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ECONOMIC DYNAMICS IN MOBILE SERVICE INDUSTRY OF CHINA

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Abstract

The current mobile service in China displays a highly dynamic competition between two major operators, China Mobile and China Unicom. Their market share concerning the number of subscriber is influenced by the subscriber base, service quality, pricing policy, etc. Current researches and analyses are mostly direct comparisons of the relative advantage of the two operators, in which weights of every item being compared are chosen almost arbitrarily and the dynamic relationships between these items are usually ignored.

This research stands from the view of China Mobile, the bigger and earlier operator, to explore the reason of its shrinking market share after SMS (Short Message Service) becomes popular in China. The dynamics between the service quality, exchange capacity, price in the mobile service are highlighted to show how these factors influence the growth of the total mobile market and the relative advantage in the duopoly as well. Long run and short run effects of these factors are differentiated so as to make it possible to suggest some proper policies for China Mobile to keep the leadership in the market.

1. Introduction

1.1 General Context

The history of mobile communications in China is relatively short, as it is everywhere. The analogue cellular mobile phone was introduced in 1987. Formerly, ***China Mobile*** was the only mobile network operator in China, until ***China Unicom*** was founded as another State-owned enterprise in 1994 when the government broke down the telecommunications monopoly with the main purposes to boost technological developments in the mobile communication industry on one side and build economic benefits for customers on the other. The latter showed an increase of products -variety and quality of services, which attracts more and more people to sign up for this service. According to the latest statistic report, total mobile subscribers have by this October, already reached 197 million. The Chinese mobile telecommunications market has become the fastest growing and potentially largest market in the world.

So far, China Mobile and China Unicom are the only two licensed operators that provide mobile communications services in China's domestic market. China Mobile dominates China's mobile market with more than 70% of total subscribers at the end of Oct 2002. Due in large part to some slanting policies by the government, China Unicom has emerged as a serious competitor.

1.2 Problem Description

For a long time, as a first-mover, China Mobile performed quite well in recruiting new subscribers. In 1999, SMS (short message service) boomed a lot in China, which endowed China Mobile with much higher compatibility value of network thanks to the larger subscriber base of its own and the impossibility of mutual transmission of short message between different operators.

However, taking even more advantages, China Mobile did not achieve an overwhelming advantage (with regard to subscriber) over China Unicom. On the contrary, its market share shrinks while China Unicom's market share has been steadily increasing since 1999. The "winner-take-all" does not happen here. Chinese mobile telecom market has thus been tending to be a duopoly market, in which rivalry does exist, rather than a monopoly market where China

Mobile pre-empted.

What is the reason behind the current rivalry situation?

Traditional opinion is: lower price, more subs

Unicom can enjoy a preferential pricing (among the slanting policies by the government) which allows it to reduce the unit prices 10%-15% below the ones of China Mobile.

But if Unicom cuts the unit price, it really can attract more price-sensitive potential subscribers at very beginning, but it will soon face a challenge to service these booming customers with new capacity.

Actually from 1999, both mobile operators in China were encountered an inadequacy in network capacity, especially after SMS was introduced and quickly became a prevalent service in mobile operations. On weekends and holidays, people are getting more and more used to send greetings to every friend they know. This imposes much pressure on operators' exchange capacity. In 2000, China Mobile just experienced such a tough time that it once stopped its subscription in a few cities because it cannot service them with adequate capacity!!

Compared with China Mobile, Unicom has some advantages with respect to capacity as follows:

- 1) It started with some new base stations, which are cosponsored by Ministries of Electronic Industry, of Electric Power and of Railways.¹
- 2) It enjoys preferential cost of capacity building due to its wider range of business.
- 3) In some areas that have not yet been covered by Unicom's mobile network, its subscribers can enjoy the roaming service provided by China Mobile. This is obliged by a regulatory move of government in 1998.

So to China Mobile, it is really a critical time period. If it just let the things as they are, its leadership may be lost to its new-comer rival.

What is network capacity for mobile service?

Operators set up base stations to realize the mobile dispatch service. Base station is a radio station in a land-mobile radio network. It comprises a transmitter, a receiver, and an antenna facility, and connects traffic between mobile subscribers and the rest of the network. Its depletion could be accelerated with the subscriber and usage increasing.

And the system usually dedicates a single radio channel/line to a specific group of users who share it. There is an optimal number of people using one line, and according to some statistics², 40 users sharing on line is the ceiling for normal connection quality. If more people use one line, interference will increase and reception cannot be guaranteed.

2. Why is system dynamics applicable to this problem?

Complex systems with many variables, long time delays, and uncertainty about the cause and effect, is harder to explain and estimate without the use of system dynamics. Providing a method of eliciting mental models about problems and visualize them as models helps your client to understand how the structure works in relation with real world inputs. System dynamics helps to

¹ See: <http://www.unicom.net>

² From <http://www.iwta.org/WhatIsCTR.html>.

structure and enhance the accuracy of data provided from surroundings with dynamic complexity, long time delays and unknown structure.

A model about the mobile service rivalry and the effect of service quality on the rivalry would help clients improve knowledge about structure and how it really works. Hypothesis about the relative competitive status and the mobile service development structure can be tested. Simulations speed and strengthen the ability to learn how a problem would look like in the future. Changes in assumptions, time horizon and hypothesis are possible to simulate for us to gain understanding about.

It is necessary to consider dynamics, cause and effect relationships, feedback structures and non-linearity of the mobile service system, to understand the behaviour of the system. On behalf of your client one should try to discover the mental models of people who will decide to choose or quit a certain operator, it is important to model how their decision making is being done. An essential question will therefore be what factors are most likely to lead to the increasing of Unicom's market share. Is it the lower price or other factors that we do not know about initially?

SD modeling also provides a link between modeller and client. The causal loop diagrams and stock and flow diagrams are a way to communicate the results of conversations in a visual manner, understood by all participants. An explanation of variables, stocks and flows would help all parties to gain a deeper understanding of how a problem occurs and what policies to chose to weaken the negative feedback loops. The final model can be used to test different policies. This is a way to optimize policies and to come up with decisions holding more expected outcomes.

3. Conceptual model

3.1 Verbal description and model boundary

When applying system dynamics to solve a problem, one should not try to model the system where the problem arises. One should try to model the problem itself, extract information what is really needed to explain how a certain behavior arises from the structure. Therefore it is useful to make assumptions and discuss what variables that are considered to be explained endogenously (arising from interaction of the variables in the model itself) or exogenously, as an input from outside the inner boundaries of the model.

It is useful to start to select what are excluded from the model and what are regarded as endogenous or exogenous variables. A model boundary chart would summarize the scope and the elicitation process where variables that are related to the problems solving process, is chosen to be in the model.

