博士論文

A Game-theoretic Analysis of Subsidy Effects on New Technology Development: A Case of Internet of Vehicles

（新技術開発における補助金の影響についてのゲーム理論的分析：Internet of Vehicles を事例として）

朱 哲岐

Ph.D. Dissertation

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Abstract

In this research, we aim to clarify the subsidy on new technology development, especially for the technologies with multiple-attributes like Internet of vehicle (IoV). Since customers choose their preferable technology based on some attractive attributes and its corresponding price instead of all attributes, taking each attribute and its corresponding subsidy into account separately can make a clear understanding that how subsidy of each attribute affects the technology development as a whole. Therefore, this dissertation focus on answering one question that how subsidy of each attribute affects the price of technology and its attribute technology level according to the structure of customers' willingness to pay (WTP). To well illustrate this issue, we also conducted a case study in the auto field in China. The net contribution of this dissertation is analyzing the subsidy effect on technology development by taking technology attributes and customers' WTP into account. This dissertation is structured into six chapters.

First, we emphasize the importance of technology development and the trend of the vehicle industry. Given the outline of the Chinese government subsidy policy on technology development especially on the hi-tech product and the policies from central government to local government, we can fully figure out that Chinese manufacturing has changed its strategy from quantity to quality. In order to fulfill this strategy, the subsidy is the most frequent tool to support the industry directly. Then we aimed to explore the customer preference of IoV attributes and their corresponding technologies since the technology of IoV consists of seven attributes in common by conjoint analysis and WTP distribution of top three attributes. In terms of related technologies of the top three attributes, we conducted two expert interviews by semi-structured form. We found that vehicle component, software and communication technologies were most related to the attributes of safety, well-being and moving management respectively.

Turning into the game model part, for the model part, to reveal the early stage of technology development, a simple model of subsidy effect on new technology development with one attribute and fixed technology level has been put forward in chapter four. This is a sequential game among manufacturers, customers, and government and consists of two manufacturers, one government and a set of customers whose WTP of IoV follow a uniform distribution. By solving the game, an analytical solution has been calculated to derive the Nash equilibrium. In this model, we found the government's subsidy had a positive effect on product promotion within some range. When beyond some limitations, the positive effects of extra subsidy would decrease, especially for the situation that the market is fully occupied.

Finally, the general model of subsidy effect on new technology development with multiple-attributes and changeable technology level. In this chapter, the decision variables of manufacturers are not only the price but also the technology level of each attribute. The decision happens simultaneously between the two manufacturers. Differential the decision variables by subsidy and assumption of second order conditions, we found under certain conditions, increasing subsidy can promote the technology level and price. In the case study of general game, according to the real data in China, the result shows, under the current situation, the government would not give any subsidy to the IoV industry. And we continued to discuss the possibility of subsidy initiation, the result shows that the government would begin to give subsidy only two conditions are satisfied. One is that the attribute should bring enough social benefit per unit

since the government subsidy would decrease the government utilities. Increasing the social benefit of a product can offset the subsidy cost. The other is that the cost of the attribute should be bigger enough which might be over the maximum WTP of the customer, which means the government can only give subsidy to the attribute which is not profitable.

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1. Introduction

1.1. The Background

1.1.1. Issues about New Technology Development

Every day, hundreds of new technologies have been revealing in the world and also many of them would be commercialized afterward. But technology adoption is a risk-taking behavior, particularly for companies who are still building market presence and have not established a trusted brand yet. This situation mostly happens in some fresh industries like Internet of Vehicles (IoV) (Chen, 2017). In this industry, policies are not mature at this moment, the government also try to understand what the customer preference and technology of the industry are and what will bring to society. So as the manufactures, they also should take the customers' acceptance into account, because there is no other relevant technology before.

Indeed, a new technology development strategy is always a hot topic along with the life of human being. There are many threats and opportunities for new technology development. A good strategy of development would survive technology, even the company itself. Jobs adopted the iMac at the right time, right place and right technology attribute, which prevented Apple Co. from bankrupt (Isaacson, 2011). By contrary, Kodak in figure 1, a past famous film producer, kept adopting the technology on roll film, which was no longer a key attribute of photograph and buried this century-old firm directly at last (Collins, 1990). Constant technological change simultaneously creates threats to established business models, while also creating opportunities for novel service offerings (Lai, 2017). As Bronwyn H.Hall and Beethiska Khan mentioned in their working papers (Bronwyn H. Hall, 2003), an understanding of the factors affecting this choice (adoption cost and invention benefit) is essential both for economists studying the determinants of growth and for the creators and producers of such technologies.

Figure 1.Failure strategy of Kodak's technology development

Some hints for the technology development strategies are being hidden behind societies. For instance, certain fast growth markets have demonstrated that the technology should be developed quickly. Taking an example of Africa's adoption of cell phones, it is seen that penetration of cell phone usage in some African cities exceeds 100 percent driven by the need for information, coupled with Africa's rapid urbanization which is driving dramatic changes in the way people share and consume information and use it to improve their standards of living (Wu, 2018).

However, that is just only the hint from markets in reality but does not provide any theoretically fundamental mechanism. From an academic point of view, current researchers are also trying to figure out the relevant factors that are possible to affect the success of new technology development. Razmak (Razmak, Belanger, & Farhan, 2018) has developed a method called techno-humanism model (THM) to test the factors in the hypothesis that would affect the new technology development. Zhanyuan Lu (zhanyuan lu, 2018) use the test fields to simulate the effect of new technology development and making some comparisons between the situation before and after the new technology adoption. Bakhtiari (Bakhtiari, 2018) collected the national process of carbon price around the world and make a comparison among each other and make a summary on that. At last, he gave some possibilities for each situation if carbon pricing is applied in Australia.

Nowadays, especially in the booming Internet days, a way of development of new technologies seems to become different as you can see it on AppStore where anybody can upload new apps through the internet. But it is not so easy to be successful as stated before. Though many researchers try to figure out what happened, most of them use a qualitative model to explain it. Although mathematical models by economic theory have been studied especially in the field of industrial organization, for instance, the number of them is not so many and also their views are limited in some specific area. It could be said that most of the preceding studies focus on an analytic point of view, but not on the synthetic point of view. Accordingly, they cannot provide any theoretical mechanism about how to create or design new technologies especially in the current Internet booming times.

Besides the technology development itself, the government also makes contributions during technology development. These days, high technology has been fully supported by the Chinese government. Since 1978, the Chinese economy has been developed quickly and now it has met the conditions that the structure of industries in China should be adjusted and optimized. The government has changed the traditional development concepts to the more suitable one that can bring Chinese society into a high-tech country. Since the hi-tech industry appeared later than in other developed countries, there is still a big gap. That is why at the beginning of the hi-tech industry, the investment from the education department is not enough. The connection between industry and education is not smooth, which result in a lack of core technology and quality. The product at the beginning stage is lack of competitiveness. Indeed, the core of hi-tech is the R&D cost. Only innovation can bring the competitiveness of the product. In order to realize innovation, companies increase its R&D, and in the meantime, the government is China has established many policies of tax or subsidy. These financial-supportive policies could encourage motivation for innovation.

After entering the 21st century, hi-tech industries develop quickly in China and they are in a golden time. In 2007 the central government published the outline of eleventh "five years

planning", they put forward eight categories of hi-tech industries and in twelve "five years planning" R&D cost in hi-tech industries have been emphasized and pushed by the related government office to promote these areas. Also, they made a target of 18% growing in CAGR. With the help of government policy, the hi-tech industry is becoming a support of Chinese economic, especially for 2016, 'made in China 2025' has been a hi-tech target in Chinese hi-tech industries.

Within the recent five years, in terms of benefit from the big market and also updating the industry structure, the Chinese government has proposed many ambitious plans on the hi-tech relevant industries, especially on artificial intelligence and advanced manufacturing. In May 2015, the Chinese government has put forward a plan called 'made in China 2025 strategy'. This is a really long strategy that contains many industries, especially targeting in the manufacturing industry. For example in this plan, the Chinese government gives a timeline of the AI industry. It will push the AI industry to accelerate quickly. Over 12 national policies have been published to promote the advanced manufacturing industry. The recent government policy on advanced manufacturing that IoV belongs to is listed in figure 2 below. Details are in Appendix C.

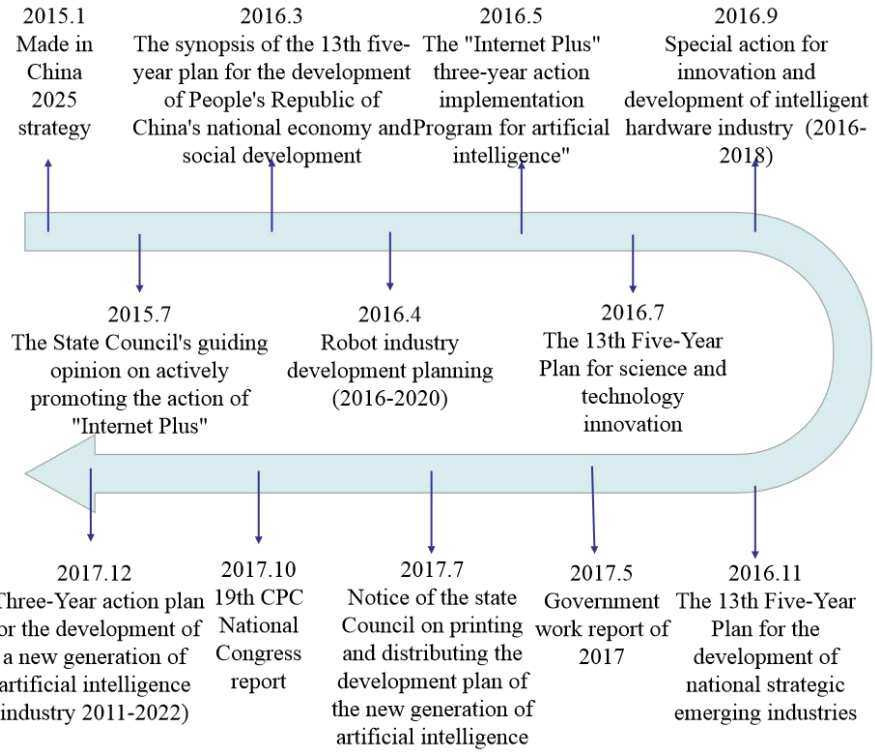


Figure 2. Time line of Chinese State policy on advanced manufacturing

Besides the central government, local governments also established many policies to promote technology development. Guizhou, one of the southwest Provinces in China, proposed a three years plan which would promote robotics, smart home, intelligent terminal, intelligent monitoring, intelligent medical treatment, and other fields. To accelerate the research and breakthrough of artificial intelligence core technology, they foster and develop the new industry of artificial intelligence further. In the northeast of China, where it is usually seen as the base of traditional industry, Jilin Province has implementation advice on actively promoting the action of "Internet plus" in Jilin Province and they give the guidance of this plan. It shows to promote the extensive application of artificial intelligence in the fields of smart home, intelligent terminals,

intelligent automobiles and robots, for which Jilin Province would give financial aids. A rich province like Shanghai makes more specific plans on how to make the promotion of advanced technologies. By 2020, the connotation of artificial intelligence application will be deepened. 6 or so artificial intelligence innovative application demonstration areas will be created. 60 or so artificial intelligence deep application scenes will be formed. More than 100 artificial intelligence application demonstration projects will be built. The research and development capabilities of frontier theories and key technologies will be significantly improved, reaching the global advanced level in some key areas. 10 or so artificial intelligence innovation platforms will be built. 5 or so artificial intelligence characteristic industrial agglomeration areas will be built. To cultivate about 10 artificial intelligence innovation benchmark enterprises. Artificial intelligence key industry scale will exceed 100 billion yuan. Other local government all around China has published the corresponding policy which fit for their own local characters, especially for the rich Provence. From a general point of view, they all publish their own 3 years or five years plan on the AI industry which is listed in figure 3. Details are in Appendix C.

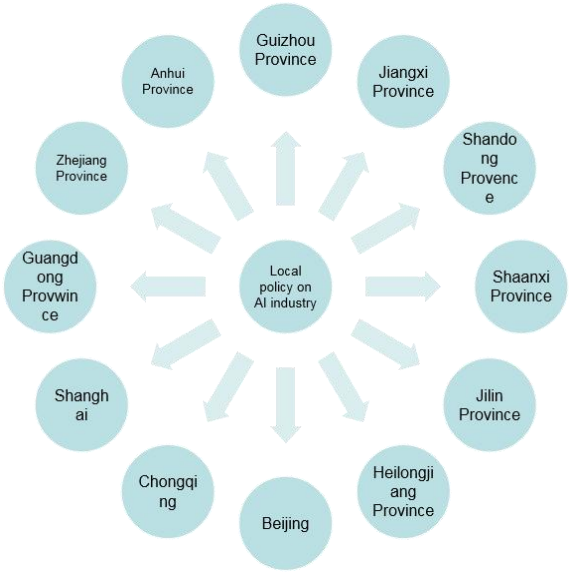


Figure 3.Local policy on technology development

1.1.2. Subsidy Policy

In China, the subsidy is a huge system with a large amount of money. It happens from the manufacturer stage to consume stage during the life cycle of a product. Since the disordered subsidy would destroy economic improvement, some disadvantages of subsidy have begun to happen these years. For society, these situations may not be rational and be a burden of State. Therefore the standardization of subsidy is quite important.

Currently, several drawbacks of subsidy in China are mainly considered to arise from the lack of understanding of subsidy (Wang, 2014). For a long time, in China, the subsidy is seen as political leverage instead of an economic tool. During that period, the subsidy policy has been abused and affected the financial revenue of the government, especially for the local government. Some specific time, the load went over tolerance of State. Also, the officer is misunderstanding the position of subsidy. Indeed, the subsidy should be used when there is a big problem in the economy and some industries should be promoted at the right time. Therefore, the subsidy

should be used for keeping society stable. Actually, as a redistributed financial tool, it should be used for balancing society. However, accompanying the increasing economic development these days, range of subsidy, types of subsidy, the quantity of subsidy have been increasing heavily, which is becoming a big burden for the Chinese government.

In terms of the management of subsidy, it is also not comprehensive. The system of subsidy management is not clear enough like the subject of receivers and the channel of subsidy. This results in the abused subsidies: for example, the local government may increase the items of subsidy freely. The same project can get many types of subsidy at the same time. This is a big cost of resources. This after payment management is also a weakness of the Chinese government, sometimes government only make the payment without monitoring the following situations, which results in many wasteful subsidies. Even when this waste has been revealed, since there is no scientific management system for this, some illegal subsidies also cannot be published.

However, subsidy indeed has some promotions in R&D cost. In terms of promotion of subsidy on the R&D, many successful cases around the world have proved the usage. The most famous one would be the Samsung Co. with the help of the Korean government; it expanded its LED industry during a hard time. After that, Korean companies have occupied the LED industry around the world. Comparing with the national hi-tech companies, private companies are more likely to focus on the R&D, and therefore they are more sensitive to government subsidies. That is why the government's subsidy is more useful for private companies in China and private companies have more freedom in technology development direction. The creative output would bring private companies more benefit when the input resources are the same as the state-owned companies.

1.1.3. Current Status of Internet of Vehicle Industry

Accompanying the civilize and the promotion of daily life, the types and number of vehicles are increasing heavily such as a private car, public car, taxi, bus and so on. The same with the communication technology moving from 2G to 4G currently, in the near future 5G would be the leader period. However, increasing convenience also resulted in many issues: for example, traffic jams, vehicle securities, and etc. These days, Nations from all over the world began to discuss the transportation problems and it has been raised to key problems all around the world. The speed, direction, position of vehicles nearby and other information like real-time weather information would help the driver respond efficiently. How to manage and arrange this information and how to output a correct response is quite important.

On the other hand, in terms of technology, 3GPP has released the standard of Internet of vehicle (Vehicle-to Everything, V2X) in Release 15 (report, 2019). Also, other standards have been established like vehicle to vehicle, vehicle to infrastructure, vehicle to the pedestrian. According to the comments of 3GPP, V2V communication technology is based on D2D (Device to Device) technology. In October 2015, the research topic called LTE V2X support structure was set in 3GPP. Compared with the traditional grid, V2X grid has two popular advantages: 1. the lower cost and easy operational system, and 2. the V2X can support the short distance information transmission over vehicles in the smart transportation system since the biggest share of information in this situation is position information.

According to the technologies maturity and booming market, Smart Way and Smart Car are two

main systems which the Japanese government put forward to make internet application in the vehicle (JSCA, 2015). Smart Way has been established in 1999 and applied in reality in 2002. Smart Car can be taken as the advanced Smart Way program. It is expected as an auto or semi-auto driving guide. In Europe, the most basic application of the vehicle net is called Cooperative Vehicle-Infrastructure Systems (Clare, 2018), this system has been initiated in 2006, it planned to apply to the infrastructure in Euro after its tests in Germany. The same as America, in 2010, the government of America starts a program called IntelliDriveSM (Wallace, 2010). It aimed to build the net between vehicle and vehicle, vehicle and construction among the road. In case, it can improve transportation effective.

Besides Japan, in China, the Internet of Vehicles (IoV), as one of the applications of the Internet of things, is booming quickly these days. It is a really fantastic technology which can change the life of human beings. It offers a fresh idea about the vehicle. Previously, the vehicle is considered as the moving tool from one place to another. That is only the past because of a non-internet vehicle cannot talk with others. Like another internet of things applications, things are inserted into the internet which means it is smart ones. In this future, you can have a meeting in your vehicle, play game in your vehicle, sleeping or other daily life in your vehicle. The vehicle is not the meaning of transport and it is a private moving space instead. That is similar to the concept of e-Palette by Toyota (Sheehan, 2018).

From the view of the state, the Chinese government published a five-year plan 'the development of Chinese internet of vehicle industry strategy and analysis'. In it, the statistics show the penetrability of internet of vehicle in 2013 is only 6%. However, it has been raised up to 9.3% within 2 years. However, the beginning of Chinese IoV is very late. In 2010, a seminar on information transmission in Wuhan has initiated. This seminar gave a brief guide of the importance of communication technology in transportation fields and proposed the conception of IoV for the first time. After that, IoV has been listed in the twelfth five-year projects as the crucial key project.

Not only this attracts the interests of the government, but also some commercial institution also has a good expect on IoV. In a report, conducted by Price Waterhouse Coopers revealed that in 2020, the potential market of IoV would be over 115.2 Billion Euro all around the world. Even in China, this share would be over 5.9 billion Euros. It is really a huge market which needs us to develop into.

Not only from the general view of IoV industry, but also from the specific industry which would support the development of IoV like the communication industry, Ministry of industry and information technology has established a policy called "Guidelines for the construction of a national industrial standard system for automobile networking (intelligent networked automobile)". By 2025, the system will form an intelligent networked automobile standard system that is capable of supporting high-level autonomous driving. More than 100 intelligent networked automobile standards will be developed, covering intelligent automatic control, the cooperative decision-making technology of network connection, and the technical requirements and evaluation methods related to the performance of autonomous driving function in typical scenarios to promote the development of integration of "Intelligent + networking" connection for intelligent automobile and comprehensive promotion and popularization of technology and products. Accompanying with this policy, Ministry of Industry and Information Technology also put forward a corresponding three-year strategy. By 2020, more than 10 key enterprises will

complete the industrial Internet demonstration construction covering the whole production process, and the networked automobile network facilities in the key region will be initially completed. Chinese government establishes the ambitious plan to support the relevant industries. Not only the Ministry of Industry and Information Technology but also other policymakers made relevant policies to develop the IoV relevant technologies. Some important policies are listed in figure 4 as followed. Details are in Appendix C.

