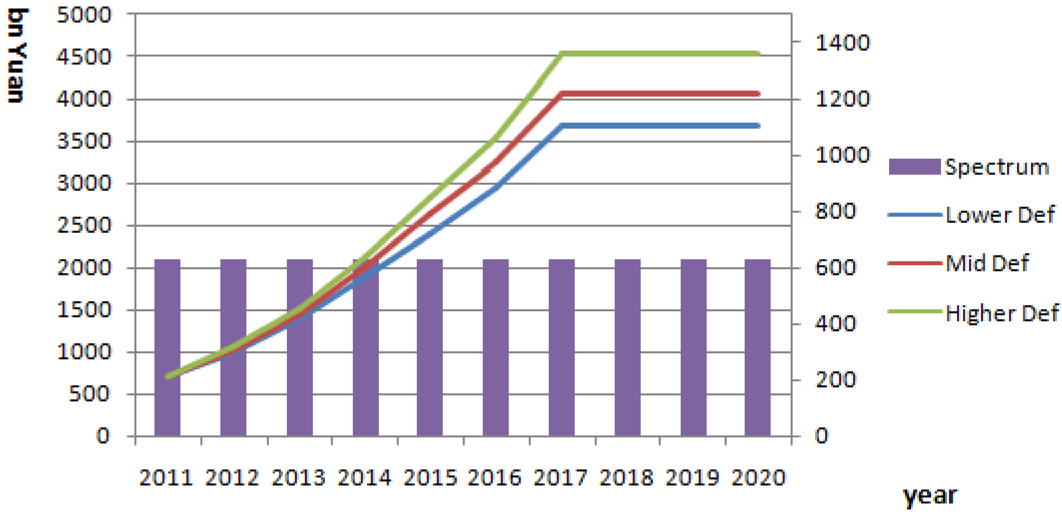

Figure AG.6 Economic benefits of IMT [Scenario (a)]

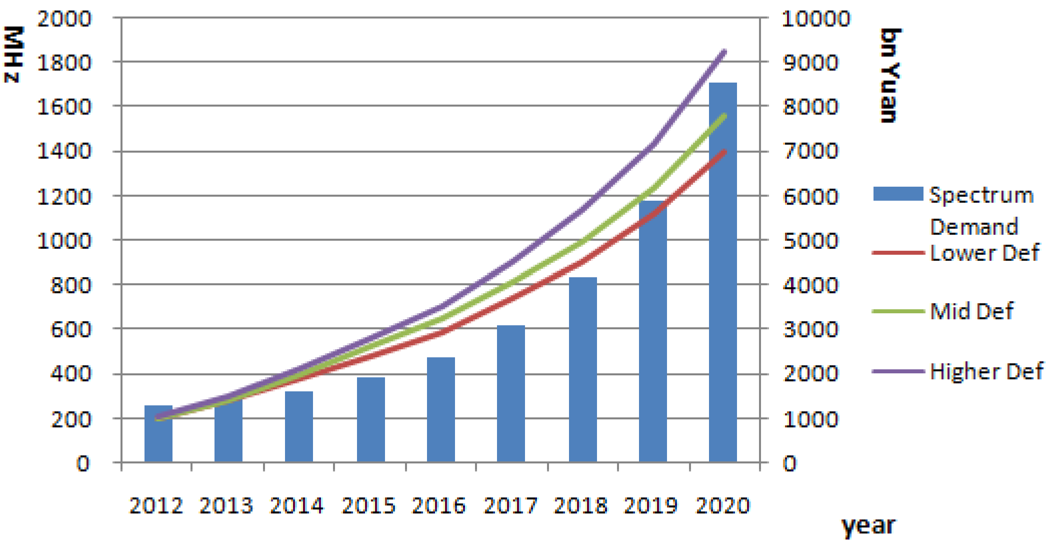

Figure AG.7 Economic benefits of IMT [Scenario (b)]

Annex H: GDP increase per MHz

Having calculated different economic benefits under each scenario, we then estimate the total value of value addition generated over the period 2011 – 2020. The results of our analysis can be seen in the Figure below. Allocation or re-allocation of one MHz spectrum band to IMT will have significant incremental benefits in other sectors in China. GDP will increase 47.7 billion Yuan if we re-allocate one MHz band to IMT.