Endogenous	Exogenous	Excluded
<ul style="list-style-type: none"> - Potential subscriber - Subscriber - Capacity - Service quality - Depletion of capacity - Investment budget for capacity - Usage - Reception rate - Word of mouth effect - Net work effect 	<ul style="list-style-type: none"> - Total population in city - Government policy: unit price of service, roaming service, loaning - Unit cost of capacity - Capacity expansion decision: threshold for building, construction time, investment time 	<ul style="list-style-type: none"> - Financing problems when in great need of capacity - Handsets and other charges reduction leading to growth of market - Location of capacity - Population growth - Economic growth - Other relative strengths

This model is to depict the mobile rivalry in a simplified way. The focus is to see the relationship between capacity adequacy and subscriber recruitment. Other relative strengths of the two operators are assumed to be the same. The key variables (endogenous) listed above should interact together and produce a certain behavior, according to the different initial and continuous values. Here are several indicators which can be used to compare the performance of either operator: subscriber number, service quality and investment budget. But due to the state-owned property for both operators, they can borrow as much as they need as long as the government feel they can capture enough subscribers in longer term to refund the current loaning. Moreover, price is also determined by government, which is to avoid “vicious price war”. So the only thing operators can do to change their relative competitiveness is to adjust their capacity building decision.

It’s a kind of imperfect competition in this market, yet anyway we can find from this model that even this imperfect competition promotes the development of whole mobile service industry in China.

3.2 Time horizon

The time horizon of the model should be long enough to capture the longest delays and indirect effects of increasing number of subscribers. Since China Unicom has put its digital mobile service in the regular way, the model should start from year 1997, where also the last data of subscribers for either operator could be used as initial values in the model. In the end of 1997, there are roughly 10 million China Mobile subscribers and only 0.5 million China Unicom subscriber. For the capacity, China Mobile enjoys a 0.5-million-channel total network while Unicom 0.1-million-channels.

It should be long enough for us to watch the dynamics of rivalry until 2047, the time when the market approaches saturation and both operators do not get much pressure from the increasing subs to expand the capacity.

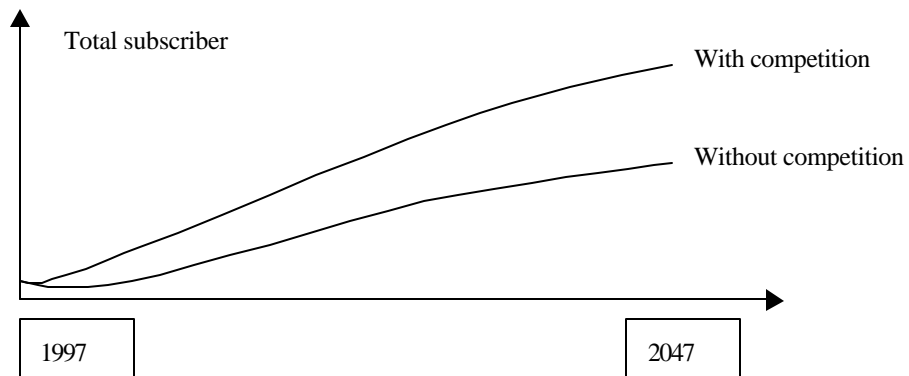
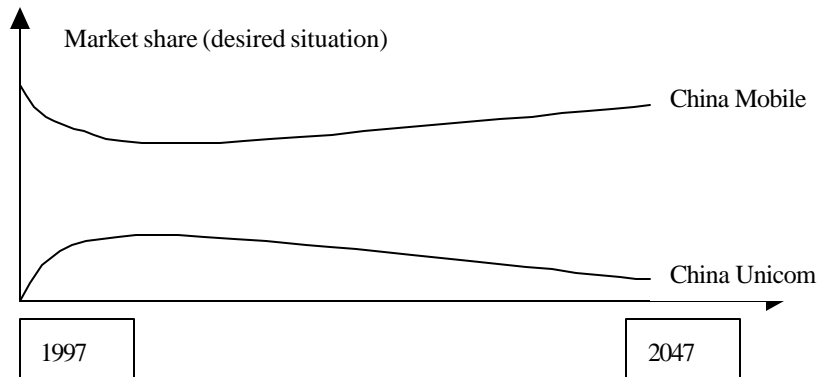
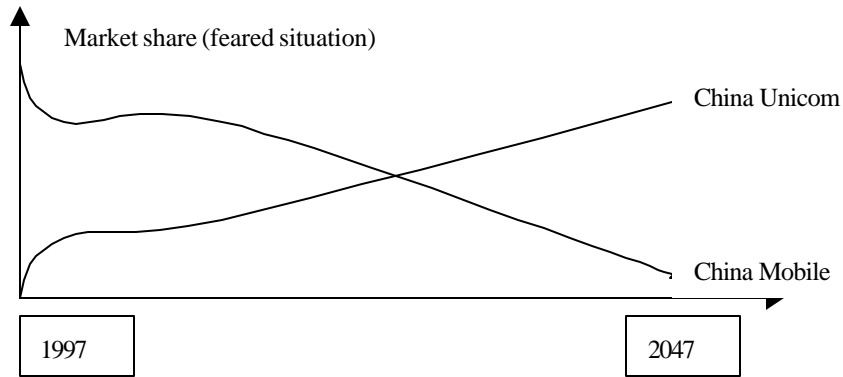
3.3 Reference modes

It is important to have a reference mode to roughly describe how a development is considered

over the time horizon. These reference points are useful in the analysis which comes later.

In this case, the current rivalry may evolve into two types of situation. And to my client, China Mobile, if they do not deal with the condition well, it will not only lose the leadership but very likely the whole market to its rival, China Unicom. However, a better response may help them reverse the trend.

As for the entire Chinese mobile service market, total subscriber number will and has been much bigger due to the competition brought by China Unicom. Note that this model only deals with the service competition in terms of capacity adequacy.