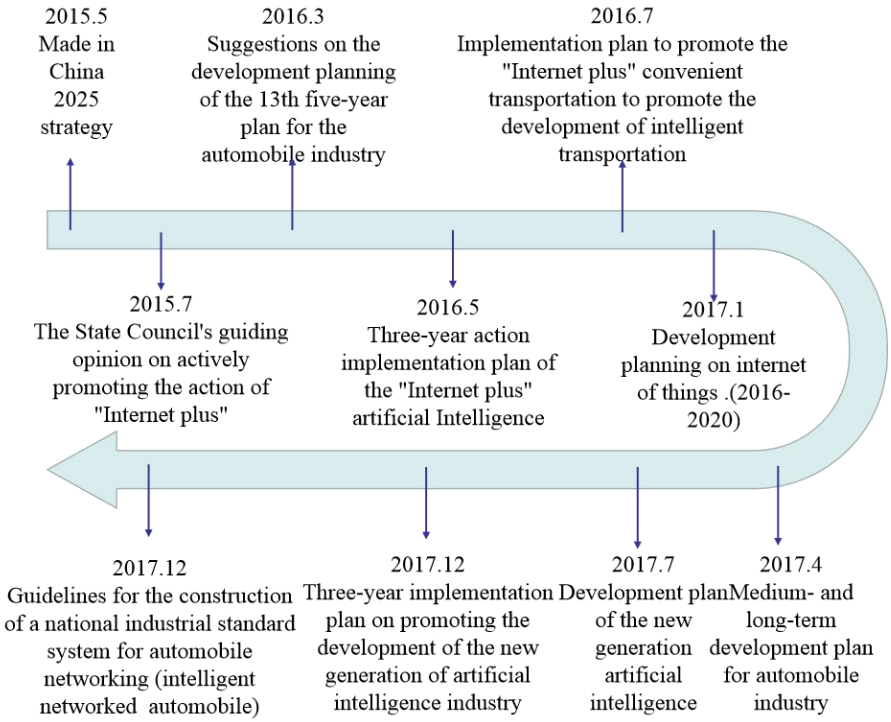


Figure 4.Time line of IoV relevant industry policy

Similar to the industry promotion plan, followed with the central government policies, local government also established several plans to support the local IoV industry. Hubei Province, where the No.2 Vehicle Company in China is located, has proposed its 13th five-year plan development and construction planning of innovation ability of Hubei province. In this plan, it shows the next five years, government Hubei would mainly focus on developing the fusion technology of vehicle and network information and accelerating the construction of the national base of innovation demonstration area of intelligent networked automobile and intelligent transportation. Relying on the Wuhan national economic and technological development zone of networked automobile demonstration area, the industry cultivates customer preference and technology where intelligent automobile develop integrated with intelligent transportation. Besides, Sichuan Province also proposed a Guiding opinion on the development of the 13th five-year plan auto industry in Sichuan province. It shows three main targets of industry areas. First is speeding up to promote the demonstration of intelligent networked car. The second is taking the opportunity of Sino-German cooperation in building test and verification pilot demonstration of intelligent networked automobile and vehicle networking standards. The last one is vigorously promoting the first intelligent networked car and car networking promotion demonstration. Other Provinces also have its own plan on IoV promotion which is listed in figure 5 below. For the details, please see Appendix C.

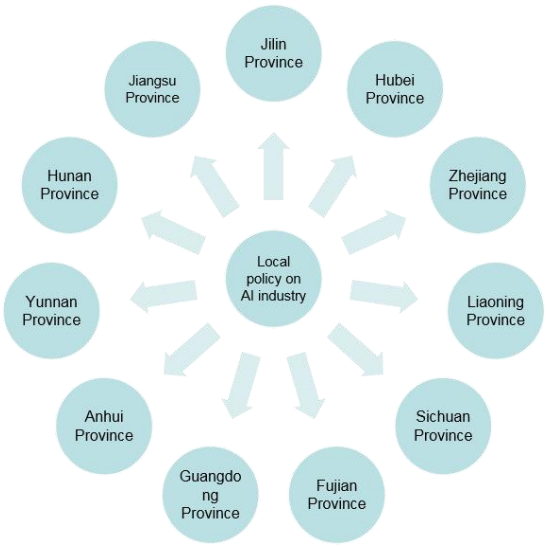


Figure 5. Local policy on IoV relevant industry

Why IoV is so hot? Actually, from a general point, IoV can reform the traffic. Because of the booming population and the density of vehicles in China, the share of an unconscious traffic accident is roaming up. Like Toyota, the concept of e-pallet would drive a future situation that in the future, auto-driving would not take place of traditional driving at all. They would both exist for some time. How to go through that situation smoothly is the key technical problem for an IoV. As statistics shows in figure 6 and 7, over 94% of traffic accidents result from drivers and other reasons are only occupied 6%. And within these accidents, unconscious driving takes 42.67% share in China.

Figure 6.The traffic accident reasons share

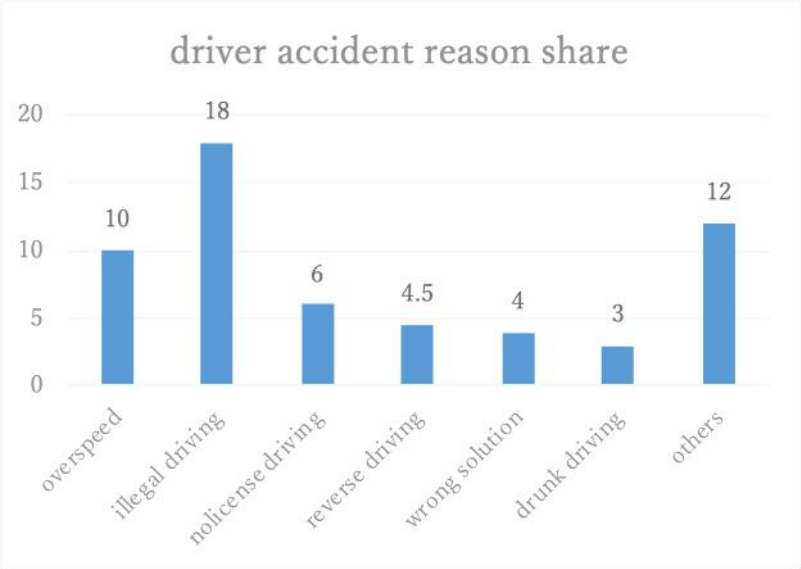


Figure 7.The driver accident reason

IoV would decrease the possibility of a traffic accident by taking actions before risks happen since it can receive all information from all the surroundings including road information, nearby vehicles and all other universal information. By calculating all these messages, IoV would send a signal to the active component and alarm the driver at the same time. By this process, the probabilities of the accident would decrease.

In terms of entertainment, from figure 8 and 9, we know application of IoV would improve the entertainment function of the vehicle, which can help the company increasing the selling. In the recent survey, the output of IoV, LED display, has been the top considerations among the customers and the preference of the size is going to bigger and bigger. IoV would back up LED display since in the future, all the information would be collected by IoV and delivered to a central screen that called here LED display. As the materials of this system, IoV plays a crucial role.

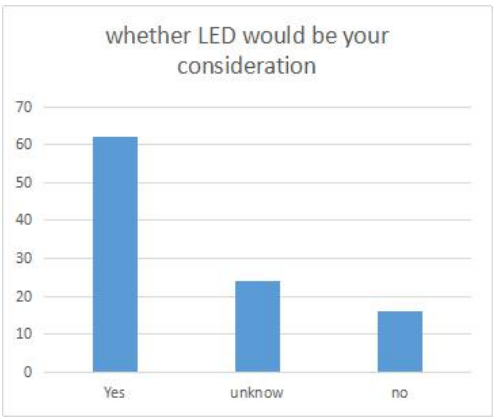


Figure 8.The survey whether LED would be your consideration when you buy a car(%)

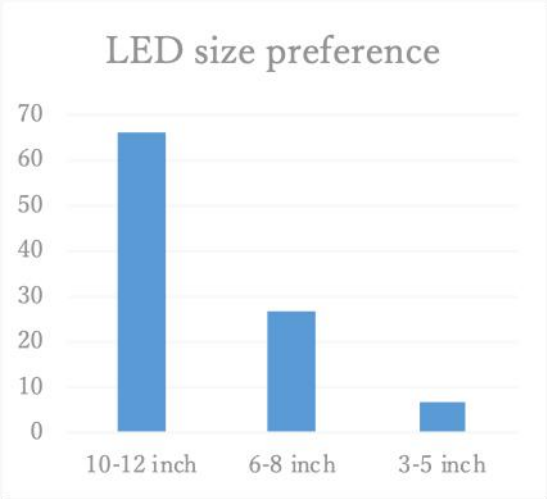


Figure 9.The LED size preference(%)

Since IoV is so helpful to us, in order to find out the customer preference and technology of this key technology, what is the key function customers mostly focus? What is the core technology manufacturer should overcome? How did the Chinese government push this technology? What would happen if one of these players changes their mind? What is the best response of each side? All these questions are related to this technology development. Anyone of these questions would result in unsuccessful business.

1.2. The Objective of Research

As it is valuable to go in deep with the IoV relevant topic as stated above, in this research, we aim to clarify the subsidy effect on new technology development with the game-theoretic method, especially for the technologies with multiple-attributes like Internet of vehicle (IoV). A game theoretic model could reveal the interdependent mechanism among government, manufacturer, and customers especially under some subsidy scheme.

To be more specific, since customers choose their preferable technology based on some attractive attributes and its corresponding price instead of all attributes, clarifying the customers' preference and their corresponding willingness to pay (WTP) with questionnaire method becomes the core of customer part.

In terms of manufacturers' side, so far there exist many kinds of technologies related to IoV. Therefore, we aim to reveal the relationship between a certain attribute and corresponding technology by expert interview to make a mapping from attribute (view of the customer) to technology (view of the manufacturer).

Finally, using the knowledge obtained by consumers' preference investigation and the expert interviews, subsidy effects on manufacturer's and customer's decisions is revealed by building a game theoretic model which represents the interdependent decision-making situation among government, manufacturers, and customers.

1.3. Methodologies

According to the objective, the corresponding research methods in this research are listed below:

A. As mentioned before, in this research, the customer preference on technologies of IoV is revealed. As one of stakeholders, customers play an important role in the IoV ecosystem. To collect the customer preference data, questionnaires is conducted to reveal the reflection of customers on the IoV product price and also its qualitative preference data are collected by the questionnaires.

B. After the customers' data collection, the preference rank would be worked out by conjoint analysis. Part utility has been calculated by conjoint analysis to find out the importance of attributes of products among customers and willingness to pay is revealed as well.

C. Besides customers, manufacturers also make contributions in technology promotion process. In order to check the core technology of IoV, expert interviews are conducted in this research.

D. Finally, a game theory model is built to analyze the subsidy effect on IoV product. Taking the players such as manufacturers, government, and customers into account, some fundamental models are constructed, in which include the factors such as cost, subsidy, price, welfare and so on. First, a simple model with one attribute is built to find out the relationships among each other. Also the behavior of customers and manufacturers under government subsidy is discussed. Second, a more complicated model by adding more attributes is constructed. Preparing some scenarios, its mechanism is analyzed by deriving Nash equilibrium. In addition, the data obtained by the questionnaire is used to simulate the model in more real situations of IoV.

1.4. Structure of the Thesis

The remaining structure of this thesis is divided into four chapters:

Chapter 2 is literature review, which contains over 300 papers or books are checked during this research. The literature about IoV, game theory, new technology development and subsidy effect is reviewed to reveal the position of this research. In chapter 3, core technologies customer preference is clarified by questionnaire and expert interviews. Using conjoint analysis, willingness to pay that people actually have is elucidated. Then, in chapters 4 and 5, a game theoretical model is constructed to analyze the mechanism of technology adoption and effects of subsidy in IoV. Chapter 4 treats a simple model with two manufacturers, customers and one government, in which only one kind of technology attributes is considered. Chapter 5 addresses a more complicated game with more several attributes. In addition, case study is conducted. Finally, chapter 6 concludes. The structure is presented in figure 10.

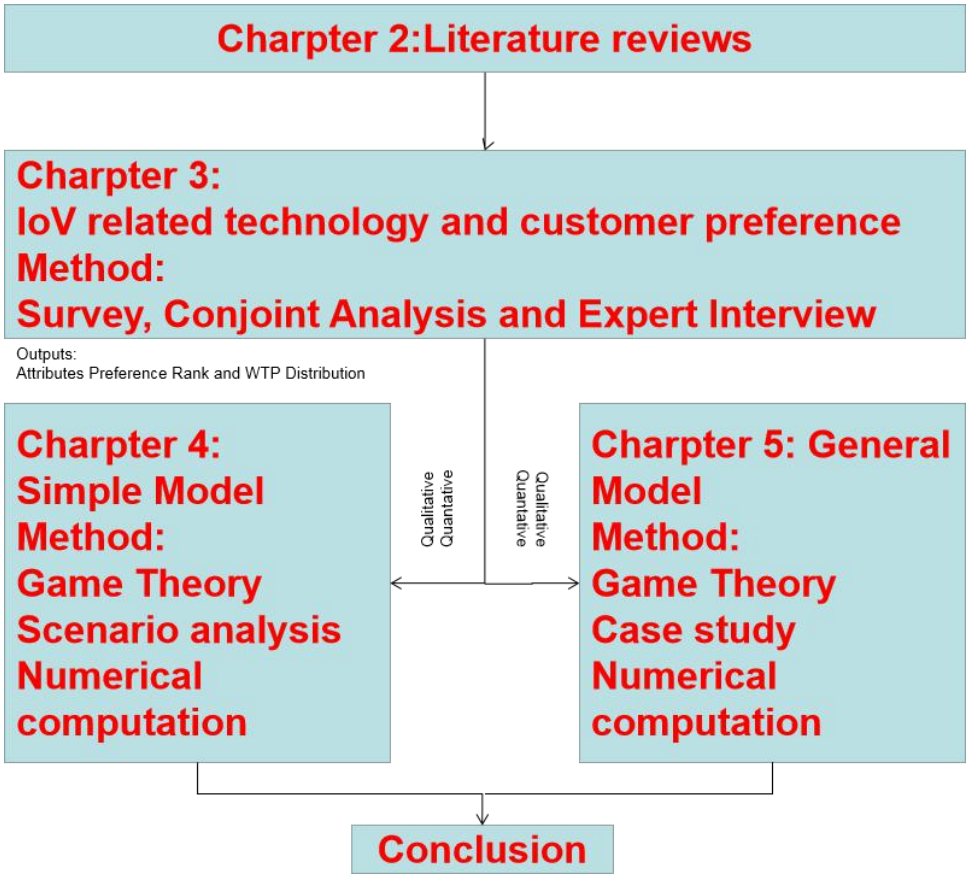


Figure 10.Dissertation structure

2. Related Literature

2.1. Technology of Internet of Vehicle (IoV)

In China, many experiments of IoV have been done during these years. A long-distance test for self-driving has been done on 16th April 2016. This test took place between Beijing and Chongqing, over 2000 kilometers. To finish this target, the vehicle passed all the goals including overtaking, channel changing, speed decreasing, U-turning and so on. In order to fulfill the situations, the implantation under different situations has also been tested like a tunnel.

Since Internet of vehicle is a fresh idea, not too many researches on the hardware side. Accurate vehicle location system needs three sub-components: data acquisition, data transmission and reception, data storage, and analysis. In order to satisfy these standards, a location system has been worked out (Jaco Prinsloo 2016). Weather and road condition determined the navigation path because IoT has been used as the transport of the GSM (Global System for Mobile communication) data.

Compare with the hardware, many researches focus on the frame of IoV, because as a special application of net, IoV needs a more quick and precise transition frame. A social internet of vehicles has been put forward and the corresponding vehicle design goals have been discussed (Leandros A.Maglaras 2016). Some key issues like security and the analysis method are also argued in the paper. After ETSI ITS scheme has been put forward, the application has never been tested before (Victor Sandonis 2016). Victor tested the architecture performance by inserting the internet. Different situations have been used like neighbor position prediction in this framework. In terms of security, a trust system among vehicles has been proposed (Shu Yang 2016). The definition of trust, the group clustering, and supervised method were all discussed in it. In order to combine the internet of things and vehicle together, the way that how to combine vehicle, IoT and cloud computing together has been argued (Juan Antonio Guerrero Ibanez 2015). Some challenges like government investment have also been mentioned.

Besides the IoV itself, the application based on IoV is the core of IoV. Whether the customer would accept IoV is depending on its application heavily. An algorithm of data collection of the vehicle by the Internet of things has been proposed (Liang Wei 2016). A process of the anti-collision system has also been described including data groping, data collection and path selection. A special Internet of vehicle has been discussed called E-health (Di Lin 2016). An algorithm has been put forward to deliver the Internet of vehicle resources since some device (e.g. electromagnetic interference) may malfunction the medical device. An algorithm that is used to avoid congestion has been put forward (Jiafu Wan 2016). The IoT has been constructed among vehicles and infrastructure. The road information has been real-time updated. On the other hand, the data security code and decode algorithm have been put forward (Eun-Kyu Lee 2015). A dynamic attributed based encryption has been tested. Besides the theory establishment, Chang has tested the performance of the transmission contract (Chang-Heng Wang 2015).

To be natural, IoV is still a web application. Communication technologies should be one of its key technologies. In this field, there are thousands of papers working on this. Typically, the development of Internet of vehicle is based on the development of communication. As we know,

information transport is depended on the bandwidth speed and real-time heavily. If the application of IoV would be used in the future, like real-time data share, there would be huge information would be transformed. However, communication technology currently may not support all applications. In order to improve the performance of IoV, researchers are also focused on the development of communication technology. Konguvel.E from India (KonguveL.E 2018) took a survey on the FFT/IFFT processors for a next-generation telecommunication system. The result shows that the mixed-radix/higher-radix algorithm combined with Single-path Delay Commutator (SDC) architecture would be appropriated for massive MIMO in 5G. Gopi. R (Gopi.R 2017) has directly discussed the video storage security technology used in the vehicle under 5G. They took an experiment to test the emergency information transmission during the heavy load network and proposed a role-based access control (ERBAC) mechanism. Kobayashi (Kobayashi. K 2017) tried different frequency to deliver the message within the anechoic chamber by next-generation wireless communication terminal like 5g. They finally found that QZ level is -30 dB or less and miniaturization internal size of the chamber is S-X = 900mm. (Lota, Sun and Rappaport 2017) Lota, Jaswinder; Sun, Shu; Rappaport, Theodore S. put forward a two-level approach that enables millimeter ware mobile radio services be more reliable under 5g. The people in the communication field are keen on 5G-application technology most. Even though the IoV is the basic technology we would concern, communication technology is still the foundation.

On the other hand, the method used to reveal the research is also important besides the technology itself. An expert interview is the easiest operating and effective way that used by researchers to reveal the future product when the interviewees are not so confident in this field. The expert interview has been widely used as a prediction of future technology for a long time. It is very convenient and efficient. By other ways, the result may not relative and direct. Nancy Niedzielski (Niedzielski 2017) presents an interview with linguistics professor and it gave the details of the method of learning the language. Ozoguz (Ozoguz 2017) has interviewed an immigration officer and it showed the reason why German needs so large number of immigration. Besides the social or health field, an interview is also used in the engineering field to find the tendency of technology. Chang.YW and Hu.CM (Hu.CM 2017) interviewed the father of 3D transistors, Chenming Hu, and professor Hu told them the application of 3D transistors and some core technology that affect the 3D transistors. Abadir.M (Abadir.M 2017) interviewed the semiconductor pioneer, Wally Rhines, who predict the market of the future semiconductor and what technology may develop within 5 years according to the current semiconductor situation. Pransky. J and Choset. H (Choset.H 2017) interviewed the CTO of Advanced Robotics for Manufacturing Institute, Dr. Howie Choset and they discussed the challenges for a Ph.D. turned into the business market since Dr. Howie Choset is running a robot company now.