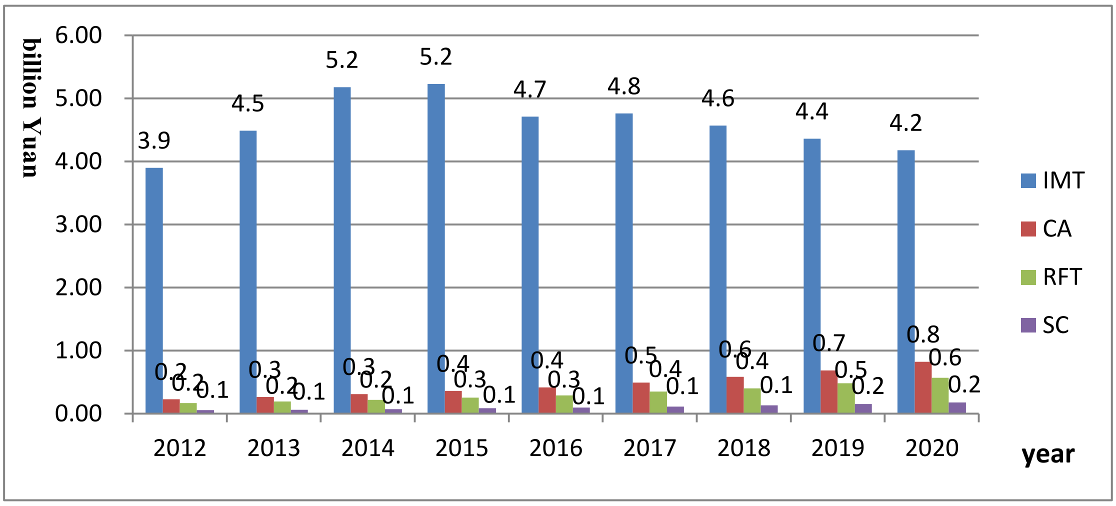

Figure AH.1 GDP increase per MHz in different sectors (product value)

Annex I: GDP Lost of Delaying Roll-out

After examining the economic benefits, we will further consider the loss of delaying the re-allocation of spectrum per MHz to GDP, as can be seen in the following figures:

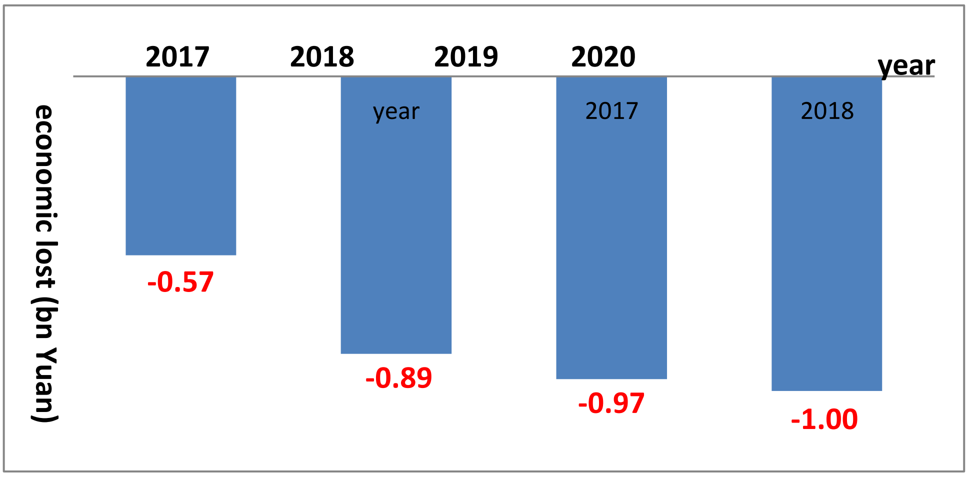

Figure AI.1 GDP lost of delaying roll-out per MHz

Delaying the decision of spectrum re-allocation will have significant impact on GDP which is shown below. As shown in fig. 18, 0.57 trillion Yuan will be lost with 2012 spectrum roll-out, and 3.43 trillion will be lost while the spectrum re-allocation time is delayed to 2020.

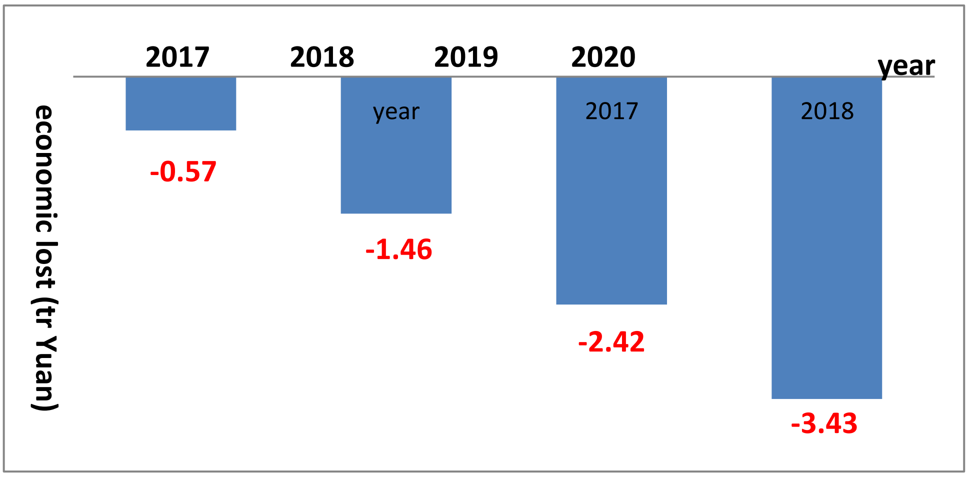

Figure AI.2 GDP lost of delaying roll-out (total)