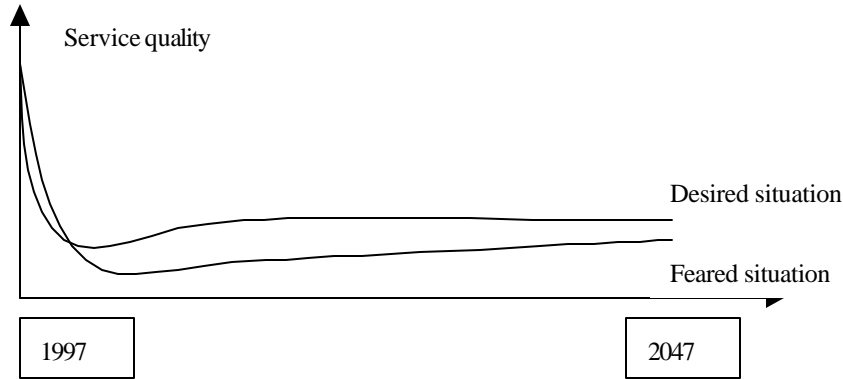


Figure 1: Reference modes

3.4 Dynamic hypothesis

The hypothesis should provide an explanation of the dynamics characterizing the problem in terms of the underlying feedback and stock and flow structure of the system. In this case, an increase in the subscriber base should lead to lower service quality, lower reception rate and accelerated capacity depletion in short-run. But in long-run it can improve the capacity adequacy by increasing the revenue accumulation which is available.

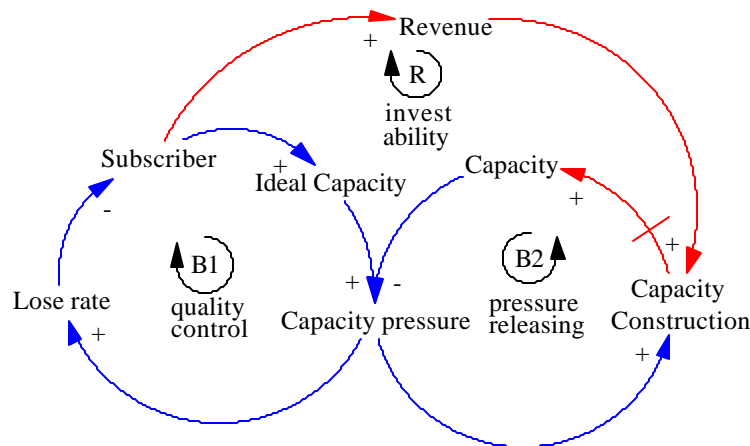


Figure 2: A simple CLD illustrating the research hypothesis

Currently the capacity problems in mobile service are caused by two reasons:

- 1) A slow and passive capacity building process
- 2) Large existing number of subscriber

B1 shows the short-run pressure relieving mechanisms generated by the system itself, yet no operators want this loop to work actively. So the only way to relieve the capacity pressure may be to build the capacity proactively before the quality has gone so bad as to incur high loss rate of subscribers.

I choose China Mobile as the client in this model. It has to make its capacity expansion decision with its increasing subscriber number. It at least should keep the current market share with the being of its aggressive rival. Another client is the Chinese Government because they have

know what the actual effects have their policies on the competition situation and its trend. It should make the policy which can best promote the Chinese mobile industry in large and can save the investment resources in the long-run.

3.5 Causal loop diagrams

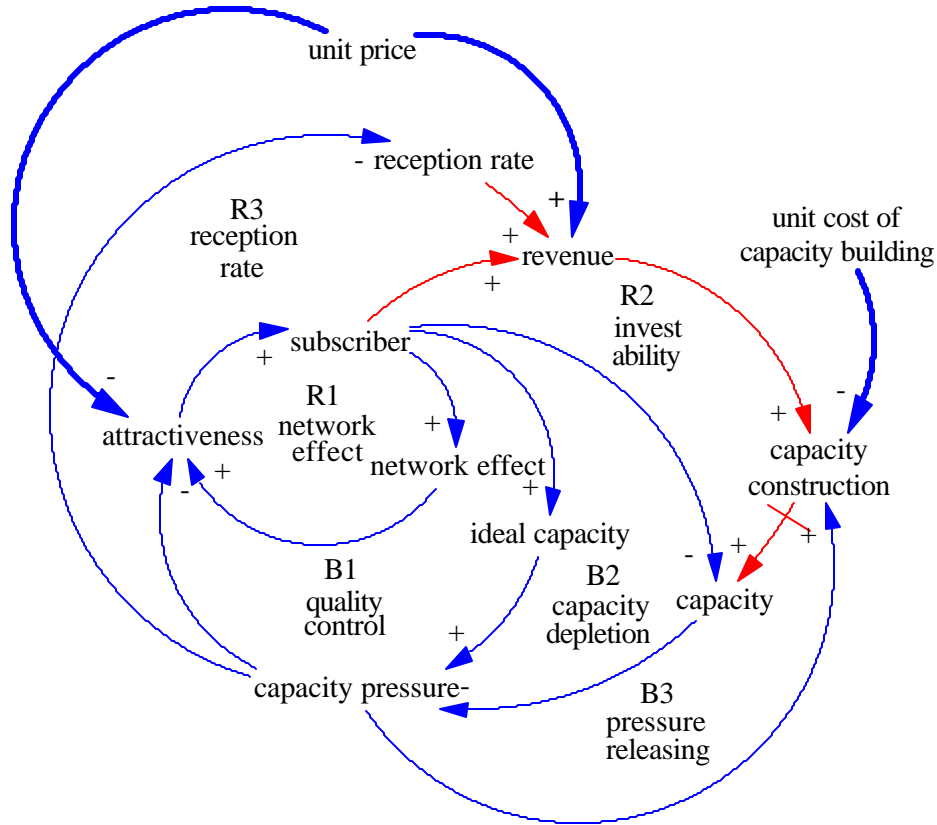


Figure 3: Causal loop diagram depicting the feedback structure within single operator

Explanation of the feedback structure

R1: Network effect

This is a self-reinforcing loop. The larger the subscriber base, the stronger network effect it has, the more attractive the operator is to those potential subscribers, and the larger increase rate it gets next time round. The network effect is quite a powerful driver of growth in mobile service industry, once started, just to reinforce its own growth. Therefore, it endows a lot advantage to the first-movers.

B1: Quality control

Negative loops like B1 are self-correcting. It indicates that when subscriber increases,

operators will need more capacity to service them, and all else equal, they will face greater capacity pressure which leads to lower service quality and higher loss rate of subscriber, so next time round, subscriber increase will be limited and not put so much pressure on the capacity. This is a short-run pressure relieving mechanism generated by the system itself, yet no operators want this loop to work actively.

B2: Capacity depletion

It is also a pressure relieving mechanism generated by the system itself. What is different from B1 is that it shows subscriber increase also can lead to accelerated depletion of the capacity, which imposes great pressure on capacity on the other hand.

R2: Invest ability

It's a reinforcing loop showing that if an operator has more subscribers, it can get more revenue from them, which it can use to expand capacity and improve the service quality. Then next time round, it will get a higher increase rate of subscriber. But like all other reinforcing feedbacks, this loop can also drive collapse: the more capacity pressure, less subscriber it will get, less revenue can be accumulated, less ability to build capacity, then next time round, even more capacity pressure.