The technological similarity is a popular method to guide researchers or leaders by the technical side. In order to find out the key technology what the manufacturer wants to develop into, a two-step process has been put forward to reveal the future technology that may support the IoV directly in this dissertation. Indeed, there are millions of components or technologies that affect IoV directly. For a manufacturer, one cannot develop all the possible technologies. According to this, a better technology path will lead to efficient resource usage. The researchers used many ways to find out the technology path and core technology the company should develop. Xu and Yang (Xu.JH 2017) developed a clustering algorithm called auto-adaptive load balancing algorithm to balance the load of each node in the clustering process. Suzuki S (SUZUKI S 2017) has put

forward a method that involves analyzing a time series of publication dates for technical documents in the technology field. Kerzendorf.W.E (Kerzendorf.W.E 2017) has proposed the application of computer linguistics techniques on astronomy literature. He developed a tool to find similar articles purely based on text. Oh.G (Oh.G 2017) found that technology trends, which are calculated by their measurements, are similar to historical trends of technology under their method. Yan.BW and Luo.JX (Luo.JX 2017) has developed a method to minimize the effect of the ambiguity of linkage between different patents in the patent network.

2.2. Consumer's Preference with Conjoint Analysis

Conjoint analysis is a multiple-factor analysis method and is quite popular in customer preference revealing field. The multinomial logit model is introduced into analysis of the utility function and the data collection is based on choice-based conjoint analysis with several levels of options (Jing Li, 2016). Professors settle down the corresponding factor. A web-based questionnaire is conducted with 91 specialists by email (Jaap Fransen, 2016). A binary logit model is used to analyze the data to find out the part-worth utilities related to gout. A literature review of the conjoint analysis with its implication in the rheumatology filed has been put forward (Taylor, 2016). Not only for factor finding but also criteria defining are mentioned in his work. Online and interview-based questionnaires are used with manipulated photographed streets (Jelle Van Cauwenberg, 2016). The different factors with different levels are listed in the photograph to offer the situations participants would choose from. Willingness to pay and conjoint analysis are combined to test the attributes of meat consumption (S. Garcia-Torres, 2016). Ordinary least squares regression is used to estimate the part worth. Four types of research are conducted (Christofer Adrian, 2016). First, one is rating, given the specific attribute, and ask the respondent to scale with 7 points. The second is important, which gives an open question and let respondents scale its importance. The third one is paired, combined two or three attributes and compared them, and asks the respondents to give the preference. Last is a score which is 100 scores per attribute. Three parts questionnaires are mailed to specialists to take the survey including demographic character, recommending oral drugs and recommendation inflection drugs (Yasuyuki Okumura, 2016). Nine-point score method and restricted maximum likelihood procedure are used to construct this research. Rating and choice are both used (D. Asioli, 2016). Rating method uses WTP with nine-point to test how likely the respondents will buy. By contrast, eight choice sets of three alternatives are used in the choice-based method. The mixed logit model is used to analysis choice data while ANOVA is used for rating method. Some methods of conjoint analysis are discussed like image (Alexander Meyer, 2016). They combined the information in the image and ask respondents to choose which reflect the inside of the respondents. Some challenging of using conjoint analysis in developing countries like weak Internet connection is also argued. Questionnaires with four attributes and two values are surveyed among 303 participants to find out the most popular attributes when they decide to study further (Zeev Shtudiner, 2016). K-means is used to cluster the data. A three-step survey with 14 scenarios is used and Hierarchical Bays method to analyze the data collected from the survey (Lee, 2016). In order to find out the best angel investor, choice-based analysis is used and each contributes (seven contributes in total) corresponding to their demographic characters are clustered (Jung WooSuh, 2016).

2.3. Survey of Measuring Willingness to Pay

Since the communities and trade have appeared around the world, the price is always the main connection between buyers and sellers. How to find out the essential value of a product and how much the add-on value could be are most concern among society. Indeed, the price is the only variable that generates the income, while all others like selling effort promotions generate costs (Monroe, 2003). Not only the applying side, the manufacturer, takes seriously on this matter because of the direct relationship with the profit, but also the customers focus on these issues for the willingness to buy. Take the phone selling in China as an example; one special type of phone is hardly sold before the price getting lower which the people can accept it.

Accompanying with this hot topic, how to reveal the natural value of a product has been researched for a hundred years and taken as the core problem in the marketing field. Primarily, there are two logic chains of price revealing. One is called cost-oriented, the other is value oriented (Breidert, 2006). Both of the two methods are totally different from each other. Cost-oriented is based on the manufacturer which the cost of every process should be considered including marketing, operation, and manufacturing. However, the value-oriented is determined by the monetary value of the product according to the customers. Because of the difference between the two methods, some measurements used to look for the value of a product are widely used correspondingly including hedonic pricing, cost and benefit analysis and willingness to pay (WTP). Hedonic pricing can estimate the market segments' value that would affect the price of products especially in the environment field (Baltas, 2001). By contrast, cost and benefit analysis are quite popular in projects selection. Each process of a product should be analyzed in terms of cost and benefit. And comparison among all the products or similar processes is conducted to find out the optimal one (David Rodreck, 2013). A successful application of cost and benefit analysis is called the travel cost method. It is widely used in tour field. The previous two methods are cost-oriented.

On the other hand, as a typical value oriented method, WTP is widely used increasingly within the latest 30 years. Because of the increasing wealth, people prefer satisfaction (personal inter value) to basic function. Referring to the previous researchers, two kinds of motivations that drive the customers' consumption behavior are the one either is useful and affordable or useless with attractive cheap price (Breidert, 2006). Among so many similar products, the one that has more add-on value with the acceptable price could be the best seller. That is why WTP become popular increasingly. It is customer oriented. The basic procedure of leading a WTP measurement can be classified into two steps. At first, a survey should be conducted among the target customers to reveal the monetary value of the special product. In this step, a bidding game, discrete choice method, payment card, and the open-end question have been used to conduct the survey. The second is the measurement. Since the WTP collected by the survey is individual preference and there may be some sample bias, the statistical method would be used to find out the essential value of the product. In this stage, the logit model and the probit model are most popular assume models. The structure of the researchers on price revealing and its method are shown in figure 11.

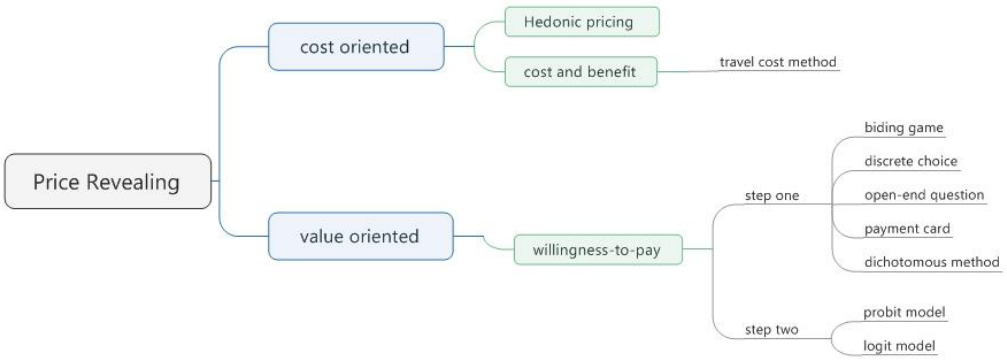


Figure 11.The structure of the research on price revealing and its method

Nowadays, there is a lot of research on WTP. Firstly, in terms of the WTP theory, Christoph (Christoph Brridert, 2006) has put forward the literature review on the comparison of the methods used in WTP including both steps and gave some suggestions on the usage of the method. Marbeau (Y., 1987) listed the details of the method used in the second step of WTP. Balderjahn (I, 1993) classified the means of WTP estimation by individual and group. Nagle and Hodlen (Nagle T.T, 2002) have considered the variables that would affect the people's WTP and discussed in terms of control and uncontrolled factor. (Kenneth Arrow, 1993) Kenneth discussed the key issues to design the contingent valuation instrument and fifteen principles to make an efficient survey on WTP were put forward including pre-survey, the formation of the survey, sample scale, and error control. Secondly, in the WTP application aspect, (Patrick De Pelsmacker, 2005) Patrick revealed that 68% of the consumers would buy things depending on the company's reputation and the younger were more socially conscious in the food industry. In this survey, the reference price was given and the part-worth utility was used to consider the contribution of each factor that affects the price. In (Richard A. Hirth, 2000) survey, several factors including human capital were taken into account to test the WTP in the medical area. Four kinds of people have been sorted to analysis and a threshold of health payment has been counted finally.

However, there is no research on the comparison of WTP applications in different areas. All the previous studies focused on the WTP itself, the abstract one, like the parameters, the methods without taking the specific field WTP applied to into account. Actually, there are some basic differences in WTP application among diverse subjects. For instance, the real purchasing method may not available for engineering industry during the WTP measurement since the expected price may not be affordable for the participants. This paper is aimed to give a literature review on the current WTP applications and make a discussion on the difference among some major subjects with their own characters.

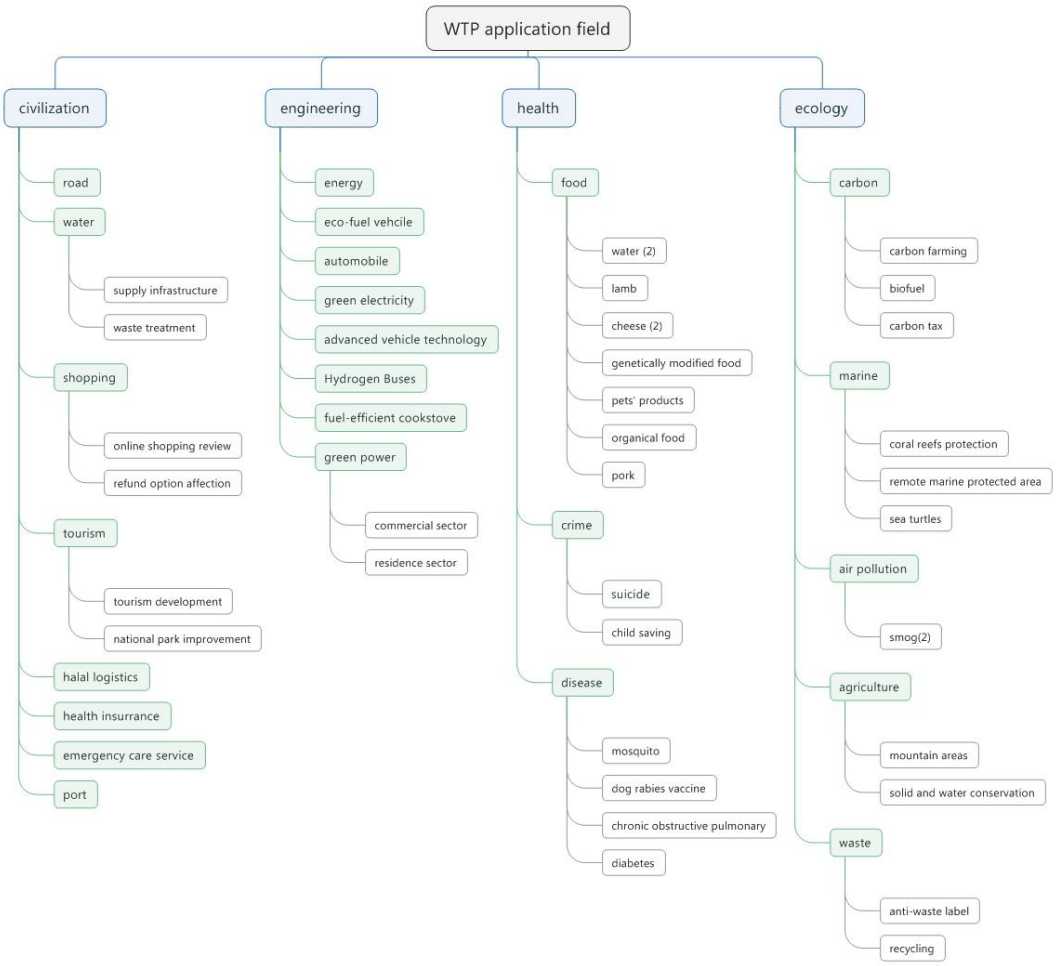


Figure 12.The literature structure of WTP recent years

The papers mentioned in figure 12 are the recent WTP applications in the major field of research. The details including survey approach, question type, modeling approach, the numbers of respondents are listed in the appendix. Some statistical results are listed in figure 13 to figure 17. Since the estimation methods have been discussed in (Christoph Brridert, 2006) Christoph's work, it does not discuss in details in this paper.

As figure 13 shows, WTP researches are popular in both health and ecology fields since the respondents are will to take part in it, especially for the health. In general, people are more concerned with their own benefits than public affairs. Even for the special diseases that only some people would concern about it. However, for the research, the target respondents are also the patients who had this disease. They also want to take part in it. This also happens in the ecology field. For example, the people who like to go to the beaches are preferred to join the marine survey. That is why these surveys are taken place around sea mostly. By contrast, engineering is least likely to be selected as the application of WTP. The total number of researches recently in engineering field on WTP is nearly half of the number in the health field. WTP in engineering is not hot since engineering is a specific field most people may not understand it deeply. Even many people do not care about engineering. Lower followers mean the reference WTP of this field is hard to decide. That is also the reason why the survey methods in this field are always face-to-face interview (figure 16). Only in this way, the details and queries

can be solved real-time. Another reason that engineering is not popular in WTP is that most of the engineering pieces are more expensive than others and the purchasing activity is less frequent. This also results in decision making hard. And even some engineering parts are examples of the application of WTP, the field also overlaps with others. For instance, the eco-fuel vehicle actually is more concerned with the WTP on the effect of the green power instead of the WTP on the technology or service directly.

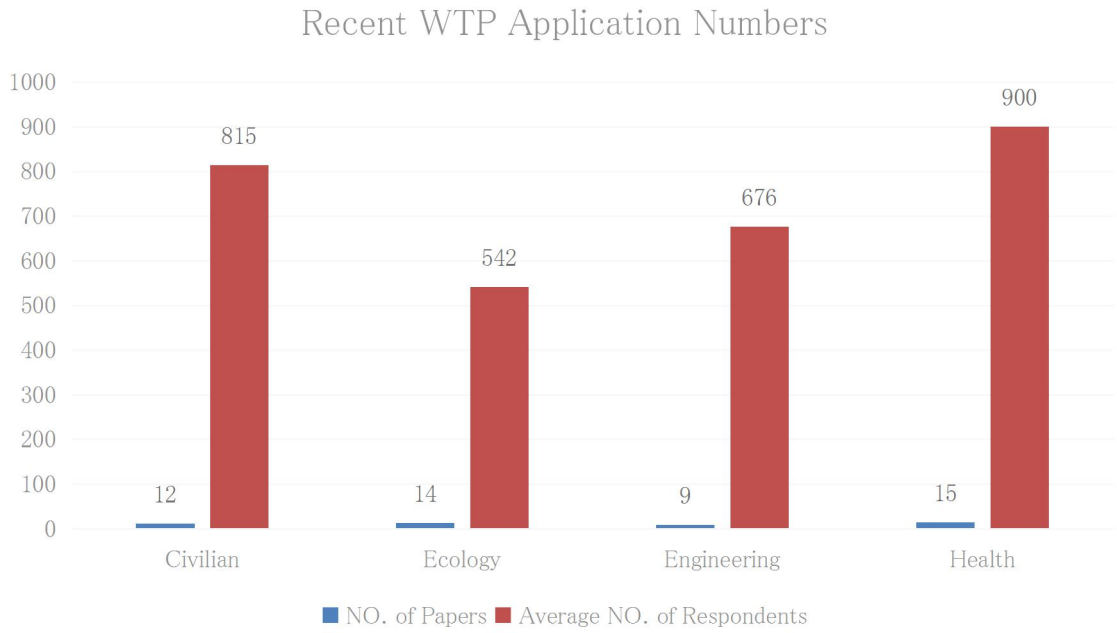


Figure 13.The WTP application numbers and respondent numbers in each field recently

Since the survey approach is the core of data accuracy, a different approach would result in a huge difference among each other. The label of computer-assisted in the figure means this survey is a face-to-face interview with the help of a computer. For example, the computer displays some pictures used in discrete choice methods. The interviewers without a computer conduct a face-to-face interview. Web-based is an online survey. Mail and phone stand for the questionnaires delivered by mail and phone respectively. Real purchase means an experiment in reality which the respondents would buy it at a price related to his WTP. It taken placed by face to face. As figure 14 to figure 17 shows, the first choice of survey approach on WTP in any field is the face-to-face survey. Since face to face survey can give feedback directly and control the survey in some dimension. It has several advantages than others. First, when the respondents do not know the subject or confuse with some words, the interviewer can give a clear explanation that can improve the accuracy and efficiency of the survey. Second, a face-to-face interview can lead to a better return rate. Comparing with the other survey method, a face-to-face interview is conducted by the interviewer that is more kind to respondents. Third, it is efficient to give some open-end question feedback by face-to-face interview instead of others. The open-end question is seldom conducted by the indirect way (e.g. web-based, mail, phone). Because the indirect way is not flexible. The question cannot be updated adaptively, even some of the computer-aided surveys can do it in some degree of freedom, and they are also based on the pre-set question database. Except for the face to face survey, in the health field, real purchase, phone or

web-based still have some markets. Because health is a personal thing, unlike public affairs (e.g. ecology). People are more concerned with their own business. As the real purchase method, since some topics of health like trace pork do not cost too much and the target product can be bought (unlike carbon), the real purchase can make a vivid market surrounding. In terms of web-based and mail survey, the advantage is that it can be widely delivered. Even the return rate is low, it has a huge population, and the result can also be acceptable statistically.

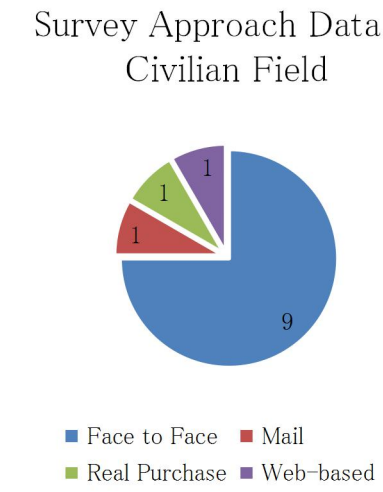


Figure 14.The survey approach data in Civilian

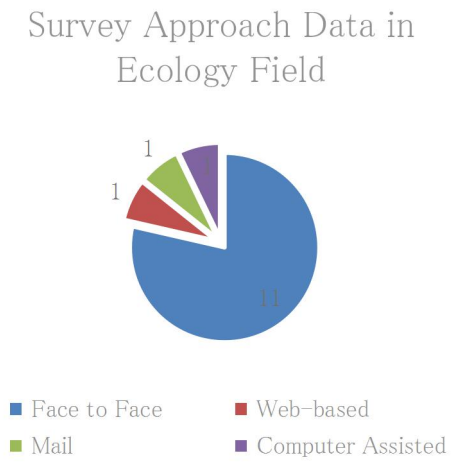


Figure 15.The survey approach data in Ecology

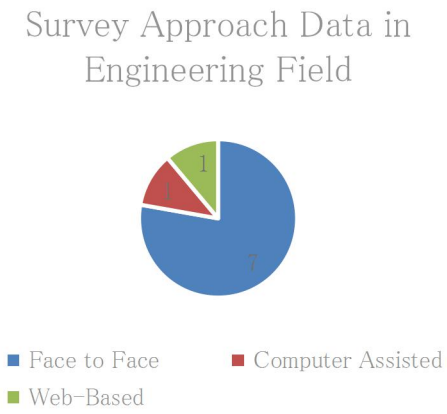


Figure 16.The survey approach data in Engineering

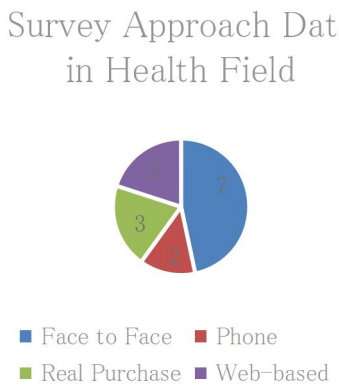


Figure 17.The survey approach data in Health

Since the survey approach is the core of data accuracy, Question type is how the survey questions organized and how the survey process took place. The dichotomous method is real-time update method. When individual accept (decline) the previous price, a new higher (lower) price would refresh. The discrete choice method is similar to conjoint analysis. It has different attributes with different levels including price. And preferred scenes combined with several attributes with a certain level and respondents would pick up the price. The payment card is that the price is listed on the card that let the respondents circle one. Open-end question is to ask the respondents WTP straight forward, while the bidding is like mutual pricing among respondents. As figure 18 to figure 21 shows, different fields have different styles. In civilian and ecology field, the methods used evenly. There is not a big difference between each method in these two fields. Most of the topics in these two fields are a future investment with governments' guiding. They are more

macro and global view. For individuals, these topics are vague. They fell they are related to their lives because of the propagating, but they cannot feel it as an emergency. Unlike these two fields, most of the engineering research is occupied by the discrete choice method. Because this is the easiest and most direct way to describe the products what the respondents would pay. For individuals, engineering can be quantization by several attributes. For example, the speed of a car can be quantization that makes the respondents can feel it. However, for the ecology, that cannot be described. Most people do not understand the meaning of the result of 1-ton carbon increasing. That is why the discrete choice method is quite popular in the engineering field. By contrast, the dichotomous method and open-end question method are preferred in the health field. Both of the methods need some knowledge about the product. Because of the knowledge, the respondents can have a reference price in his mind. They can choose their best price without too much external help (e.g. details description in discrete choice method).