R3: Reception rate

It's another reinforcing loop driving capacity pressure even larger when it is increasing and making it smaller when it's reducing. The more capacity pressure, the lower reception rate leading to lower revenue incoming, the less ability to build capacity. And next time round, there's even more capacity pressure.

B3: Pressure releasing

This is a decision-making loop by operators, intending to keep the capacity pressure from growing too large. When the pressure is increasing, they will resort to build more capacity, after a construction delay, they will get more capacity and the pressure will be somehow relieved.

And unit price and unit cost for building capacity are treated as exogenous factor to influence the recruitment of subscriber and capacity construction.

The diagram above shows the feedback structures within either operator, but since both operators share the same market, thus for each operator, these loops do not operate separately but instead develop with those of its rival. And the linkage in between is the subscriber number, service quality and relative attractiveness.

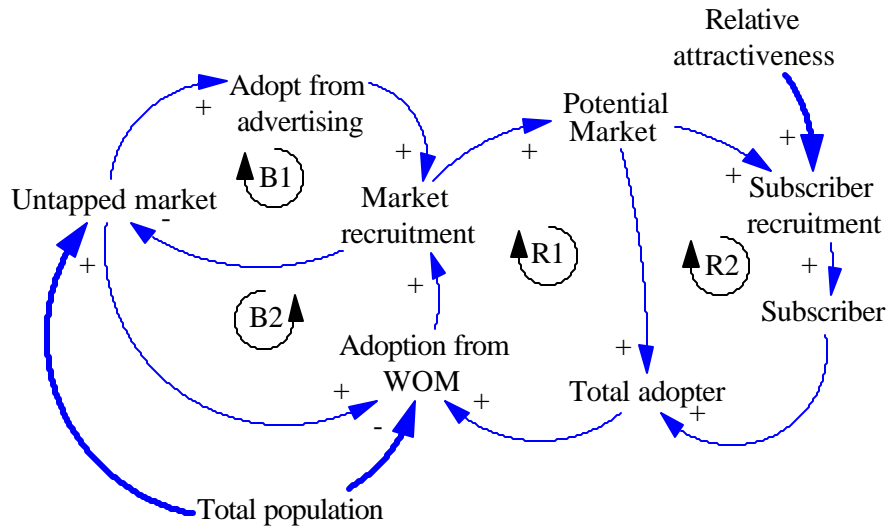


Figure 4: Mobile service market growth

B1: Adoption from ads

B2: Adoption form Word of mouth effect

R1: Potential market growth

R2: Mobile subscriber base (for both operators) growth

3.6 Sectors

The model of rivalry in mobile service market and capacity control is divided into four sectors:

- Quality formation
- Capacity building decision
- Investment capability
- Market growth & share

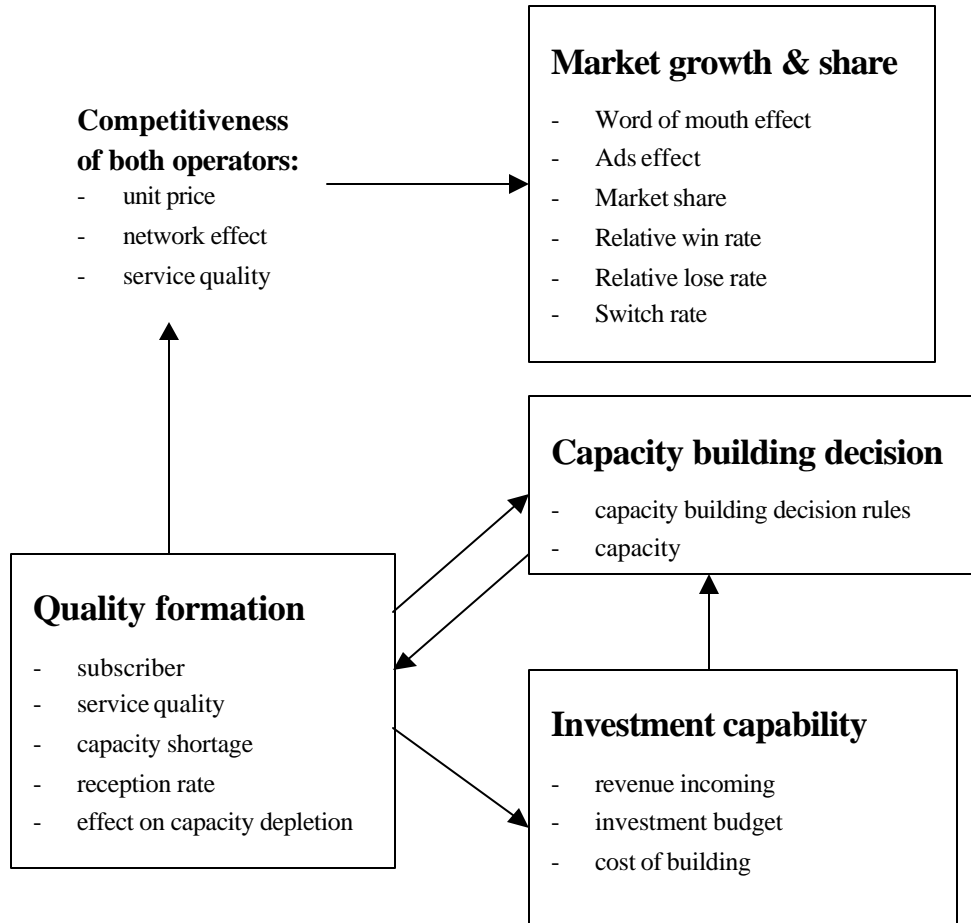


Figure 5: Sectors in model

4. Formal model

Quality formation

Capacity building decision

Investment capability

Market growth & share sector

(See detailed structure in Baserun.sim in zip file named "sim")

5. Simulation and Behavior analysis

This chapter represents the result of model simulation under three scenarios: market growth, market share and a policy design.

(During the behavior analysis, an incorrect modeling of switching rate was discovered. Because switching only happens when capacity is adequate, so it only happens at the beginning of

the simulation when subscriber of Unicom is very small. This leads to the abrupt change number in its subscriber and service quality, which seems like nonsense. Therefore, I just introduce a variable named “Bench Switching Rate” to smooth it. It means how much of an operator’s subscribers will switch at most in one month, even though they perceived the other operator’s quality is much higher. It helps to achieve the situation in which if there is one operator provide service quality above 1, subscribers with another operator will not so hurry to quit but just wait to see if the sound quality is durable, and switch to enjoy that quality gradually. This is similar to the reality.)