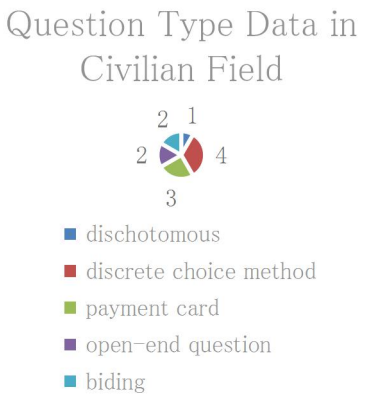


Figure 18.The question type data in Civilian

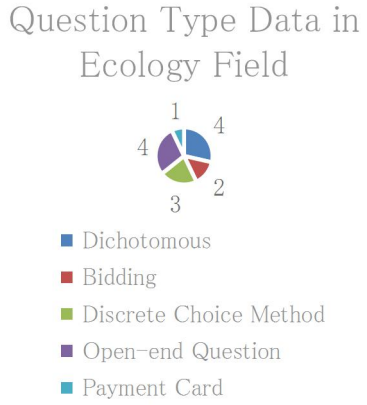


Figure 19.The question type data in Ecology

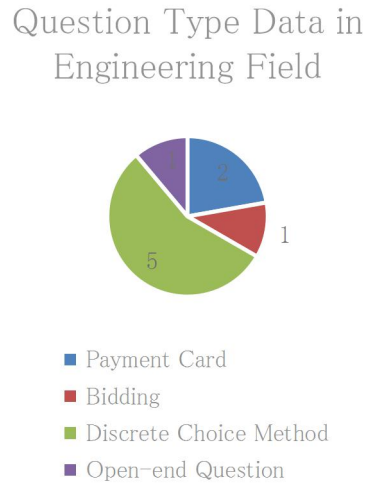


Figure 20.The question type data in Engineering

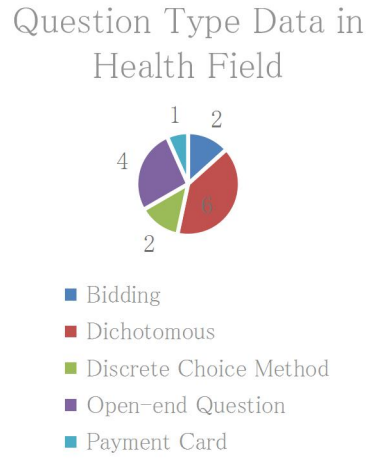


Figure 21.The question type data in Health

2.4. Government Subsidy Policy on Hi-tech

IoV is a future technology and hi-tech. In China, especially in the 21 century, hi-tech is growing fast. In order to support these industries, Chinese has published many policies like <The funding

guide for SMS 2013>. Since the reform and open, our market economy is booming. Currently, we confront the industry structure adjustment; many traditional economic concepts have been changed. The hi-tech service has expanded to the hi-tech manufacturing industry. Comparing with traditional manufacturing, hi-tech manufacturing has its own key technology, creative mind, and well-educated human resource. Because of these, the hi-tech industry pushes other industries to update. However, at the beginning of the time, education is not good and the enterprise cannot gain enough core technologies. Many enterprises lack competitive power. For the hi-tech enterprise, the core competitive power and routines are research and development. In order to make a harmony creative atmosphere, encourage the enterprise to be innovation and increase their R&D cost, the government publishes many policies to promote them including IoV industries. In this paper, the relationship between government policies and enterprise innovation would be revealed. Since how much effect government policies can make for an enterprise is hard to calculate, a parameter should be selected as standard. Because in the enterprise, there is an accounting issue called R&D cost and it directly reflects the innovation ability of a company. And indeed, it is affected by government policies.

In general, there are many researches on the development of hi-tech industries. (Zhize, 2007) Mr. Zeng gave the definition of the hi-tech service industry: Through the development of technology and well-educated people, based on high R&D cost and a large number of patents application, expand from the hi-tech manufacturing and form an advanced service industry. He also made a conclusion of attributes of the hi-tech enterprise. Yangdong Wang (Yangdong Wang Y. Y., 2007) through the hi-tech service industry is originated from the service industry and integrated traditional service industry and hi-tech industry. They are aimed to innovate and offer the added value to the traditional manufacturing industry. He is also an analysis of the origin of the hi-tech industry: 1. The update of industry innovation. 2.SMS integrated. 3. The result of the value chain. Qingyan Shi (Qingyan Shi, 2010) pointed out the function of hi-tech industry and proposed 4 criteria of this industry: 1. From industry to define the hi-tech instead of event 2. Core works and core asset to define. 3. The integrity of industry 4. Match with the national economy industry classification. By contrast, in terms of the current situation of the development of hi-tech industry, Yangdong Wang (Yangdong Wang J. Z., 2009) current stage of the hi-tech industry can push the national industry promotion and trans conformation. Wang (Yangdong Wang Q. A., 2010) gave a case study on the hi-tech situation in the Pearl River Delta area by SWOT. He listed some factors affect the development: location, industrialization level, policy, the balance of economic, the past model of development. Chen (Huapeng Chen, 2006) summarized the hi-tech industry, compared the tendency of the industry and made a conclusion that information knowledge and hi-tech manufacturing are key branches of the hi-tech industry.

The government should consider the classification of technology innovation and technology digesting before the policies publishing. The government should not encourage copying instead of self-innovation. In term of this, Wen (Wen, 2005) proposed that the government should choose the project carefully, in order to ensure both sufficient government expenditure and hi-tech development at the same time. Liu (Wen Yao, 2010) the positive externality of Hi-tech industry need to be intervened by the government. Governmental tax or finance policy can decrease the risk of the hi-tech industry.

In terms of subsidy policy, there are many definitions of subsidy among western economics; basically, they come from the definition of UN called ‘system of national accounts’. In that book,

the subsidy is defined as the current transfer from government to producer. Some scholars take the subsidy as the negative tax. 1962, Friedman (Milton, 1962) mentioned the negative tax in his book called “Capitalism and Freedom”. He thought the subsidy should be variable according to the income status. The people with higher income need not get a higher subsidy. However, in the socialist system, whether to use tax or subsidy to adjust the economy is mainly depending on the gap between the value and price of the product (Song, 1986). When the price is lower than its value, the government can use the subsidy to adjust or use tax when the price is bigger than value. However, these theories cannot be always true during practice. We consider some value cannot be measured during the design stage. Marx also has defined subsidy as a backup fund, which is different from the current practice. In this research, we define the subsidy as a financial policy which is used to meet the development target of the government.

Technology development naturally is knowledge. It has the characteristics of public products. Therefore, if these products only distributed freely, it will be less effective, even malfunction because of its classification of public product. With the help of the government, the innovation subject is the manufacturer. The only tools for the government of standardizing are tax or subsidy. Subsidy makes the externality of public product internalization, which encourages the manufacturers to make progress in technology development.

Many researchers in China are doing researches on subsidy effects on technology development. Liuyin Chen (Chen, 2004) tries to build the policy system on hi-tech development in China including subsidy, tax, financial, patents, human resources, international trading and so on. Ying Jiang (Jiang, 2003) proposed some suggestions on how to improve the policy environment to build a complicated policy system in the hi-tech industry. She thought a comprehensive system of subsidy, finance, and the law would be the base of industry development. Lirong Sun (Sun, 1999) figured out the unreasonable subsidy system would affect the fair competition and social resources allocation. The encourage policy is not higher enough to attract more excellent employees. Ming Cong (Cong, 2003) considers the revolution of subsidy system cannot be delayed.

Around the world, scholars used their own data from their own countries and analysis from many aspects. However, conclusions may be opposite from each other. Capron H (Capron H, 1997) revealed that the government financial support has a strong positive effect on the enterprise research and the way of supporting need to be creative since different way will make a different result. Lichtenberg F (F., 1989) thought the grant-in-aid has a substitution effect on the company’s research events. This effect mainly affects that grant-in-aid encourages the need for production factors and push the R&D cost increase, which will depress the research event. Holemans B and Sleuwaegen L (Holemans B, 1988) used the data in Belgium and got a totally opposite result of Canniehael. They found the grant-in-aid has an obvious complementary effect on research event. They are positively related to each other. Levy DM and Terleckyj NE (Levy DM, 1983) used American macroeconomic data to regression the coefficient of complementary effect between R&D and grant-in-aid.

Researchers above are a focus on the macro view, in terms of micro-economic view, Norberg-Bohm (V, 1999) went through the relationships between subsidy and development activity in the company. He thought the government should play the role of technology direction offering and increase the supply of technologies. By this way, the revolution of technology would become more balanced. Garcia-Quevedo (J., 2004) used the regression method to compare the

army offering company with subsidy and without subsidy. He made a conclusion that the government can push technology development by government purchasing. With the help of government subsidy, the company would have a better research capability. Lichtenberg (R, 1987) also used the regression method and the data from the army offering companying with and without the subsidies. However, he got a totally different conclusion that the increasing subsidy would decrease the R&D cost made by them. This is also called the substitution effect instead of motivation effect. Government purchasing also increase the single product needs which depress the motivation of innovation on other products.

In practice, government expenditure always comes with preferential tax policy. They cannot leave alone. Therefore, many researchers do research on the effect of both of them. Andrew Michael Spence (Spence, 1974) found both government expenditure and preferential tax policy can promote the research events. In a long run, both of them can release the risk of running a company, however, when the company went into stable time, the government should consider the quantity of government expenditure avoiding the substitution effect. Mamuneas TP (TP, 1999) focused on the American manufacturing industries. He revealed that both government expenditure and preferential tax policy can increase the expenditure of R&D. The direct aids may cause technology spillover and substitution effect of other products. Guellec D (Guellec D, 1997) found whether takes government expenditure as a substitution or encourage is depending on the level of government support. Wallsten SJ (J W. S., 2000) built a function of grant-in-aid and found every unit of government expenditure would drag 0.74 unit of enterprise expenditure on R&D. Hall BH (H, 2002) pointed out the well-communication can improve the internal and external environment of innovation. The government should improve that area.

Since the government has two ways to support the hi-tech company and each way has some sub-ways like direct aids in government expenditure, finding out the effect of each subway is very important.

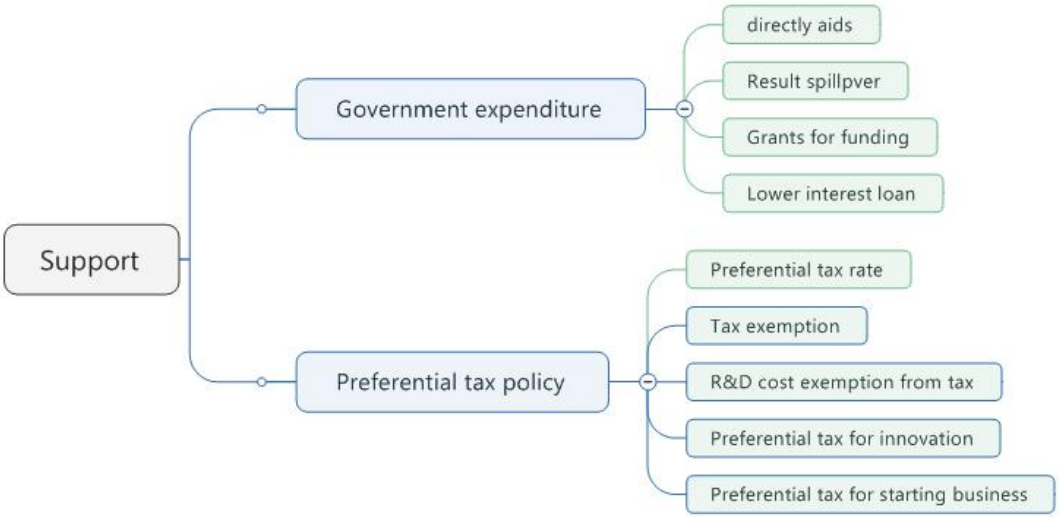


Figure 22.The government support methods

2.5. Subsidy Issues with Game Theory

Previously, we found many researches do researches on subsidy issues. Most of them adopt

econometric analysis using a statistical approach and empirical data. However, besides econometric analysis, there are still many other methods that suit the subsidy issues. In this section, we revealed several researches on subsidies with game theory. Cong liu (Cong Liu, 2017) developed a game model to figure out the inefficient subsidies in green vehicle industry in China. He takes the government mental politic power into consideration and put forward three scenarios combined with subsidy and tax. Since he used the evolutionary game, he found the current subsidy policy is not a stable point. Chen (Wanting Chen, 2018) consider the pollution problems and put forward an evolutionary game to simulate the response of manufacturers who would get a subsidy from the government because of eco-friendly and also get tax from the government because of pollution. He examined the evolutionarily stable strategy and figure out the best scenarios of subsidy plan by comparing different plans. Tong Shu (Tong Shu, 2017) take customer WTP into account during the remanufacturing game process, they simulated the procedure with one local and one un-local manufacturer. Under a certain subsidy plan, what are their decisions on recycling used products? Guang Zhu (Guang Zhu, 2018) also considers the carbon issues with the help of game theory. She wants to reveal the way that how to optimize the strategy of low carbon investment for suppliers and manufacturers in supply chains. In order to make it clear, she also tests the factors by scenario analysis. In Amer (Amer Magdi, 2015) research, subgame perfect Nash equilibrium is used to reduce the effect of the government subsidy on the user consumption, prices and producer and distributor profits. Fan Ying (Fan Ying, 2015) estimate a dynamic entry game using data on potential and actual entrants, allowing for heterogeneous option values of waiting. They find that giving subsidies to smaller markets are more cost effective in reducing monopoly markets, but giving subsidies to only lower-cost firms are less cost-effective than a nondiscriminatory policy. Subsidies in only early periods reduce the option value of waiting and accelerate the arrival of competition. Zhang Dehua (Dehua, 2016) analyzes the related behaviors between farmers and governments using completed information dynamic game model and comes to the conclusion that the key influential factor on farmers' alternative rotation behaviors is the economic interest factor and the reasonable subsidy mechanism from governments. Finally, he proposes the following countermeasures and suggestions: implementing alternative rotation subsidies, strengthening supervision for subsidy payment, fostering deep processing industries to increase the added value of agricultural products, extending the period of land transfer to ensure effective land improvement for land operators. Gu xiaoyu (Gu xiaoyu, JUL 24-27,2016) built a model among government, electric/gasoline vehicle manufacturer, retailer, and ultimate vehicle customer to study subsidy policy and consider two situations that in subsidizing electric vehicle that is given subsidy to electric vehicle customer or electric vehicle manufacturer in the early electric vehicle development stage. Ma Junhai (Ma Junhai, 2016) built a dynamic duopoly game model in two cases with different government subsidies based on the innovation inputs and outputs, respectively. It shows the degree of government innovation subsidies impact the stability and entropy of the system. Chen Meng (Meng, 2017) establishes a complete information static game model for the fixed amount subsidy strategy and the fixed proportion subsidy strategy. He analyzes its strategic equilibrium solution and reasonable price range and concludes that Mobile company expand the market share through the subsidy in the short term, but it cannot be maintained for a long time and needs diversification the profitability approach.

As the literature shows, not many researches used the game on subsidy issues. The used scholars

are mainly in the energy field. They want to figure out whether subsidy would result in fewer environmental problems. Though there are several papers on engineering field, they focus on the existing technologies and most of them use the evolutionary game to simulate the stable market of technologies.

2.6. Industrial Organization Issues with Game Theory

Game theoretical model has been widely used in industrial organization field especially in the field of monopoly, pricing and M&A since in these fields, players, strategy and utility would be all considered in the model. Many researchers used game theoretical model to solve the industrial issues. Zhiyuan Wang (Wang, 2012) figured out the Chinese industry transmission realization by game. He revealed the problems happened during industry transmission, especially for corruption. He proposed that a reward and punishment system is needed to solve this problem and all players in the game would know this system. Tao Yu (Yu, 2013) pointed out that the nature of the industrial organization is a mechanism of regulation and a balance among the companies in the industry. By using game theoretical model to simulate the competitions among companies in the industry, we can analysis the industry revolution path. When the external factors including technology, policy or internal factors like market share reach to some degree, the reorganization of game theoretical model for the owner of the company would change. They would trigger the strategy shift to a new game and resulted in the new industrial organization. Fuguo Sun (Sun, 1995) put forward a review on the game application in modern industrial organization. He mentioned that game is widely used in economics especially for the industrial organization. He pointed out that analyzing of behaviors of companies is based on several assumptions. One is that the behavior of a company is not only determined by the market structure but also the expectation of actions of another company, that means psychology is also useful for behavior analyzing. This kind of thinking brings a frame of monopoly analyzing. Hanhui Chen (Chen, 2011) discussed the decent of responsibility of the international companies in China with SCP scheme from the industrial organization point of view. He used SCP scheme in industrial organization and game theoretical model to explain the decent of responsibility of the international companies in China according to a review of current researches. He proposed that this kind of status results from unbalanced economic development and local protection that some industries in China are torture and independent. Because of the interests of international companies and domestic sides, dual standards of social responsibility are easy to form. Chen zhiguang (Chen Z. , 2004) used the game theoretical model to reveal the anti-trust application in the industry. He proposed that game theoretical model could be used in the anti-trust situation since it can be used in partly monopoly situation.

Besides the industrial organization revolution, many scholars also study competition among companies by game theoretical model. Shan Shan (Shan, 2012) thought game theoretical model could help us understand the strategy, object clearly. She first proposed a differential game theoretical model of monopoly situations with two players under symmetry information. She used the game theoretical model to give suggestions on strategy choosing in the communication industry. However, there are three drawbacks of the game theoretical model. One is less coverage of economic factors. The other is a rational degree of the human being is over-trusted. The last is that this paper mainly considered the external factors instead of internal factors. Lin

Liu (Liu, 2006) analysis the efficiency of “farmer + company” organization. This kind of organization is mature in the Chinese agriculture industry. In the paper, he used game theoretical model to find out the reason for lower-efficiency. And according to the findings, he put forward an infinite repeated game model and revealed that “farmer + company” organization would shift from the prisoner game to repeated game. Pankaj Ghemawat (Pankaj Ghemawat, 2002) wrote a book on game in industrial competition. He put forward many competition models from the price strategy in the short run to innovation strategy in the long run.

Some other researchers also do researches in some specific industries. Iwata (Iwata Gyoiehi, 1974) used the statistical method to check the difference between the real balance in reality and balance calculated by theory. He used the glass industry in Japan as a case in which the result is a wonderful match. So as Gollop (Gollop, 1979) took coffee bean as an example.

In terms of technology diffusion, Ali (Ali, 1993) used game theoretical model to give a strategy to select the technology development path, one is the small innovation called incremental innovation. The other is a big innovation called pioneering. It is also taken the technology uncertainty associated with project completion into account. Chandy (Chandy, 1998) proposed that consider a different point of view on successful technology adoption is the willingness to cannibalize of the manufacturer. Morris (Morris, 1997) used game theoretical model to simulate the multi-firms optimization frameworks on life cycle analysis of quality of after -sales service and the price. He found the ratio of service quality on price is characterized by equilibrium. Using a modified version of a method developed by Rosen (Rosen, 1974), they estimate costs as a function of a brand's attributes. A profit-maximizing product position and price can then be determined by using game theoretic approach along with the demand and cost equations.

In terms of R&D issues in industrial organization, Suzumura (Suzumura, 1992) examines the positive and normative effects of cooperative R&D. He considered maximizing the joint profit by committing the member firms from the R&D point of view. He found in the absence of spillover effects and insufficient cooperative R&D level, the no cooperative level may go over the first and second best level of R&D. D'Aspremont (Claude D'Aspremont, 1988) mentioned that relations among competitors are not always the same as whole cooperative or non-cooperative. He revealed that cooperative behaviors can play a positive role in industries if firms active to invest R&D activities generating spillover effects. Dasgupta (Partha Dasgupta, 1980) did research on the nature and consequence of competition in R&D. He used the factor of the speed of research, the number of independent research labs and level of risk undertaken. He found the market equilibrium might entail excessively fast research with insufficient risk-taking. Richard J Gilbert (Gilbert, 2006) did research on what decided the investment in R&D. He found that the extent of competition in product markets and in R&D, the degree of protection from imitators, and the dynamics of R&D competition are the key issues. Dawid (H.Dawid, 2013) considered the investment behavior of duopolistic firms subject to technological progress. He revealed if the new product is neither a close substitute nor a strong complement of the established product, positive synergy effects in R&D cooperation is necessary to make it more profitable for firms than R&D competition. Considering the market structure and R&D relations, R.Cellini (R. Cellini, 2005) investigated dynamic R&D for process innovation in an oligopoly where firms invest in cost-reducing activities. He proved that the industry R&D investment increased monotonically with the increasing number of firms. Barbara J. Spencer (Barbara J.Spencer, 1983) did research on the theory of government intervention that provides an explanation for “industrial strategy”

policies such as R&D or export subsidies in imperfectly competitive international markets. He clarified that a government would undertake Industrial strategy if no other government does, but be well to negotiate limitations on such policies in the event of retaliation.

2.7. Positioning of the Thesis

This dissertation constructs a game-theoretic model to clarify the mechanism of decision-makings on technology adoption focused on the IoV industry, especially investigating effects of subsidy policy on technology development. Because game theoretic models of R&D have been studied in the field of industrial organization, in this sense, this dissertation can be regarded just as an applied study in the field. However, compared with preceding studies, this study has the following remarkable uniqueness, which is able to position the dissertation as a not-simple-application-of-industrial-organization study.

1. Application to IoV considering several empirical aspects:
   Related studies in industrial organization usually adopt a simplified and abstract model to express company's R&D decisions, in which they especially focus on strategies in corporative or competitive situations considering price and/or technology spillover aspects. However, few scholars address technology development issues on product attribute levels. Against that, as explained the detail in the later chapters, this dissertation develops a model with multiple attributes for which each manufacturer makes a decision as technology development. This approach enables to analyze manufacturer's technology development decisions from a microscopic point of view. Furthermore, in order to understand expert investigates several empirical situations in IoV, key specific technologies that can be useful for IoV interviews and additionally consumers' willingness-to-pay for technology attributes in IoV is also examined by questionnaires.

2. Focus on effects of subsidy policy on technology attribute levels:
   So far there are many studies related to subsidy policy. However, a remarkable characteristic of this dissertation is that a subsidy scheme of technology attribute levels is modeled. Accordingly, it is possible to discuss what kind of technology attributes in IoV manufacturers should develop and how much they are supported by subsidy. This is an important aspect in terms of technology management. In addition to that, another remarkable characteristic is introduction of a new type of government profit function. In conventional economic-theoretical models, they usually pursue social surplus maximization or Pareto efficiency. Therefore, they do not consider a specific government profit function. Different from those conventional approaches, this dissertation dares to define an independent profit function that the government player has. In the model, the government player makes a decision on subsidy level to maximize the profit, the detail of which will be explained in chapter 4. By this arrangement, the model can shed new light on a way of subsidy schemes. For example, the government might have to protect some technologies that domestic companies have from foreign companies, which would be basically difficult to express only by social surplus. Similarly, it is also difficult to incorporate social issues like unemployment, environmental preservation, etc. Therefore, introducing an independent government profit

function, such kind of issues can be proactively addressed by defining the appropriate government motivation structure.

3. Attention to a synthetic point of view—how to design or create new technologies:
   The preceding studies presented in sections above mainly pay much attention on an analytic point of view, which means that they want to understand the existing and observable phenomena. In the meantime, many previous researches in engineering fields mostly focus on specific technologies related to IoV and its physical realization/implementation. They do not usually consider how to synthesize new technologies from a societal point of view and also do not consider any interdependent situations where manufacturers and consumers interact each other. Against these studies, this dissertation pays attention on the upcoming IoV industry where any actual IoV products have not completely realized and diffused yet, and then ascertain what technologies of IoV and how manufacturers should develop to increase social benefit. In that sense, this dissertation somewhat reflects an aspect of technology management. In other word, this dissertation's focus is how to create value in societies is, which can be thought as one type of *technology management for innovation* studies that consider social value by developing and utilizing technologies.

Positioning of research can be shown in figure 23.

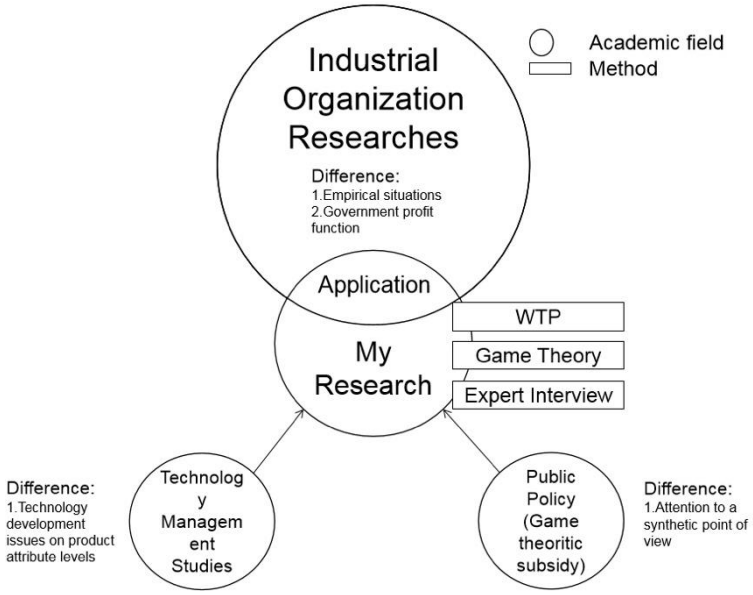


Figure 23.The position of this research among related literature

3. IoV Related Technology and Customer Preference

In this chapter, some concepts of IoV would be explained and their attributes would also be introduced at first. Second, since there are two surveys in this chapter, some basic explanations, and each survey design description would be put forward. Third, the first survey is analyzed by conjoint analysis. Fourth, the second survey is analyzed by willingness to pay. Fifth, the related technologies corresponding to the customer preferred attributes would be revealed by an expert interview. Sixth, make a conclusion on this part and list some data for the followed chapter.

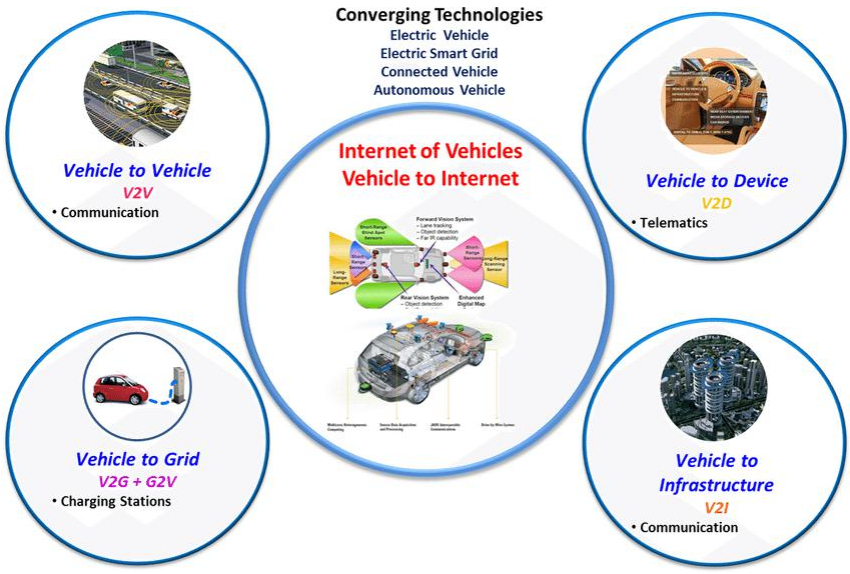
The structure of two surveys and three steps are below. First, using conjoint analysis, we find the dominant attributes (three in this study) among customers. Second, the study constructs the WTP-population relationship of IoV with a combination of attributes filtered in the first survey. These relationships could support the management of IoV technology. In this step, this study applies the CVM. Third, the study calculates the average price of each type of IoV with a combination of attributes using the logit method. After that, an expert interview is used to reveal the corresponding technologies of preferred attributes.

3.1. The Relevant Concepts of IoV

3.1.1. The Concept of IoV

Internet of vehicle is a network that mainly consists of the location of the vehicle, speed of vehicle and route of the vehicle. By application of GPS, RFID, sensors, GPU and so on, the vehicle can collect the surrounding information. By application of the Internet, all the information of all the vehicles can be converted to the CPU of IoV product. By computer science, all the information would be calculated in a short time and output a set of optimal actions that lead the vehicle to avoid traffic jam or traffic accident.

The IoV is not only one network, but it is also a network set based on inter-vehicle network, vehicle-vehicle network and mobile network inside the vehicle. They transmit the information according to the communication contract. The information transmission among vehicles, between vehicle and infrastructure, between smart home and a vehicle is an example of IoV application.



Official Net of HuaWei

Figure 24.The net work of IoV

3.1.2. The Concept of IoV Product

IoV product is a wide range of products including information collecting devices (e.g. sensors), information analysis devices (e.g. CPU) and information action devices (e.g. ABS). However, in this research, we only focus on the information analysis devices, in China we also call it T-box which offer the interface to corresponding action device and receive the information from some types of sensors. Since this is a brain of the IoV, what is the main function of the PCB inside and whether it is powerful or not would result in a different performance of IoV. For example, currently, the popular function of T-box is navigation which means currently most action devise related to navigation would be developed most.

Stated as the reputable consulting company Strategy& that the future vehicle should contain 7 attributes according to the internet of vehicle applications. In order to match these functions, the IoV product should develop the corresponding interface and PCB. At least, they should enrich some platforms of these functions to support these future attributes.

Referring to the report of IoV published by Strategy& co., the seven attributes of IoV which is also the seven development paths of IoV product are listed as followed:

A. Moving management: functions that allow the driver to reach a destination quickly, safely, and in a cost-efficient manner. For example current traffic information, parking lot or garage assistance optimized fuel consumption.

B. Vehicle management: functions that aid the driver in reducing operating costs and improving ease of use. For examples: vehicle condition and service reminders, remote operation, transfer of usage data.

C. Entertainment: functions involving the entertainment of the driver and passengers. For examples: Smartphone interface, WLAN hot pot, music, video, Internet, social media, mobile office.

D. Safety: functions that warn the driver of external hazards and internal responses of the vehicle to hazards. For examples: collision protection, hazard warnings, and emergency functions.

E. Autonomous driving: functions involving partially or fully automatic driving. For examples:

operational assistance or autopilot in heavy traffic, in parking, or on highways.
F. Well-being: functions involving the driver's comfort and ability and fitness to drive. For examples: fatigue detection, automatic environment adjustments to keep drivers alert, medical assistance.
G. Home integration: functions that link to the smart home kits. For examples: voice control of lights at home in your vehicle.
All the attributes above are the future of IoV product technology.

3.2. IoV Attributes Preference Among Customers by Survey and Conjoint Analysis

As stated previously, there are seven attributes of IoV, the one customer prefer to would determine the technology development path. Therefore, this survey would reveal the most attractive attributes among customers.

3.2.1. Survey Design

To obtain a precise result, this study uses an online survey instead of face-to-face interviews, as this technique keeps the geographical bias at a minimum. The survey was posted to the most popular Chinese survey website (wenjuanxing, 2016). The delivery time is from August 3, 2016 to September 18, 2016. As this survey is oriented for Chinese vehicles, it uses Chinese as the basic language in the survey. All pictures in this study are translations. The survey has three parts.
The first is the description. To remove the technical blind spot, a brief description of IoV and its seven attributes are displayed at the head of the survey with simple examples. figure 25 shows the exact description of the survey. Table 1 shows the details of each attribute.

Survey on the Price Distribution of Internet of Vehicle

Base on PWC (https://www.strategyand.pwc.com/cn/home/report/connected-car-2015-study) the attributes of the IoV has been dividend into seven parts. You can treat IoV as an application of internet of things. The definition of the seven attributes are listed as follows:

1. Autonomous driving: Operation of the vehicle without a human driver at the controls, existing only on a partial basis. Examples include self-parking cars, motorway assistance, and the transportation of goods by trucks on well-delineated routes.
2. Safety: The ability to warn the driver of road problems and automatically sense and prevent potential collisions. Examples include danger warning signals and emergency call functions.
3. Entertainment: Functions that provide music and video to passengers and the driver. Examples include smartphone interfaces, Wi-Fi or Local Area Network hotspots, access to social networks, and the "mobile office."
4. Well-being: Optimization of the driver's health and competence. Examples include electronic alerts that detect or mitigate fatigue, and other forms of individual assistance.
5. Vehicle management: Support for minimizing operating cost and increasing comfort. Examples include remote control of car features, displays of service and vehicle status, and the transmittal of traffic data.
6. Mobility management: Guidance on faster, safer, more economical, and more fuel-efficient driving, based on data gathered for the vehicle. Examples include real-time traffic information displays, displays of repair and service-related information, and the transfer of usage data.
7. Home integration: Links to homes, offices, and other buildings. Examples include the integration of the automobile into home alarms or energy monitoring systems.

The products mentioned in this survey are integrated with these attributes with different levels. The different levels give a different performance of IoV.

Figure 25.Brief description of the survey

Table 1.Details of each attribute

Attribute	*Quality Categories*
Moving Management	High: high precision of route planning
	Middle: average precision of route planning
	Low: poor precision of route planning
Vehicle Management	High: high quality of minimizing operating cost
	Middle: average quality of minimizing operating cost
	Low: poor quality of minimizing operating cost
Entertainment	High: broad range of entertainment function
	Middle: average range of entertainment function
	Low: narrow range of entertainment function
Well-being	High: broad range of driver's health and competence

	Middle: middle range of driver's health and competence
	Low: narrow range of driver's health and competence
Autonomous driving	High: more options on automotive
	Middle: average options on automotive
	Low: fewer options on automotive
Safety	High: more sense on potential collisions
	Middle: average sense on potential collisions
	Low: few sense on potential collisions
Home integration	High: more types of compatible devices
	Middle: average types of compatible devices
	Low: fewer types of compatible devices

The second part is the main body. Owing to the seven attributes and three levels (high, middle, low) with each, there would be 37 combinations in the full-profile method. Even the choice-based pair compare method would have over 100 pairs. This is an impossible mission for respondents. Therefore, orthogonal table (Li, 2010) has been introduced in to decrease the number of profiles. Since there are seven attributes and each attribute has three technology levels, we should choose the table from the table family of seven factors with three status. In order to minimum the number of profiles, table L18(37) has been picked up for this dissertation. The original table is shown in table 2 below. Experiment No. means the number of profiles, also known as experiment index. Characters a to g are the factors considered in the experiment where is the attribute as my research. The value 1 to 3 in the main body of table is the status or evaluation criteria of corresponding factors. Table L18(37) allow each factor to have three status. In my research, this can be interpreted as the technology level of each attribute. The exact table used in my research is shown in table 3.

Table 2. orthogonal table $L_{18}(3^7)$

Factors / Experiment No.	a	b	c	d	e	f	g
1	1	1	1	1	1	1	1
2	1	2	2	2	2	2	2
3	1	3	3	3	3	3	3
4	2	1	1	2	2	3	3
5	2	2	2	3	3	1	1

6	2	3	3	1	1	2	2
7	3	1	2	1	3	2	3
8	3	2	3	2	1	3	1
9	3	3	1	3	2	1	2
10	1	1	3	3	2	2	1
11	1	2	1	1	3	3	2
12	1	3	2	2	1	1	3
13	2	1	2	3	1	3	2
14	2	2	3	1	2	1	3
15	2	3	1	2	3	2	1
16	3	1	3	2	3	1	2
17	3	2	1	3	1	2	3
18	3	3	2	1	2	3	1

Table 3.Details of 18 products in the first survey

The level of each attribute	**Moving Management**	**Vehicle management**	**Entertainment**	**Well-being**	**Autonomous driving**	**Safety**	**Home integration**
Product one	High	High	High	High	High	High	High
Product two	High	Middle	Middle	Middle	Middle	Middle	Middle
Product Three	High	Low	Low	Low	Low	Low	Low
Product Four	Middle	High	High	Middle	Middle	Low	Low
Product Five	Middle	Middle	Middle	Low	Low	High	High
Product Six	Middle	Low	Low	High	High	Middle	Middle
Product Seven	Low	High	Middle	High	Low	Middle	Low
Product Eight	Low	Middle	Low	Middle	High	Low	High
Product Nine	Low	Low	High	Low	Middle	High	Middle
Product Ten	High	High	Low	Low	Middle	Middle	Low
Product Eleven	High	Middle	High	High	Low	Low	Middle
Product twelve	High	Low	Middle	Middle	High	High	Low
Product Thirteen	Middle	High	Middle	Low	High	Low	Middle
Product Fourteen	Middle	Middle	Low	High	Middle	High	Low
Product Fifteen	Middle	Low	High	Middle	Low	Middle	High

Product Sixteen	Low	High	Low	Middle	Low	High	Middle
Product Seventeen	Low	Middle	High	Low	High	Middle	Low
Product eighteen	Low	Low	Middle	High	Middle	Low	High

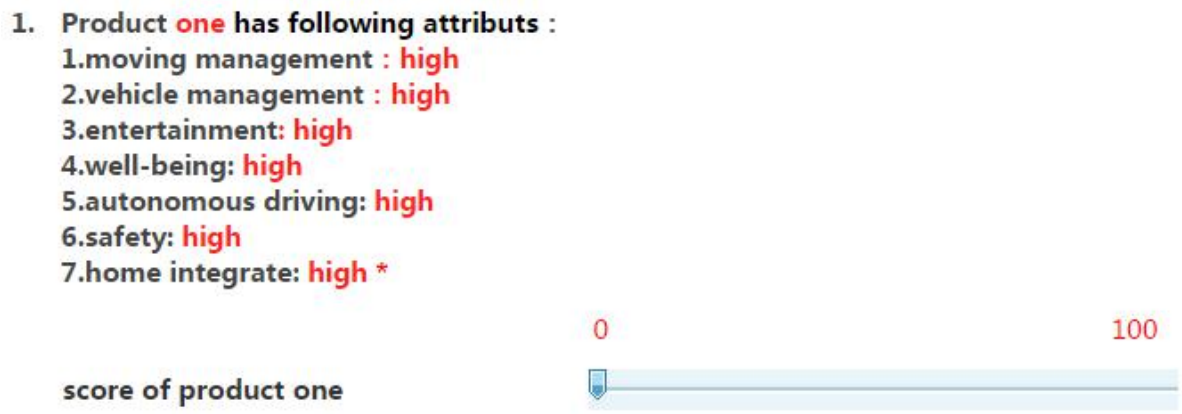


Figure 26.The structure of the question

The third part is demographic questions, which include age, education, and salaries.