5.1 Scenario 1: Market growth

In this scenario, we compare two situations: The first run is the condition where there is only one player there, so called “monopoly market”. We achieve this by setting the lose rate, subscriber increase rate, switch rate, attractiveness, capacity and service quality of the second operator (Unicom) to be zero. The second run is the condition where there are two similarities controlling the market, so called “duopoly”. We just assume both operators all the same except that they have different initial subscriber and line capacity numbers.

Figure 6: Market growth (available in mktgrow.sim)

In the first run, the resulting Total subscriber=Subscriber1=440 million, Service quality1=0.86, LineCapacity1=9.48 million. In the second, resulting Total subscriber=873.45 million, Subscriber1=497.1 while Subscriber2=376.35 million, Service quality1=0.977, Service quality2=0.996, LineCapacity1=12.14 while LineCapacity2=9.37 million. We can see that with the competition from Unicom, not only the total subscriber gets much higher value, but the subscriber of China Mobile and service quality as well. That is because competition stimulates the incentive of China Mobile to build capacity more frequently.

5.2 Scenario 2: Market share

In this part, we first assume the two similarities, then add some “privileges” China Unicom enjoys, which is endowed by the government. We do the simulations one by one in order to see clearly what individual effect will these privileges have on the rivalry situation both in short and long run.

Scenario 2.1: The base run

(two similarities only with different initial subs and lines)

Figure 7: Base run (available in baserun.sim)

We see from the graph that both operator’s subscriber number enjoy a growth shaped like S.

The reason behind that is the strength shifting among different causal loops. At the very beginning, the whole market grows slowly but both quality drop quickly because there are enough capacity so that expansion is not needed, when these initial capacity is fully utilized and subscriber is still increasing, the quality will drop below 1 which causes the pressure to increase capacity. But for releasing the pressure, there is another loop to count on—invest ability, when invest ability

loop gets more strength, that means operator gets more from subscriber than spending on shortage brought by them, then operator will improve its quality back to 1 with a construction delay, during the time its loss rate for subscriber is reduced so that its subscriber increase increasingly.

But if with the increasing pressure, invest ability loop does not get so much strength as to meet the capacity shortage, then the quality control balancing loop will dominate, that is quality cannot be improved by capacity expansion, so it leads to greater loss rate and subscriber increasing cannot get so much speed as it did last time. Its loss rate will not decrease until it gets enough revenue to meet the shortage brought by the existing subscriber. Then the subscriber increase rate will be speeded up again. But in the longer term, another problem will happen, --capacity depletion loop will get more strength so that subscriber will have a compound effect on capacity shortage. Even if revenue accumulated at that time is enough to compensate this compound effect, subscriber increasing cannot gain much speed because this time the diffusion negative loop dominates the system and there are very small people left in the untapped market.

And we also can see from the base run, the relative market share experienced four phases--

(1) Marketshare of operator1 is shrinking in the first 40 months while operator2 gaining the share.

That is because the initial quality2 is much higher than quality1, so subscriber1 just switch to operator2. (This is also the reality, China Unicom gradually gains the marketshare after 1997.)

(2) Operator1 regain the share gradually while operator2 shrinking.

With the booming subscriber, operator2 also will face a severe quality trouble, we can see in month 40 the time when its share reaches the highest, its quality drops to the lowest (even much lower than operator1). Meanwhile, it has not yet got enough revenue to meet the capacity shortage, for it now quality control loop limits the increasing of its subscriber. At the same time, totally different things happen to operator1, on one hand network effect makes it win more subscribers, on the other, it can get revenue to meet some shortage generated by the increasing subscriber, pressure leasing and network effect loop together make it regain the market share lost before.

(3) Operator1 once again loses the share to operator2, to some extent.

As stated before, another problem will happen when subscriber base becomes larger and larger--capacity depletion loop will get more strength. This time operator1 will first be dominated by this loop because it has more subscribers. So it loses marketshare to operator2 although it wins more new recruitment, it loses still more than the latter.

(4) Market saturation

At this period of time, even if quality can be improved and capacity shortage can be met with enough revenue, subscriber increasing cannot gain much speed for each operator because this time the diffusion negative loop dominates the system and there are very small people left in the untapped market.

Scenario 2.2: Low-price privilege

(set Unit price2=0.85, 15% below Unit price1)

(the second run is base run)

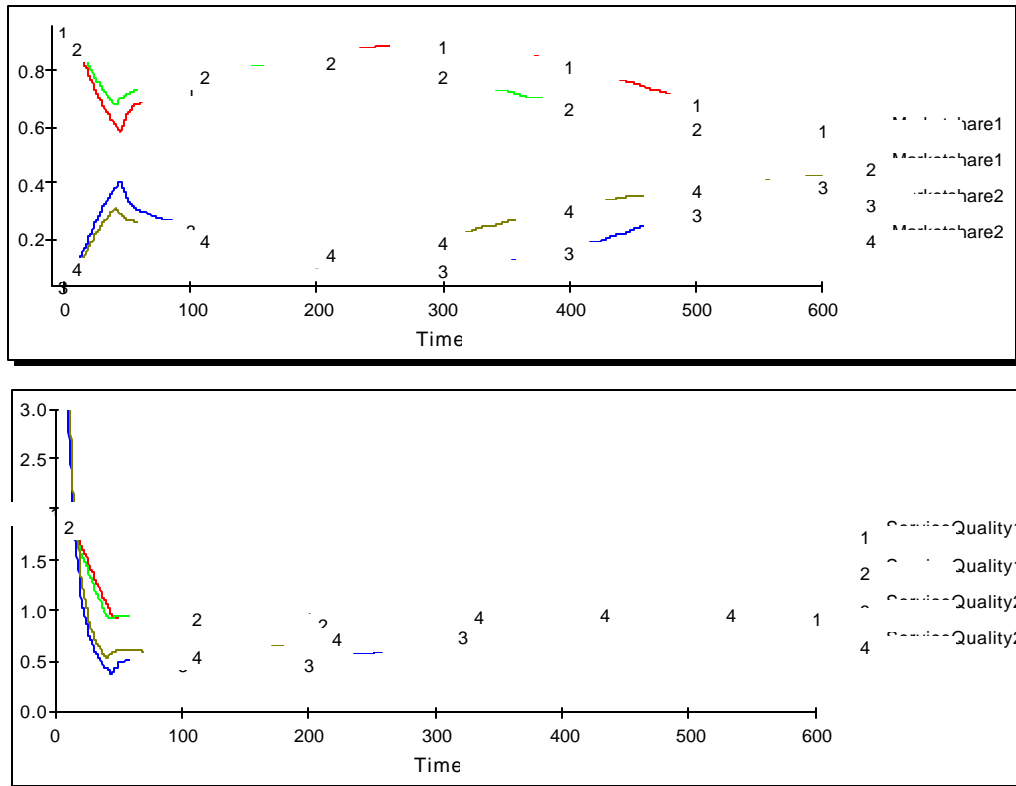


Figure 8: Lower-price privilege

Compared with base run, we can see that in the first phase operator2's marketshare peaks at a higher point (40% compared with 30% in base run). This is because lower price leads to bigger attractiveness at the beginning, but booming subscribers soon imposes much more pressure on the capacity than in base run, which makes it experience longer time in phase2 and a deeper point in marketshare (5% compared with 15% in base run). This is because it takes longer time for operator2 to accumulate enough revenue (as compared with normal price) to meet the shortage if it recruits new subscribers too aggressively at the beginning. It is a typical better-before-worse pattern.