3.2.2. Calculation of Importance of Each Attribute

According to the survey result, we can derive the utility of every technology level of each attribute by conjoint analysis. The mechanism of conjoint analysis is described by xiaoqun He (He, 2010). Utility calculation equation is as follows:

$$U(x) = \sum_{i=1}^{n} \sum_{j=1}^{m_i} a_{ij} x_{ij} \tag{3.1}$$

where U(x) is the total utility of all attributes; n is the number of attributes while m is the number of technology level of attribute i. x_{ij} is the dummy variable and a_{ij} is the part utilities of j-th technology level of attribute i. a_{ij} as the utility function can be calculated below:

$$a(x) = \sum_{i=1}^{n} \sum_{j=1}^{m_i} b_{ij} k_{ij} \tag{3.2}$$

$a(x)$ is the score of each profile. b_{ij} is the coefficient related to part utility. k_{ij} is the dummy variable. By solving equation 3.2, b_{ij} can be calculated and part utilities would satisfied following constraint:

$$\begin{cases} a_{i1} - a_{i3} = b_{i1} \\ a_{i2} - a_{i3} = b_{i2} \\ a_{i1} + a_{i2} + a_{i3} = 0 \end{cases} \tag{3.3}$$

By solving 3.3, the part utility of every technology level of each attribute is worked out and the importance of each attribute can be tested by following equation:

$$I(x) = \frac{Max(a_{ij}) - Min(a_{ij})}{\sum_{i=1}^{n} [Max(a_{ij}) - Min(a_{ij})]} \tag{3.4}$$

3.2.3. Result of Survey

Based on the high-efficiency website, during the over one month delivery time, there are 437 respondents. Since automotive discard function has been settled which means if the survey is uncompleted it will be discarded, the 437 respondents are effective and the average time cost is 210 seconds. The answers are collected from many provinces which listed in figure 27. Chongqing gets the most attractions because of the developed vehicle industry.

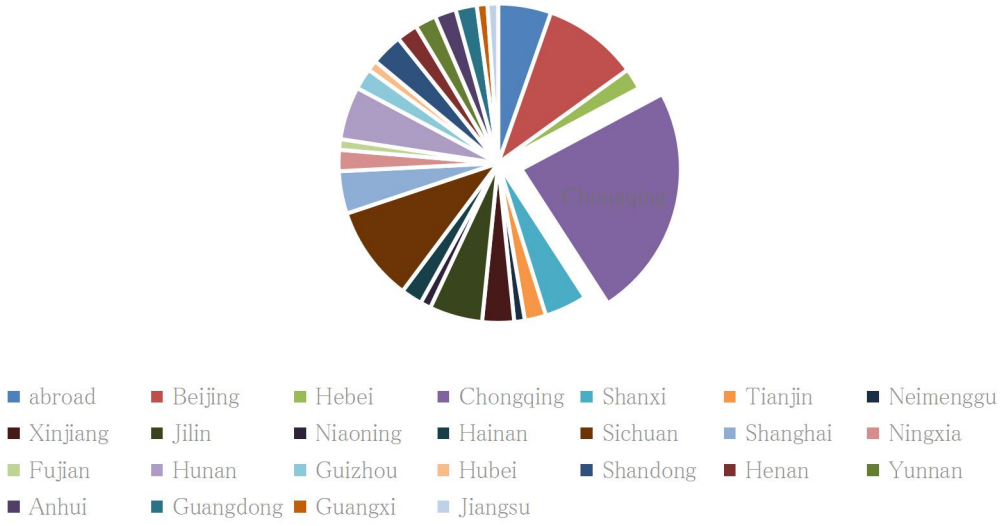


Figure 27.The information source

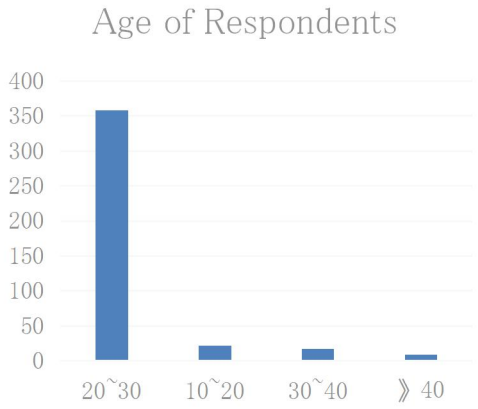


Figure 28.Age of respondents

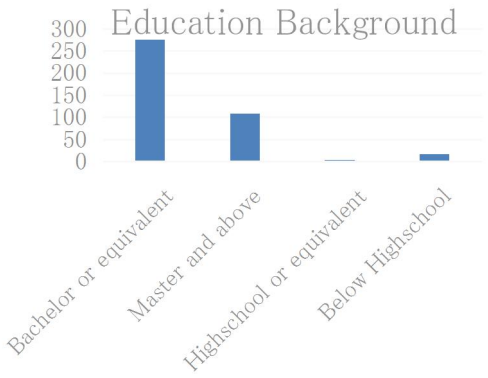


Figure 29.Education of respondents

The ages of respondents are concentrated to 20 to 30 which is the strongest purchasing power of the vehicle in the near future. Respondents with a bachelor degree and above are occupied over 95% which can prove the effective answers partly.

The utilities in this paper have been calculated under R program by conjoint analysis package (Andrzej Bak, 2018) . We use conjoint analysis to derive the part utility and importance of each attribute. The importance of seven attributes is shown in figure 30 and part utilities are listed in table 4 below.

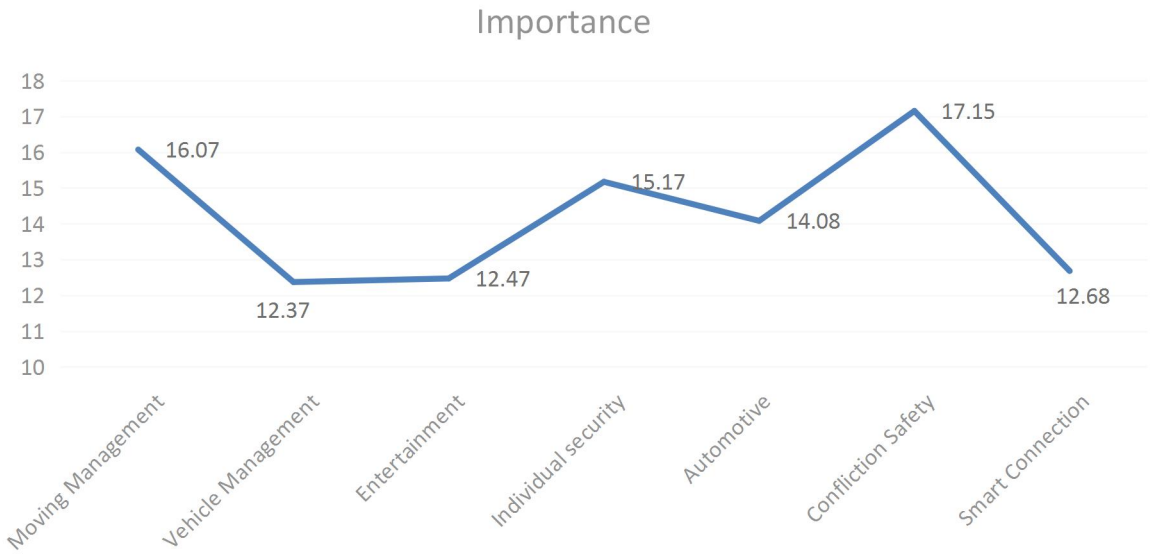


Figure 30.The importance of seven attributes

Table 4.The part utilities of IoV

	Moving management	Vehicle management	Entertainment	Individual security	Automotive	Confliction safety	Smart connection
High	34.50	24.27	13.16	49.74	34.64	55.78	13.54
Mid	-12.03	0.15	11.69	-0.66	-0.37	-0.21	11.42
Low	-22.96	-25.81	-24.86	-43.10	-30.84	-53.66	-2.49
F-statistic: 14.09						P-value: <2.2e-16	

As table 4 shows the F-statistic is 14.09, P-value is less than 2.2e-16. From the statistical aspect, this survey can be statistically acceptable. As figure 31 shows, the first three considerable points of the IoV among these respondents are confliction safety, moving management and individual security. And the most unattractive features are vehicle management, entertainment and smart connection which is a little bit surrealism for respondents. The magnetic functions are practicability over others. By contrast, other functions more likely happen in the science fiction movie or luxury vehicles. In some degree, they can reflect the people still take the vehicle as the safest transportation other than entertainment or management tools in the near future.In the beginning, if the investor invests too much in other functions like entertainment, it may meet a big culture shock in the market. To be specific, in terms of confliction safety, automotive, individual security and vehicle management, the difference of each level of a certain attribute is quite even which means technology level of this attribute would affect the customer evenly. However, the difference between the high level and middle level of the moving management is bigger than others (percentage) which means in moving management filed people are sensitive with the quality. On the other hand, for smart connection and entertainment, the difference between high level and mid-level is small which means the customer is not eager to buy the product with a high level of smart connection or entertainment.

3.2.4. Section Summary

Previously, researchers around the world are keen on the technology break-through of IoV along with the promotion of the IoV. However, is this way right or wrong? How it changes our lives and what is the benefit among customers are never studied before. Indeed, this is truly crucial for a future product since it may be born in the wrong time. This part is aimed at finding out the desirable attributes of IoV according to the report (PricewaterhouseCoopers, 2015). This is valuable because the developing process of IoV can be outlined and the value of the product can go through. In this paper, conjoint analysis is used for data mining. The surveys are posted online in China and over 400 effective questionnaires are received. Referred to the result, the culture shock between the traditional understanding of vehicle and the new definition of the vehicle is still exited even in the young generations. They take safety and essential driving as their most important consideration. And the advanced technologies like entertainment and smart connection which recognized as the hi-tech among youth are less attractive.

There are still some drawbacks of the method, even this survey is simplified by its best. However, the relationship between each question is not intensive. And the price is not considered in the survey. In future research, the drawbacks would take into consideration.

3.3. Quantitative IoV Attribute Preference: WTP Distribution of IoV Product by Survey

After the determination of the importance of each attribute, the WTP distribution of each attribute with the corresponding level would also important. For example, if improve the level of navigation system results fewer additional customer, the manufacturer has no motivation to do

so. This part would reveal the incremental price would result in the number of people who give up to buy.

3.3.1. Survey Design

In this section, we use the three attributes collected from the previous survey as the elements. The IoV products used in this survey all comprise of these three attributes with two quality levels: high quality and middle quality. This survey is also delivered via website (zhuzheqi, 2016) and the delivery window is from December 11, 2016 to February 11, 2017. Like the previous survey, this one is also in Chinese.

The survey contains three parts. The first is the description. Similar to the previous survey, some terms should be clarified. The details of the description are shown in figure 31 below.

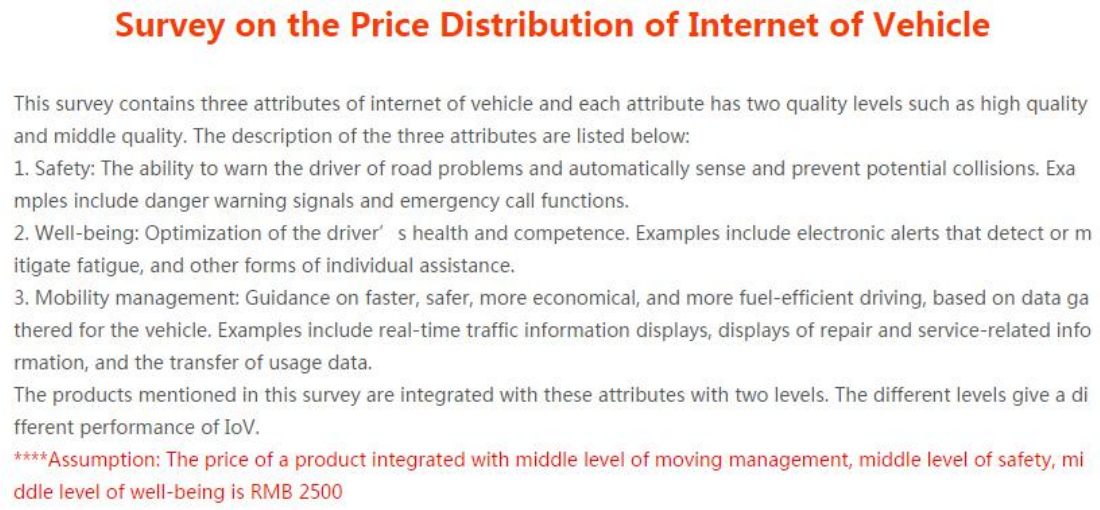


Figure 31.Description of the price distribution survey

The description gives details of each attribute and lists how the quality of the attributes are decided, as service quality standard (red ones). As the respondents may have no idea of the price of the corresponding product, we provide the reference price of a product with middle quality among all three attributes (green one) for comparison.

The following section is a WTP experiment with dichotomous questions. First, a product with a certain quality of three attributes and a reference price is given to the respondents to accept or decline. If the respondent accepts this price, a higher price would be given to bid and if not, the lower price would be given. After three turns, an open question would be given to the respondent. An example of the dichotomous question and the open question is listed below.

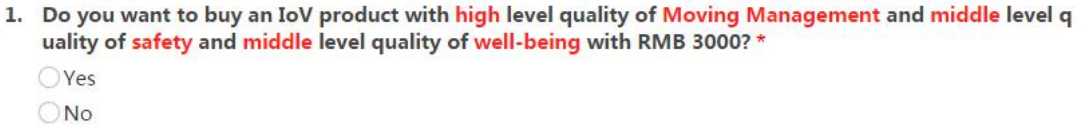


Figure 32.A dichotomous question

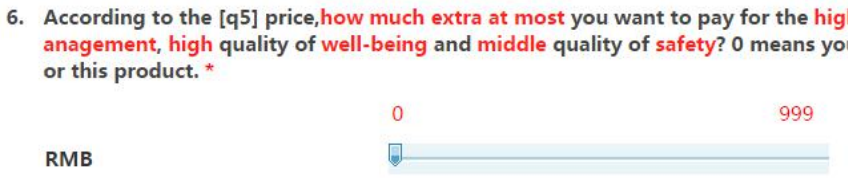


Figure 33.An open question

The last part is also a demographic question, which includes gender and salary.

The payment schemes of the dichotomous method are shown in figure 34.

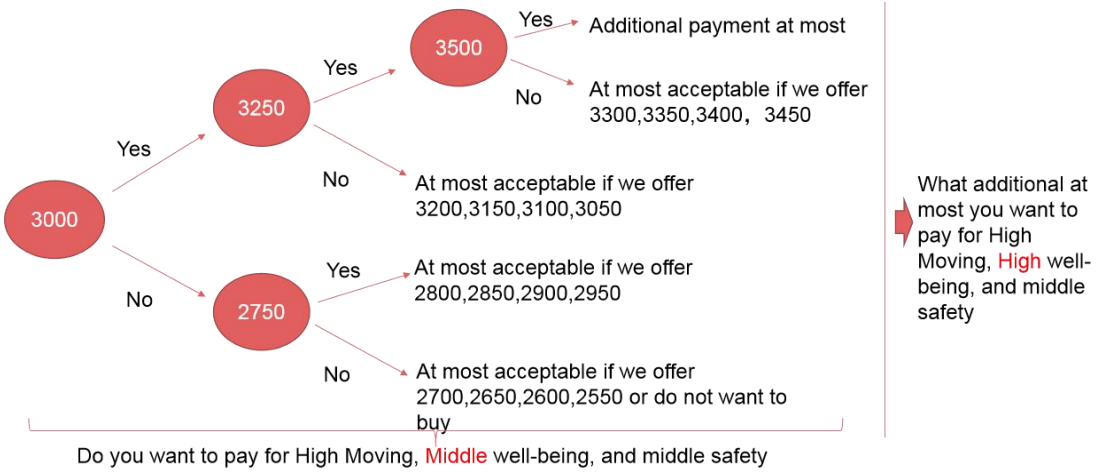


Figure 34.Bid scheme of the dichotomous method (CNY)

There are eight types of products and three of them are interviewed by bid process, as the other types of products are tested using open questions, owing to the workload. The other situation is tested by the extra payment method. For instance, according to the payment of high quality of moving management, middle quality of well-being, and middle quality of safety, how much extra do you want to pay for the high quality of moving management, high quality of well-being, and high quality of safety. Thus, the expected WTP of high quality of moving management, middle quality of well-being, and middle quality of safety can be described as high quality of moving management, high quality of well-being, and high quality of safety, plus the average value of the extra payment.

3.3.2. Calculation of Average Willingness to Pay of IoV Product

As the assumption of WTP, the bid price and individual characters (gender and salary in this study) can affect WTP. The decision of individual i, y_i whether to buy would be defined.

$$y_i = X_i\beta + bid_i b + \alpha \tag{2.1}$$

β, b, α are estimated parameters, bid_i is the bid price and X_i are characters of individual i.

According to the answers in the second survey, Hanemann (M., 1984) represented the single bound probability of affirmative answer and negative answer using the dichotomous method as follows:

$$P^y = 1 - D(bid, \theta) \tag{2.2}$$

$$P^n = D(bid, \theta) \tag{2.3}$$

P^y stands for the probability of affirmative answer (answer with yes) and P^n represents the probability of a negative answer. $D(bid, \theta)$ stands for the cumulative distribution function, (CDF) refers to the parameter θ and bid price bid. This also can be interpreted as the CDF of an individual's maximum WTP, as the response would be "yes" only the bid price is less than the maximum WTP.

For a normal product, the price distribution always has a long right tail (Chul-Yong Lee, 2016). Accordingly, the most widely used parametric distribution of WTP is the logistic and log-logistic function (Kerr, 2000). As the log-logistic function is better than the logistic one in terms of goodness-of-fit, this study uses the log-logit model. Bishop (Bishop, 1979) proposed $D(bid, \theta)$, which satisfied the log-Logit CDF as follows:

$$P^n = D(bid, \theta) = \left[1 + e^{\alpha - b(\ln(X_i\beta + bid_i b))}\right]^{-1} \tag{2.4}$$

where $\theta \equiv (a, b)$, which means that the estimated probability of price by the maximum likelihood method can be described as follows:

$$InL(\theta) = \sum_{i=1}^{N} \left\{ d_i^y \ln P^y(bid_i) + d_i^n \ln P^n(bid_i) \right\} \tag{2.5}$$

d_i^y and d_i^n are dummy variables. If the answer is yes, d_i^n equals 0 and d_i^y equals 1.

Based on this theory, this study uses three-turn bids. The level of the following bid price is referred to the answer of the previous bid price. For instance, if the individual accepts the first bid, the second bid price would be higher than the first one. If not, the price of the second bid would be lower. If the individual refuses the second bid with acceptance of the first bid, the third bid price would be between the first and second price. Thus, there would be eight situations in this study. (a) p^{yyy} all the answers are "yes"; (b) p^{nnn} all the answers are "no"; (C) p^{yny} first "yes" second "no," third "yes"; (d) p^{ynn} first "yes," second "no," third "no"; (e) p^{yyn} first "yes," second "yes," third "no"; (f) p^{nny} first "no," second "no," third "yes"; (g) p^{yyy} first "no," second "yes," third "yes"; (h) p^{nyn} first "no," second "yes," third "no." Under the assumption of utility maximizing of the respondent, the likelihood of the answer could be represented as follows. In the case of (a), bid_{i1} is the first bid price of respondent i. bid_{hi2} is the higher price of the second bid. bid_{hi3} is the higher price of the third bid.

$$p^{yyy}(bid_{i1}, bid_{hi2}, bid_{hi3}) = \Pr\{bid_{i1} \le \max WTP, bid_{hi2} \le \max WTP, bid_{hi3} \le \max WTP\}$$

$$= \Pr\{bid_{i1} \le \max WTP \mid bid_{hi2} \le \max WTP, bid_{hi3} \le \max WTP\} \Pr\{bid_{hi2} \le \max WTP \mid bid_{hi3} \le \max WTP\} \Pr\{bid_{hi3} \le \max WTP\}$$

$$= \Pr\{bid_{hi3} \le \max WTP\} = 1 - D(bid_{hi3}, \theta) \tag{2.6}$$

As $bid_{hi2} \le bid_{hi3}$, $\Pr\{bid_{hi2} \le \max WTP \mid bid_{hi3} \le \max WTP\} \equiv 1$. Thus, other cases are represented below:

$$P^{yny}(bid_{i1}, bid_{hi2}, bid_{li3}) = D(bid_{hi2}, \theta) - D(bid_{li3}, \theta) \quad (2.7)$$

$$P^{yyn}(bid_{i1}, bid_{hi2}, bid_{hi3}) = D(bid_{hi3}, \theta) - D(bid_{hi2}, \theta) \quad (2.8)$$

$$P^{nyy}(bid_{i1}, bid_{li2}, bid_{hi3}) = D(bid_{i1}, \theta) - D(bid_{hi3}, \theta) \quad (2.9)$$

$$P^{ynn}(bid_{i1}, bid_{hi2}, bid_{li3}) = D(bid_{li3}, \theta) - D(bid_{i1}, \theta) \quad (2.10)$$

$$P^{nny}(bid_{i1}, bid_{li2}, bid_{li3}) = D(bid_{li2}, \theta) - D(bid_{li3}, \theta) \quad (2.11)$$

$$P^{nyn}(bid_{i1}, bid_{li2}, bid_{hi3}) = D(bid_{hi3}, \theta) - D(bid_{li2}, \theta) \quad (2.12)$$

$$P^{nnn}(bid_{i1}, bid_{li2}, bid_{li3}) = D(bid_{li3}, \theta) \quad (2.13)$$

After these three-turn bids, the range of true WTP has narrowed rapidly and the log-likelihood function takes the form

$$InL(\theta) = \sum_{i=1}^{N} \{d_i^{yyy} \ln P^{yny}(bid_{i1}, bid_{hi2}, bid_{hi3}) + d_i^{yny} \ln P^{yny}(bid_{i1}, bid_{hi2}, bid_{li3}) +$$
$$d_i^{yyn} \ln P^{yyn}(bid_{i1}, bid_{hi2}, bid_{hi3}) + d_i^{nyy} \ln P^{nyy}(bid_{i1}, bid_{li2}, bid_{hi3}) + d_i^{ynn} \ln P^{ynn}(bid_{i1}, bid_{hi2}, bid_{li3}) +$$
$$d_i^{nny} \ln P^{nny}(bid_{i1}, bid_{li2}, bid_{li3}) + d_i^{nyn} \ln P^{nyn}(bid_{i1}, bid_{li2}, bid_{hi3}) + d_i^{nnn} \ln P^{nnn}(bid_{i1}, bid_{li2}, bid_{li3})\} \quad (2.14)$$

d_i^{nnn} is a dummy variable, and if it is equal to 1 it means that the respondent's answer is similar to case (a).

As Hanemann (M., 1984) mentions, the maximum likelihood (ML) estimation θ, can be solved by

$$\frac{\partial InL(\theta)}{\partial \theta} = 0 \quad (2.15)$$

Since $\theta \equiv (\alpha, \beta)$ according to Equation 4 and 1, the WTP can be expressed as

$$WTP = \exp(-\frac{\alpha + X\beta}{b}) \quad (2.16)$$

3.3.3. Result of Price Distribution

After delivering the questionnaire for over two months, we received 464 answers with 440 effective. Table 5 lists the payment willingness distribution of interviewees under the dichotomous method.

Table 5.Payment willingness distribution of interviewees under the dichotomous method

The product identification	The answer of the first bid	The answer of the second bid	The answer of the third bid	Number of people	Percentage of all people
HMM	No	No	No	42	9.5

MHM	No	No	No	50	11.4
MMH	No	No	No	30	6.8
HMM	Yes	Yes	Yes	90	20.4
MHM	Yes	Yes	Yes	135	30.6
MMH	Yes	Yes	Yes	150	34.0
HMM	Yes	Yes	No	42	9.5
MHM	Yes	Yes	No	40	9.0
MMH	Yes	Yes	No	35	8.0
HMM	Yes	No	Yes	12	2.7
MHM	Yes	No	Yes	15	3.4
MMH	Yes	No	Yes	15	3.4
HMM	No	Yes	Yes	4	0.9
MHM	No	Yes	Yes	20	4.5
MMH	No	Yes	Yes	15	3.4
HMM	No	No	Yes	10	2.3
MHM	No	No	Yes	15	3.4
MMH	No	No	Yes	5	1.1
HMM	No	Yes	No	18	4.1
MHM	No	Yes	No	15	3.4
MMH	No	Yes	No	25	5.7
HMM	Yes	No	No	82	18.6
MHM	Yes	No	No	70	15.9
MMH	Yes	No	No	120	27.2
HMM	NA[1]	NA	NA	140	31.8
MHM	NA	NA	NA	80	18.1
MMH	NA	NA	NA	45	10.2

NA1 “NA” means the respondent does not want to pay for this product

The decision regression function in this study is shown below.

$$y_i = \beta_1 age + \beta_2 gender + bid_i b + \alpha \quad (2.17)$$

Table 6.Description of parameters of the decision regression function

Parameters	Unit	Description
y_i		The decision dummy variable, 1 means yes, 0 means no
age	year	3 age ranges: 1 means 10~20, 2 means 20~30, 3 means 30~40
$gender$		1 means male, 0 means female
bid	RMB	The last bid price
μ_i		The intercept of regression

Table 7.Socio-demographic factors (N=440) and corresponding population data

Variables	Mean	Std. Dev.	Min	Max
Gender (male =1)	0.4	0.79	0	1
Age	5.19	28.4	20	40

Table 8.Coefficient of each parameter and statistics information

The product identification	a	Z-value	b	Z-value	β_1	Z-value	β_2	Z-value	Mc Fadden R2	AIC	Expected WTP
HMM	-24.19	-2.6**	0.006287	2.5*	1.35	1.4	1.24	1.0	0.339	33.46	3190
MHM	-10.33	-2.2*	0.004423	2.6**	-2.17	-1.99*	-0.10	-0.1	0.268	43.5	3288
MMH	-31.52	-2.8**	0.011196	2.8**	-4.59	-2.0*	0.01	0.01	0.554	31.29	3586
HHM	-24.19	-2.6**	0.006287	2.5*	1.35	1.4	1.24	1.0	0.339	33.46	3619
HMH	-24.19	-2.6**	0.006287	2.5*	1.35	1.4	1.24	1.0	0.339	33.46	3647
MHH	-10.33	-2.2*	0.004423	2.6**	-2.17	-1.99*	-0.10	-0.1	0.268	43.5	3790
HHH	-10.33	-2.2*	0.004423	2.6**	-2.17	-1.99*	-0.10	-0.1	0.268	43.5	4126

**p<0.001

*p<0.01

According to equation 17, the parameters and coefficients are listed in Table 8 above.

Table 5 and table 8 reveal the WTP distribution (relationships between price and number of people want to buy) of different types of products. For instance, the price distribution of products with high quality of moving management, middle quality of well-being, and middle quality of safety (HMM), middle quality of moving management, middle quality of well-being, and high quality of safety (MMH) and middle quality of moving management, high quality of well-being, and middle quality of safety (MHM) are shown below.

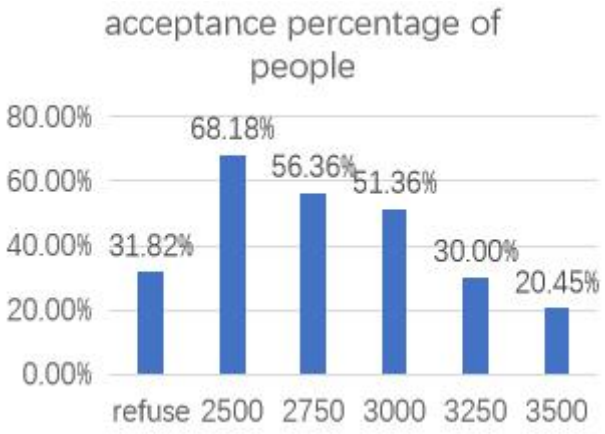


Figure 35.Price distribution of HMM

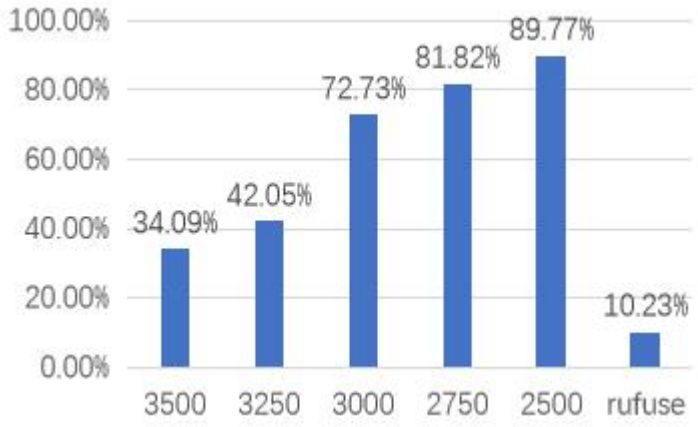


Figure 36.Price distribution of MMH

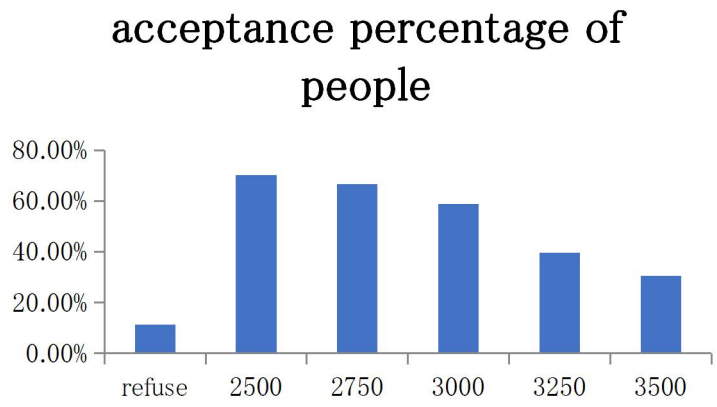


Figure 37.Price distribution of MHM

3.3.4. Discussion on the WTP Distribution

From figure 30 and Table 3, the favorable attribute of IoV for the Chinese is safety, with 17.15% importance. The top three concerning attributes are safety, moving management, and well-being, respectively. This is surprising, as the idea of IoV originates from entertainment (ranked sixth) and autonomous driving (ranked fourth), which seems not so attractive to the Chinese. In contrast, the considerations of a traditional vehicle, such as safety, still affect consumer decision making strongly. To test whether this is due to the respondents' unfamiliarity with IoV, we ask 10 randomly chosen respondents whether they had heard of IoV. They all answer yes. Therefore, we assume that the Chinese are not ready for rapid changes in vehicle systems. Even for future technologies, their primary consideration is still safety, which is one of the defining characteristics of a traditional vehicle. Table 7 proves this point. The Chinese are willing to pay an additional CNY 1000 (30% of the original price) in advanced security systems, e.g., the WTP difference between HHH and HMM. This payment is much higher than additional payments for the advanced moving management system (average CNY 150), e.g., the WTP difference between MMH and HMH. This is a guideline for technology management, which can enable a scientific arrangement of technology development. The manufacturer should first develop the attributes of security,

especially for the Chinese market. Similarly, with other attributes in Table 3, in the beginning, if the manufacturers invest too much in other functions such as entertainment, it may be a big culture shock for the market. Specifically, in terms of safety, autonomous driving, well-being, and vehicle management, the differences between each level of any certain attribute are quite even, which means that the high levels of this attribute would affect customer evenly. However, the difference between the high level and middle level of the moving management is bigger than in others (percentage). This means that in the field of moving management, people are sensitive to quality. On the other hand, for smart connect and entertainment, the difference between high level and mid-level is small, which is fine for respondents that prefer normal quality.

On the other hand, table 4 shows that some consumers do not want to pay for this product, e.g., answers with NA. Especially for HMM, over a quarter do not want to pay. Table 6 shows that respondents who take the second survey are mostly male and young (20~30), who consider this product. In technology management, designers should consider the growing share of female and elder population in the vehicle market. For example, designers can enhance the attributes of IoV for females or the elderly, e.g., beauty, and augmented reality.

3.3.5. Section Summary

This study gives a brief outline of each attribute of IoV and its presence in the Chinese market. There are two surveys included in this study. The first focuses on all the attributes and attempts to reveal the dominant attribute in the Chinese market. This survey is conducted with the rating scheme and evaluated by conjoint analysis. The results reveal that people in China are more concerned about safety-related attribute than entertainment or autonomous driving. In the second survey, the top three attributes picked up from the first survey are included in the questionnaire to make a virtual product. The CVM is used to construct the survey and the different dichotomous method with two bounds is built to collect the data. The WTP is evaluated by log-logit model. The second survey proves the result of the first survey that the security attribute of IoV is more attractive among people in China. The WTP distribution of the product is calculated.

The results of this study can be used as a guideline for technology management in IoV. Manufacturers can arrange systems and direct the development of technology. For customers, different IoV products can leave a holistic impression of the concept.

3.4. Related IoV Technologies of Customer Preferred Attributes

Since the top three preference attributes have been picked up, the technologies related to these attributes should be revealed. Because in this dissertation we would clarify the subsidy effect on technology development with multiple attributes. Therefore, what technologies manufacturer likes to develop and what technologies are core technologies of IoV product would be figured out first. By the previous section, the need for the customer has been revealed. The manufacturer should take this into account and transmit the needs into technology realization. This part is to

bridge the attractive attributes with corresponding technology by the method of expert interview.

3.4.1. Designing the Question Items

The main objective of this section is to identify core technologies according to the related attributes. However, there are many IoV related technologies and also this is a future product. In order to make the interview more professional, we collected the IoV related technical words. And we asked the professors major in the different engineering department at Chongqing University to category these technical words into six industries. Related professors give the standard of these catalogs. The process can be listed below:

1) Build up the technical words set. These words are coming from over 200 patents which support IoV technologies. The example of technical words set is shown in figure 38, the full set can be seen in Appendix A.
2) Shown this technical word set to each professor and ask him to pick up the technical words which belong to his technical field.
3) If this word belongs to his technical field, we would continue to ask whether this technical field has sub-branch and add this word to this technical field.
4) If this technical field has several sub-branches, we would ask again whether this word belongs to one of these sub-branches.
5) All these works have been done and go to the next word

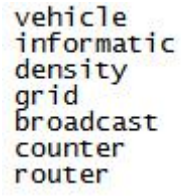


Figure 38. The example of technical words set

After the professors' classification, these technical words can be classified into six industries which included several sub-branches. This clarification is shown in figure 39.

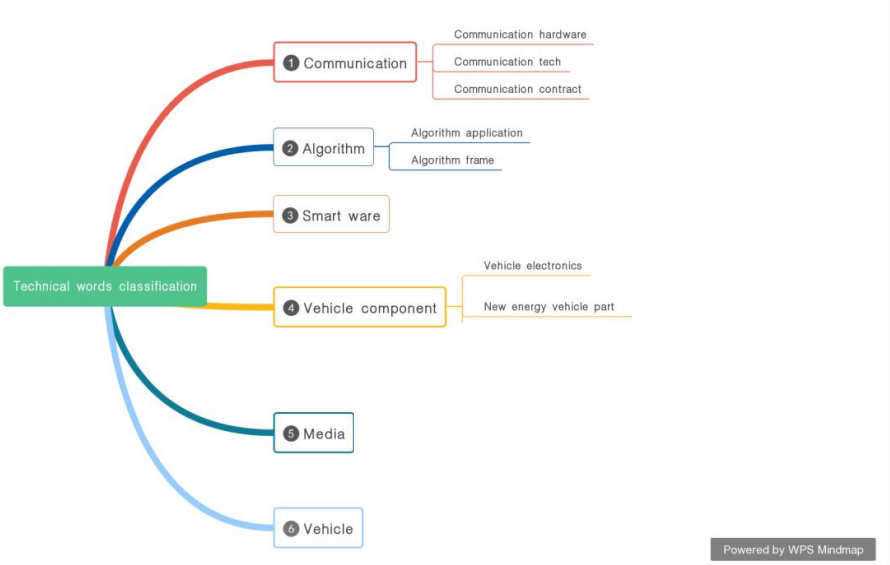


Figure 39.technical word classification

As we see from figure 39, we cluster the technical words into 6 types: communication, algorithm, smart ware, vehicle component, vehicle, and media. To be specific, six type technical words can be continuously classified as 11 sub-types: communication hardware, communication tech, communication contract, algorithm application, algorithm frame, smart ware, vehicle electronics, new energy vehicle part, traditional vehicle part, media, and vehicle.

These classifications are from the academic point of view. However, in the manufacturing stage, some theoretical technologies may not be realized by the limitation of manufacturer capability or some other limitations. Therefore, the expert in manufacturing field should take these technologies into account.

The main objective of this section is to identify the important technologies corresponding to the top three attributes. If there is more than one technology that supports the attribute, we should figure out the degree of importance qualitatively. In the meantime, we also should find out some characters of each core technologies like development risks.

In order to clear the target of this expert interview, we concluded the following three main topics based on the classification of technologies proposed above: first, according to the top three attributes, among the technologies classified by the professors, which technology is the core technology of each attribute; second, except for the classified technologies, is there any other technology which is more important than current core technology; Third, in terms of development risk, the rank of these core technologies.

3.4.2. Semi-structured Interview

To reveal the core technology of the top three attributes in the manufacturing field, we conducted the semi-structured interview. In this section, we would present the question examples asked during the interview process and demographics of experts and the approach of analysis.

A. Question Examples

During the expert interview process, we used various types of questions. We use the structured questions for the specific answers like the core technology of attribute well-being in terms of manufacturing processes. There still have many unforeseen questions on IoV by the formation of open questions, like how do you think IoV would change the vehicle industry. The semi-structured interview would be divided into two parts. One is the general outline of IoV and some insights given by the expert on IoV. The other part is our research questions. In order to make a logistical interview, the semi-structured questions have been listed in table 9 below.

Table 9. Structured questions

Question Index	Questions
Q1	What is the IoV effect on society?
Q2	What are the basic technologies that affect IoV most?
Q3	What technologies or aspects should manufacturers develop first?
Q4	Are there any advantages and disadvantages of these technologies?
Q5	Is there any real product in the market?
Q6	How about market competition?
Q7	According to the PwC report, which technologies would be related to any one

	of the IoV attributes?
Q8	Risks or costs among each support technologies?

The interview processes would be listed below according to the structured questions and the top three attributes and the classified technologies. During the interview process, some structured questions may be answered in the previous answer. Therefore these questions would be skipped. The processes are listed below:

- Self-introduction and given the target of this interview. The example question: My name is Zhu Zheqi from the University of Tokyo and I am a Ph.D. student on IoV strategy. I am here today for your brilliant insight idea on the future of IoV.
- Proposed open-end questions on the future of IoV. The example question: Do you think the state would keep an eye on the IoV as Tesla does?
- Shown the expert the top three attributes and the classified technologies.
- Put forward the structured question. The example question: Previously I have done a survey among customers that let them pick up the top 3 attributes they want to buy. According to the statistics, the top 3 are safety, moving management and well-being. In your opinion, among these three attributes, which technology would support each most among communication, algorithm and vehicle electronics.