Therefore, we can conclude that government's preferential price policy just promotes China Unicom to expand its marketshare in shorter run, say, 4 years. In the longer term, say 10-20 years, this over-expansion will cause a lot pressure on its capacity and additionally lower pricing also hurts the invest ability when it wants to meet the capacity shortage. In reality, this really happens because at the present most people feel China Unicom just generates poor quality, totally different from the condition when it newly introduced mobile service in the market.

Scenario 2.3: Preferential construction cost

(set the Unit Cost of Capacity2 to be 4000, 20% below that of operator1)

(the second run is base run)

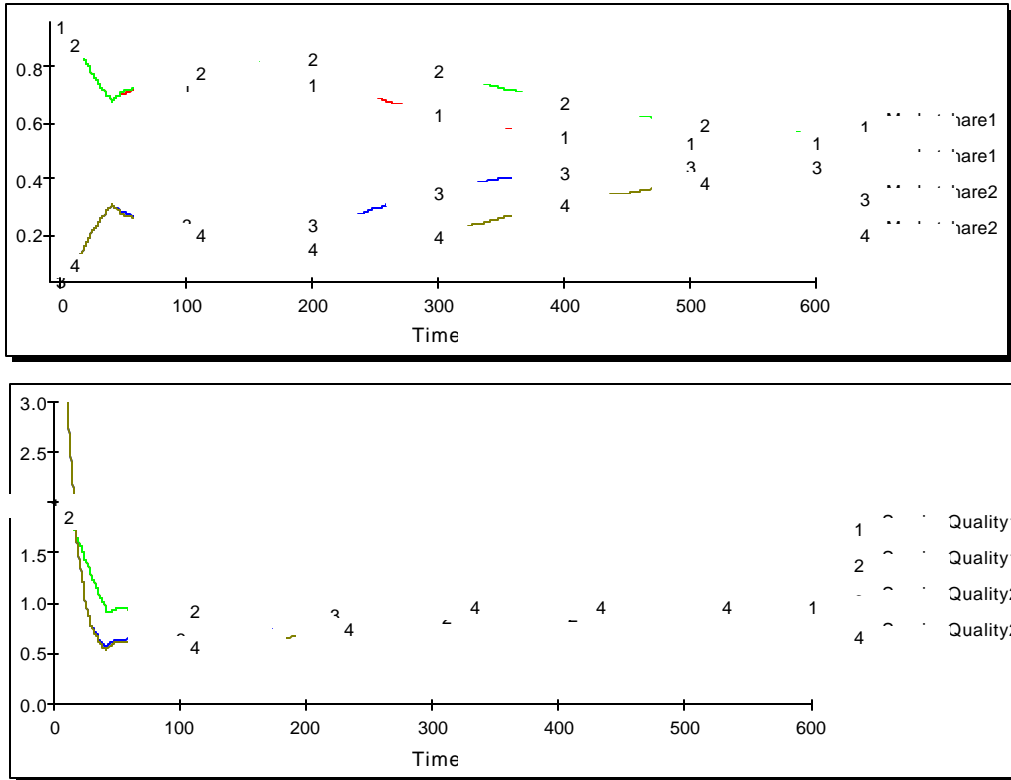


Figure 9: Preferential construction cost

We can see from the figure above, as compared with base run, operator2's performance is nearly the same in phase1, but in phase2, it really gets benefit from lower construction cost of capacity. This increases the strength of invest ability for it, so operator2 now can release the pressure from the booming subscriber at the beginning quite better than in former cases.

Scenario 2.4: Roaming service transfer

(From month 12, 20% of operator2's subscriber were starting to generate pressure on operator1's capacity rather than on operator2.)

(the second run is base run)

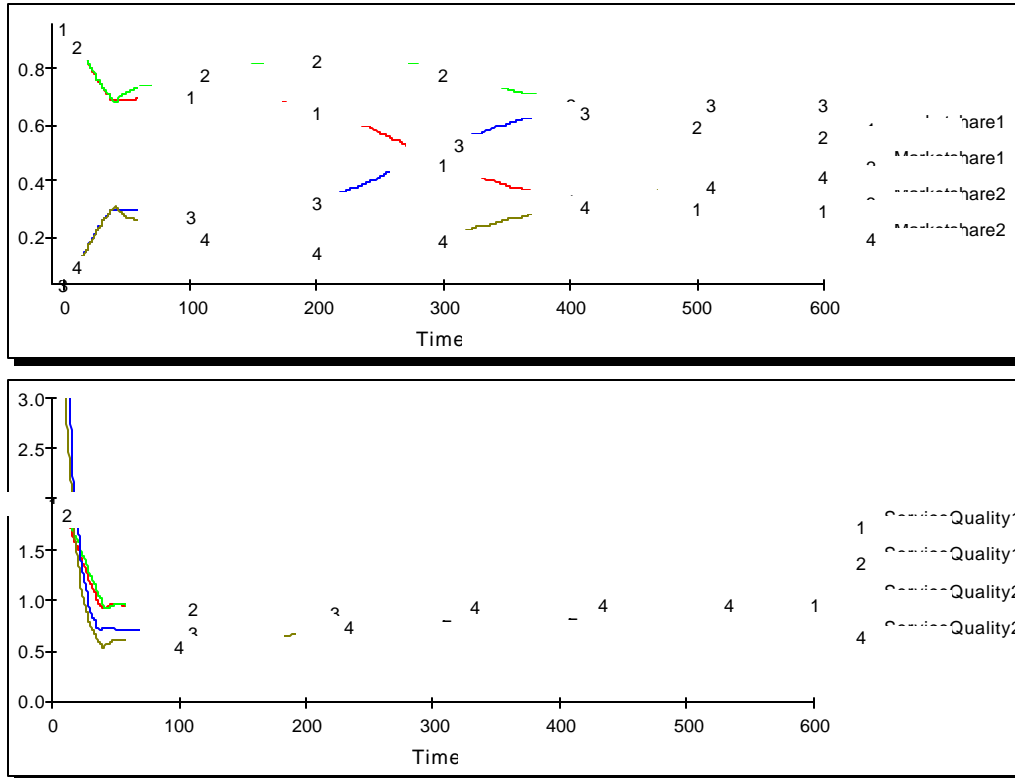


Figure 10: Roaming service transfer

Compared with lower construction cost, this preferential policy has stronger effect on improving operator2's competitive status in longer term: in the second phase, operator2 has reversed the trend. That is because from month 12, new subscribers choosing operator2 do not only generate pressure on itself, 20% of them will impose pressure on its rival too. So it is easier for operator2 to get out of the quality trouble after the 1st phase's booming. Meanwhile, now operator2 can enjoy more subscribers but only incur less capacity shortage, which is helpful to its revenue accumulation and later taking the leadership before the market went saturated.

Scenario 2.5: Current situation (combination of above effects)

(Unit price₂=0.85, Unit cost for construction₂=4000 and from month 12, 20% roaming service transfer.)

(second run is base run)

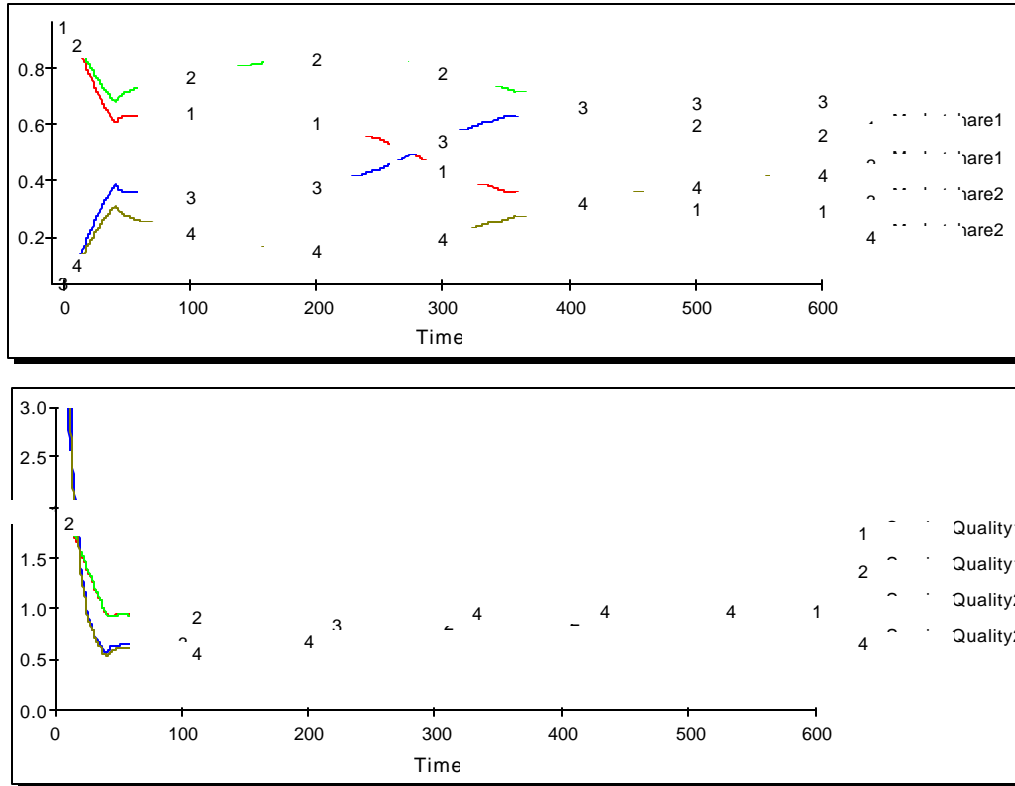


Figure 11: Current situation (combined effects)

The figure above is the result of combined effect of operator2's advantages. In phase1, operator2 attracts more subscribers because of its lower price and gets many switches from operator1 because of higher quality. In longer term, its invest ability hurt from low-price will be offset by lower cost of construction, so its behavior is very similar to the last scenario. Roaming service transfer policy influentially affects the behavior.

5.3 Scenario 3: More active construction policy

How can our client then respond to this unattractive future of rivalry? If we are standing on the present time point, which is the 48 months after starting the simulation, we can change the construction policy taken by our client.

In this scenario, we just introduce another variable for operator1, called Proactive Build Policy1= $\text{MAX}(\text{BuildCapability1}, \text{DesiredBuilding1})$. Operator1 adopted this policy after 48 month, that is, it supplants the Reactive Build Policy1 in 48 month, which takes the minimum of Build Capability and Desired Building. That means as long as it has any invest ability, it will invest on capacity even if there is no capacity shortage at all, and if the invest budget is not enough to meet the shortage, operator1 can from now on ask the state-owned bank for a loan. Because of its state-ownership, there will be no problem to get a loan even if it is heavily debted. And if it is in debt, the revenue incoming this month will go to repay the loan directly and not form the invest ability for this month.

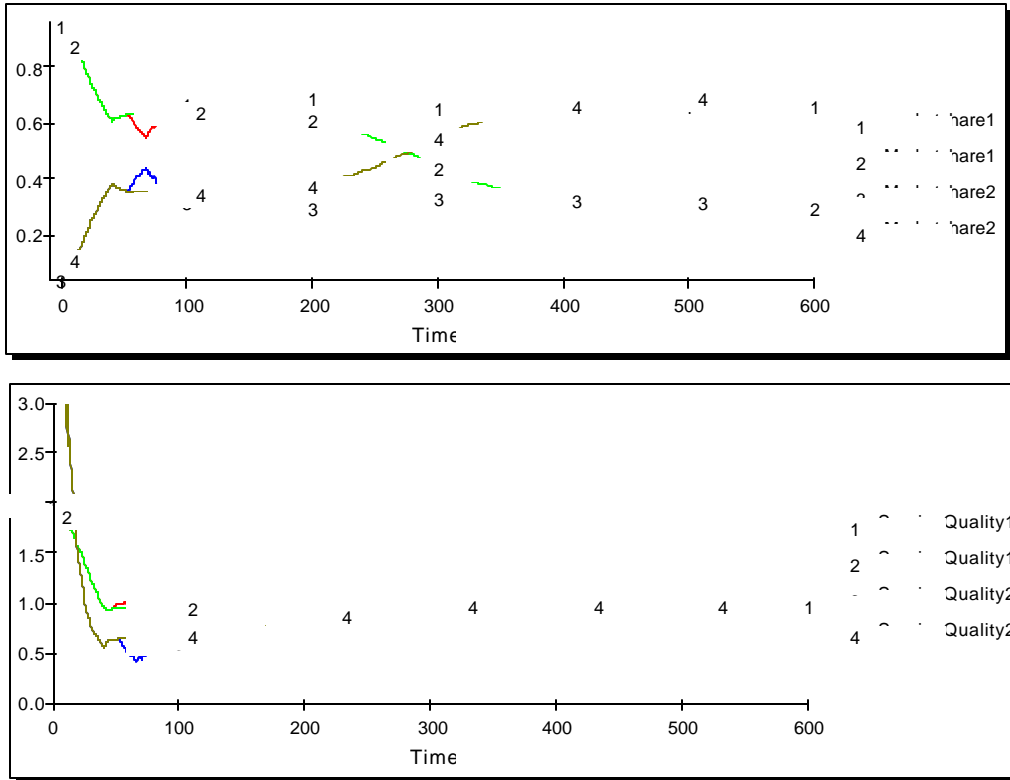


Figure 12: Proactive building policy1 by operator1

We can see, if our client adopted proactive building policy on its capacity construction from month 48, it will reverse the situation in the long run. And for a very long time, its marketshare will keep at a certain level (67%). This is because the availability of loan increases our client's invest ability. In long run, no matter how big pressure it has, it can release it by using the loan.

But we can also see, in some 10 months after the adoption of this aggressive construction policy, marketshare of operator2 surprisingly increases, the peak of it is even higher than under current situation. The reason behind that is our assumption made here: only if both operators' perceived quality is below 1, people will quit the service and leave the market at a certain rate. But if there is one operator provide service quality above 1, subscribers with another operator will not quit but just wait to see if the sound quality is durable, and switch to enjoy that quality gradually. So after operator1 adopted proactive construction policy, those with operator2 will not so hurry to leave the market but to choose to wait for a while to decide if switch or leave. That is the reason for the short-term negative effect for the proactive building policy.

In reality, our client can increase its invest ability not only by asking for a loan, but also from the compensation fees which is paid by its rival for the roaming service transfer. Or it can just increase its percentage of revenue for investment on capacity, the resulting trend will be changed too.

(set the percentage of revenue for investment1=0.5, which is two times and a half than rival.)

(second run is current situation)

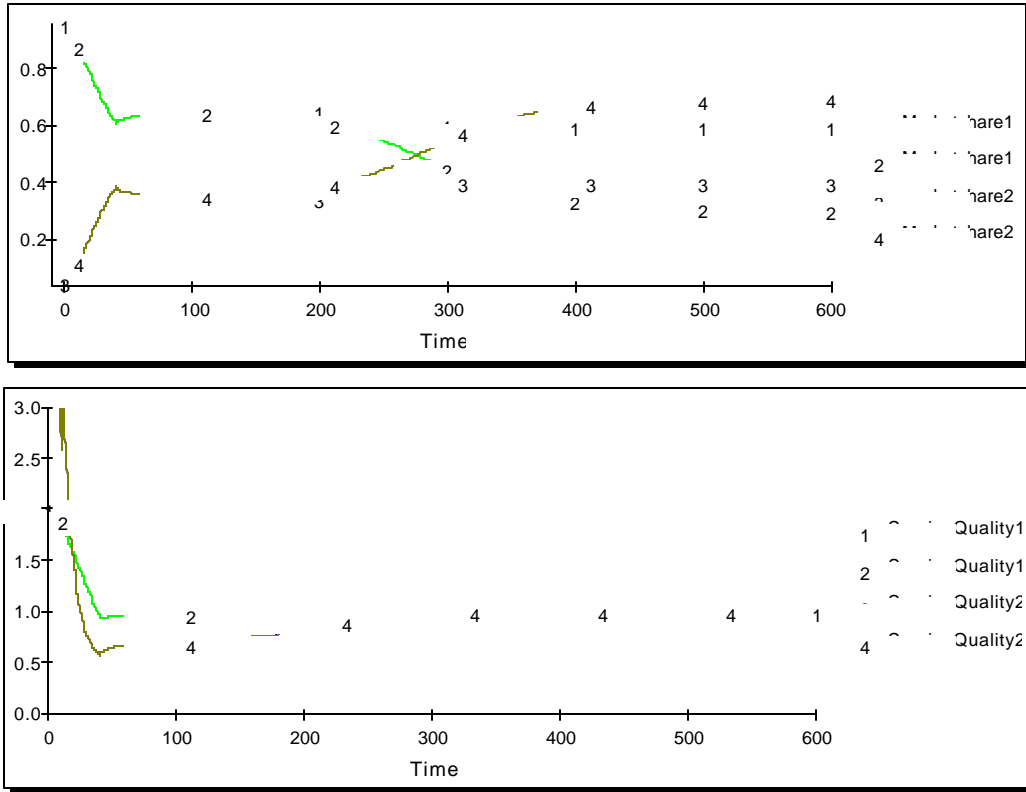


Figure 13: Proactive building policy2 by operator1

6. Major findings and results

The purpose of the project is to investigate the cause of current rivalry pattern in Chinese Mobile Service Industry, and, based on the understanding of the problem and assumption of boundary, to develop a proper policy for our client to solve the problem.

After experiencing a process from identifying problems at the beginning, building and testing a model, to analyzing the behaviour and developing policy, we have deepened our understanding of the whole issue and finally come to the following conclusions with proper confidence:

First, what lead to the increasing of Unicom’s market share are the combined effects of its initial higher quality, lower pricing, lower construction cost and roaming service transfer. Among them, initial higher quality only generates very short-term effects because its abundant capacity will quickly be fully utilized with the increasing market. Lower pricing slanting policy regulated by the government generates a better-before-worse effect on Unicom’s competitiveness and it only can help Unicom attract subscribers aggressively in the short run. In the longer run, it just hurts Unicom’s invest ability which is essential to release the pressure brought by the booming subscribers. But in this case, low-pricing’s longer term negative effect will be somewhat offset by Unicom’s lower construction cost, which improves invest ability. So the very influential factor affecting the rivalry pattern in longer run is the roaming service transfer policy. It will lead Unicom to even dominate the market in some twenty years.

Second, there’s an obvious market expansion and service quality improvement in mobile

service industry of China with the competition brought by Unicom. And although in short run, China Mobile will lose some new recruitment to Unicom, this actually lets China Mobile accumulate subscriber without its quality dropping so quickly, so that the revenue can be accumulated more stably, from which China Mobile really benefit in the long run.

Third, China Mobile can react to this by taking more active building policies. But of course, this should be balanced with other operations in China Mobile, it may think if these money is invested on R&D, it will boost the attractiveness more and attract the subscriber more than if it is used in improving the exchange quality. In reality, our client must have this concern, but it is out of the boundary of this model.

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