B. Expert Demographic

We totally interviewed two experts in the IoV or vehicle industry. Both of them are the top expert in this field.

For the first interviewee:

- Name: Mr. Song
- Time: 10:00 a.m. – 11:00 a.m., 27th, November, 2017
- Interviewer: Mr. Zhu Zheqi
- Demographic: The first interviewee is the board secretary of an IoV technology company that the top 1 company on IoV in China and trading at Shenzhen Stock Exchange. Mr. Song, Ph.D., has been working in the IoV and strategy field for several years.

The second interviewee:

Name: Mr. Wang

- Time: 4:00 p.m. – 5:00 p.m., 4th December, 2017
- Interviewer: Mr. Zhu Zheqi
- Demographic: The second interviewee is the top 3 vehicle industry analyst among all the vehicle industry analysts in Chinese security corporations. Mr. Wang is still the chief analyst of the vehicle industry of a top 5 investment bank in China.

Since IoV is a future product, currently, there is fewer manufacturer try to do some research in this product because of the unclear market. Mr. Song is coming from the company that produces the exact IoV product. Though this product now may not contain all the attributes of IoV, this is the closest company who manufacturer the IoV product. Within his experience, he knows the technical issues during the manufacturing processes better than any others. He has been working in this field for 10 years. And over 200 employees are hired in his company.

Comparing with Mr. Song, Mr.Wang is the top vehicle industry analyst in China. He knows well on the government policy of the IoV. Also, he has written a report over 60 pages on the current status of IoV supported technology. He has been working in the vehicle industry for over 14 years.

According to their demographic, we want to reveal the specific answer from different people. For Mr. Song, we mainly focus on the technical realization in the manufacturing side and the core technology according to the top three attributes. Mr. Wang, we mainly consider the characters of each technology, like development risk, government support.

C. Interviews

The interviews were conducted between interviewee and me. They are all conducted face-to-face personally. All expert interviews were recorded using a phone recorder and explained this interview would be recorded.

D. Data analysis

For data analysis, we followed the qualitative content procedure. The three steps of this precede are: (1) data preparation, (2) coding categories, (3) interpretation. These three steps are described in details below:

1) Data preparation

In this step, we record the interview and separate the semi-structured answers and open-end answers.

2) Coding categories

Since there are many qualitative answers and comparison, we should make a standard to category these answers. We defined the main categories as high, middle and low. High means the relationship between both two factors are highly related or the character is very important for this technology. Middle means the relationship between both two factors are moderate related or the character is moderately important for this technology. Low means the relationship between both two factors are lower related or the character is less important for this technology.

3) Interpretation

In this step, we should translate the interview record into the category put forward in the last step. Some specific words would help us to define its category like core, most and so on. Also, some additional answers of open-end question would be translated here.

For example: when I ask previously I have done a survey among customers that let them pick up the top 3 attributes they want to buy. According to the statistics, the top 3 are safety, moving management and well-being. In your opinion, among these three attributes, which technology would support each most among communication, algorithm and vehicle electronics. Mr. Wang answered this is an interesting issue. From his view, he thought communication affect moving management most, followed by well-being and last is Safety. And this order is totally different from vehicle electronics. From the aspect of the algorithm, moving management comes first, followed by safety and last is well-being.

During this answer, we can reveal that in terms of communication technology, the relations between attributes and this technology from high to low are moving management, well-being, and safety.

3.4.3. Findings of Interview: communication, algorithm and vehicle component are the top three technologies.

After the expert interview process, we can conclude that communication technology is basic technology, followed by algorithm and vehicle electronics. Even media, smart ware are also

important for IoV, however, they may not consider as the choice at the beginning of IoV since it cannot be commercial even if it has been worked out. In China, government policy is another or main consideration for a company to select the technical path. And for some general attributes of the three fields are listed below:

Table 10.Some general attributes of the three fields

Attributes	Development Cost	Government support	Development Risk	Time Opportunity Cost	Benefit
Communication	High	High	High	Low	High
Algorithm	Low	Low	Low	Middle	Low
Vehicle Electronics	Middle	Middle	Middle	High	Middle

According to the relationship between IoV attributes and customers, the relationship between the three technology and the three attributes is listed below:

Table 11.The relationship between the three technologies and the three attributes

	Moving management	Well-being	Safety
Communication	High	High	Low
Algorithm	Middle	Low	Middle
Vehicle Electronics	Low	Middle	High

As we can see from table 10, the government supports communication technology most and also its cost is the biggest among the three core technologies. Among the three technologies, software technology has less support from the government through its development risk is lowest. This may result from the main cost of a software company is the human resources cost. Because of the mature market of the vehicle industry, the development risk of the vehicle electronic industry is less than the communication industry, especially during the communication updating time from 4G to 5G. Higher development cost means higher government support.

From table 11, we can figure out the communication technology support the moving management and well-being attribute most and vehicle electronic is the core technology of safety attribute. Therefore, the manufacturer would pick the right technology to develop into in order to win the corresponding market.

3.5. Summary

In this chapter, at first, some concepts of IoV are introduced including IoV and IoV products. It gives a fundamental understanding of IoV technology and what will do in this section. Second, in order to reveal the relationship between the customer and IoV products, two surveys are conducted and the data of price appetite and preference of customer are revealed. According to the WTP and conjoint analysis, the WTP distribution of customer is found and the corresponding issues are discussed. After the revealing of the top three attributes, we continue to figure out the related technology corresponding to these attributes. We collected the IoV related technical words and clustered into 6 groups and 11 sub-groups. These groups are technical fields defined by different professors and their students from corresponding departments. From the statistics view, major technical words are focused on communication, vehicle, and algorithm. To prove whether this is true in the manufacturer field, semi-structured interview of two expert interviews

have been arranged. From the expert view, the most important technology in IoV is communication. And the platform that supported by algorithm and vehicle electronics are also crucial for IoV. Some of the three technology attributes are also revealed in table 10. And all of the three technologies are currently under research in different companies. The relationship between customer choice and manufacturer choice is also revealed in table 11.

4. Simple Model of Subsidy Effect on New Technology Development with One Attribute

In the previous chapter, key technologies and consumer preference about IoV were ascertained. Then, this and next chapters take an approach with game theory because technology development and its diffusion are interdependent relations and thus a game theoretic model can appropriately address such a situation. In particular, we analyze the effects of the subsidy on technology development decisions using a game theoretic model comprising manufacturer players, customer players, and the government player.

As a simple model first, in this chapter, a model with two manufacturers, one government and one set of customers, which is modeled as a sequential game called Stackelbrg game, has been built to simulate the situation that the two manufacturers cannot change the technology attribute level but one has higher level than another. In reality, IoV may start to be developed from a certain of technology attribute first, for example, navigation. The resolution of it is highly depended on the technology supported by the capital investment. Therefore, a different company with different resources may result in IoV with different performance and this status cannot be changed within a short time. Also in order to go through the subsidy effect clearly and transit to complicate model smoothly, we set the technology level fixed in the simple model as a special case and leave the general one to the following chapter. The simple model is aimed to analyze this situation.

As the details will be explained in the following sections, the game theoretic models in this dissertation are constructed mainly focusing on price competition (chapter 4) and attribute level competition (chapter 5). Then, using the models, effects of subsidy to each attribute on decisions among manufacturer and customer players are analyzed especially by introducing the government player as an internal player who makes a decision rationally. Therefore, models in the dissertation can address a sort of mechanism under price and technology attribute competition. However, in industrial organization studies related to technology development, other factors like technology spillover, network externalities, R&D cost, etc. are often considered. However, this dissertation does not address them, but instead, does focus on more fundamental factors such as price and technology attribute level. We could clarify the mechanism on model structures with price and attribute competition. This is the framework that this dissertation addresses.

4.1. One Attribute with Fixed Technology Level Game

We consider a game-theoretic model comprising two manufacturers, customers, and the government, in which one manufacturer produces new products with advanced technology and the other manufacturer produces products with normal technology. Here, decisions are modeled as a four-stage game. As presented in Figure 40, The government first makes a decision about subsidy/tax, the normal manufacturer would decide its price before advanced manufacturer does,

and then customers make their decisions of purchasing products.

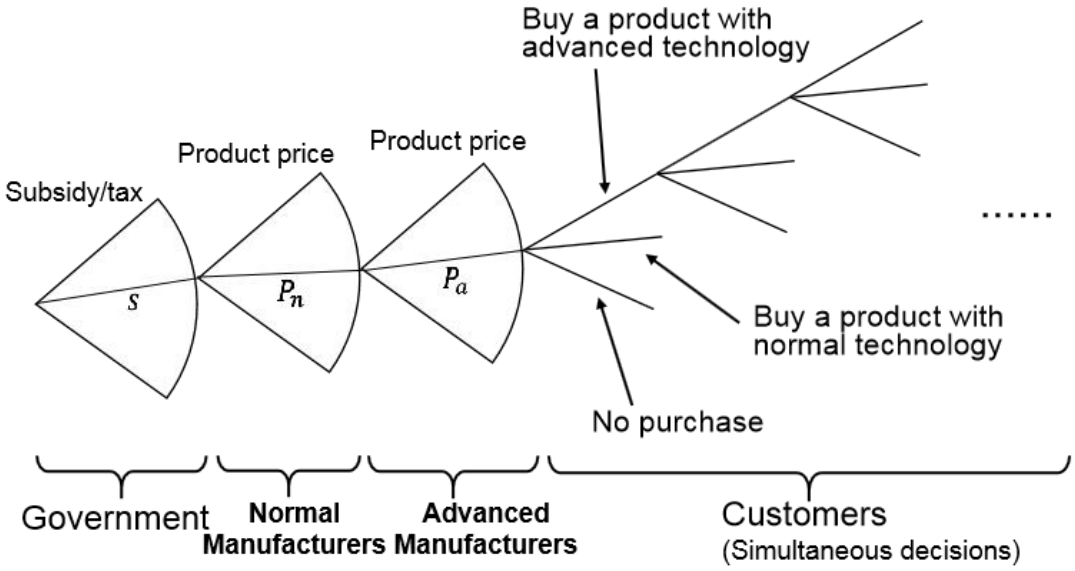


Figure 40.The game tree

4.1.1. Definition of Player

The players in the game are those who are closely related to the development of the new technology. In order to make this game easier to simulate and make the relationship more clear, in this chapter, three players are considered including government, customer and manufacturers.

Manufacturer: Manufacturer is the technology controller. The different manufacturer would remain its own technology level, which means technology intensive manufacturer would produce more advanced new technology. Two manufacturers are presented, one produces normal new technology and the other produce advanced new technology. Both of them only produce one type of new technology with the same attributes. The only difference between new technologies is the attribute level. For example, manufacturer A has a new technology with a middle quality of investigation and safety. Manufacturer B has a new technology with a middle quality of investigation and advanced quality of safety. In this chapter, the technology level of attributes of one manufacturer cannot be changed, which means the manufacturer can only produce one type of new technology with fixed technology level.

Government: people create Government. The target of the government is to protect the rights, occupations, and freedom of the people. The power of the government came from people. That is why the government would improve the social welfare by power delivery process. The role of government in technology management is that they establish the policies on technologies like forbidden, economical support. There are a lot of levels of government in China. In this research, only the state government would be taken into consideration, so that there is only one government in the game. The justification tool of government in this research is subsidy or tax.

Customer: Customer is the receiver of the new technology. The customer would buy new technology after taking price and quality account. In this chapter, the willingness to pay would be used as the description of the customer's needs. The customer would choose normal new technology or advanced new technology to buy or buy nothing. The only consideration for the

customer to buy one new technology or not is price.

4.1.2. Definition of Strategy

Strategies mean what options each side can choose. in this chapter, the aim is to find out the subsidy effect of new technology among each side.

Manufacturer: For a manufacturer, the price is set by them. However, this is depending on the willingness to pay of customer, government's policy and the competitors' price. in this chapter, there are two manufacturers, how to set price for each of the manufacturer is the key strategy.

Government: new technology is hi-tech which can improve social welfare in different ways. As the government would guide the technology to improve some specific welfare first. To awake customers' conscious, the government usually give an additional payment to the manufacturer if one target new technology has been sold to the customer. In this chapter, the strategy of the government is maximizing its own utility.

Customer: Customer do not know the technologies in details, they only know whether it is valuable for them to buy one new technology. In this chapter, the strategies of the customer are whether to buy a normal or advanced new technology at its corresponding price.

4.2. Game with Linear Cost Function

4.2.1. Model

Manufacturer

Manufacturer is assumed as a technology producer, so that they respectively have a different technology performance level. Because there are two manufacturers in the model, we call them "advanced manufacturer" and "normal manufacturer" and corresponding products are called "advanced product" and "normal product". The performance level is reflected on customer's willingness-to-pay (WTP), and thereby high performance makes customer's WTP high. The manufacturer j's profit is simply defined as

$$E_j = P_j Q_j - c_j(Q_j) \quad j \in \{a, n\} \tag{4.1}$$

where j stands for the index that identifies manufacturers: a means advanced manufacture and n is a normal manufacturer. Herein, P_j , Q_j and $c_j(\cdot)$ signify product price, sold quantity and production cost, respectively. For simplicity, the cost function is assumed to be a linear function, $c_j(Q_j) = \bar{c}_j Q_j$, where $\bar{c}_j$ means the production cost per unit and $\bar{c}_a > \bar{c}_n$ is assumed. Each manufacturer decides the price maximize their own profit.

Customer

Customer is assumed as a technology user. In the model, the customer's preference for technology is described by the magnitude of WTP for each product. Customers respectively have

a different WTP and customer i's WTP for manufacturer j's product is expressed as W_{ij} . Then, customer i's utility is defined as

$$U_i \begin{cases} W_{ia} - P_a & (purcha\sin g \quad an \quad advanced \quad product) \\ W_{in} - P_n & (purcha\sin g \quad an \quad normal \quad product) \\ 0 & (purcha\sin g \quad nothing) \end{cases} \tag{4.2}$$

Here, we assume that W_{ia} and W_{in} are uniformly distributed in $[W_{a\min}, W_{a\max}]$ and $[W_{n\min}, W_{n\max}]$ respectively, and also that for any i, $W_{in} < W_{ia}$ must be satisfied because the advanced technology can attain higher performance. Based on the profit function, each customer decides one from among purchasing an advanced product, a normal product, or nothing in order to maximize their profit.

Government

Government is a policymaker to promote new advanced technology or protect existing normal technology. We model the government as a decision-maker about subsidy or tax. It is assumed that in the case of new technology promotion, the government subsidizes the advanced manufacturer and in case of normal technology protection, tax is imposed on new technology. To express this situation, we introduce a variable, s, expressing that a positive s signifies the subsidy and a negative s the tax. The subsidy or tax is assumed to be directly reflected on the advanced product price, meaning that customers face the price of $P_a - s$ as the final price.

In the model, the two roles of technology are supposed: one is to benefit consumers and the other is to mitigate a sort of social costs that the government incurs. Then, the government profit is defined as follows:

$$G = G_b - SC - sQ_a \tag{4.3}$$

where G_b stands for the total customers' benefit, SC is social costs and sQ_a means the total subsidy payment (or tax income). Herein, G_b is defined as $G_b = \alpha_a Q_a + \alpha_n Q_n$ because the benefit depends on the total sold a number of both products; α_a and α_n respectively signify a coefficient, representing the amount of benefit per product; and $\alpha_a > \alpha_n$ is assumed because the new technology creates higher benefit for customers. In the meantime, SC is defined as $SC = \beta(1 - Q_a - Q_b)$, implying that as the total number of both products increases, the social cost decreases. To sum up, the new technology outperforms normal technology in terms of customer's benefit, and both technologies are at the same level with respect to social cost mitigation. Under this circumstance, the government as a policymaker makes a decision of subsidy (or tax) level to maximize the profit. However, s must be satisfied with $P_n < P_a - s$.

All variables are summarized in Table 12.

Table 12.The descriptions of abbreviation

Variable	Description
Customer side	
Q_n	The number of customers who purchase normal products
Q_a	The number of customers who purchase advanced products
F_n	The number of customers who can afford normal products
F_a	The number of customers who can afford advanced products
π_c	Consumer surplus (The total sum of customer's utility)
$W_{n\max}$	Maximum WTP of normal product among all customers
$W_{n\min}$	Minimum WTP of normal product among all customers
$W_{a\max}$	Maximum WTP of advanced product among all customers
$W_{a\min}$	Minimum WTP of advanced product among all customers
Manufacturer side	
P_a	Price of a advanced product
P_n	Price of a normal product
$\bar{c}_a$	Coefficient of production cost function of advanced products
$\bar{c}_n$	Coefficient of production cost function of normal products
E_i	Manufacturer i's profit function
Government side	
s	Subsidy or tax imposed on a advanced product
α_a	Coefficient of amount of benefit per advanced product
α_n	Coefficient of amount of benefit per normal product
β	Coefficient of social cost that the government incurs
G	Government's profit function
G_b	Total customer's benefit
SC	Social cost that the government incurs

4.2.2. Nash Equilibrium

Because this model is a four-stage game, Nash equilibrium is obtained by means of backward induction. First, let us consider the best response of customers at the third stage. Each customer independently decides whether to purchase a product or not. Their decisions are based on respective values of WTP, and in case of $U_i > 0$ customers will purchase a product. Therefore, the following affordable number of customers can be derived from the assumption of uniform distribution of WTP values.

$$Fa = 1 - \frac{Pa - s - Wa_{\min}}{Wa_{\max} - Wa_{\min}} \tag{4.4}$$

where Fa means the number of customers who can afford a product with advanced technology, which is normalized to 0-1 range. Similarly, the number of customers who can afford products with normal technology is derived:

$$Fn = 1 - \frac{Pn - Wn_{\min}}{Wn_{\max} - Wn_{\min}} \tag{4.5}$$

Similarly, Fn is normalized to 0-1 range.

By the assumptions of, $P_n < P_a - s$, and the $W_{in} < W_{ia}$ uniform distribution of WTPs, the number of purchased products, $Q_j, j \in (a,n)$, can be derived as the aggregated behavior of respective customer's best responses.

$$Q_a = F_a, Q_n = F_a - F_n \tag{4.6}$$

Second, we consider the normal manufacturer's best response. Since the normal product has been in the market before the adoption of the advanced product, decisions are usually made by normal manufacturer first, which means, in the backward process, the best response of advanced manufacturer would be derived before the normal one. Under a certain subsidy or tax scheme decided by the government, advanced manufacturer rationally chooses product price. Thereby, the best responses for the advanced manufacturer is obtained by solving the following first order conditions using Q_a above.

$$\frac{\partial E_a(P_a)}{\partial P_a} = 0 \tag{4.7}$$

Third, after solving the advanced manufacturer, under the subsidy or tax scheme of government, product price of the normal manufacturer would be derived by solving the following first order conditions using Q_n above.

$$\frac{\partial E_n(P_n)}{\partial P_n} = 0 \tag{4.8}$$

Fourth, we derive the best response of the government. Similarly to the manufacturer's case, it is obtained by solving the following first-order condition, substituting the best response prices and the purchased quantities in the government profit function.

$$\frac{\partial G(s)}{\partial s} = 0 \tag{4.9}$$

By that, the Nash equilibrium is obtained as follows:

$$s^* = \frac{\beta - \alpha_n + 2\alpha_a + 2\bar{c}_a - 2Wa_{\max}}{4} \tag{4.10}$$

$$Pa^* = \frac{\bar{c}_a + s^* + Wa_{\max}}{2} \tag{4.11}$$

$$Pn^* = \frac{(Wn_{\max} - Wn_{\min})(\bar{c}_a - s^*) + Wa_{\max}(Wn_{\max} + Wn_{\min}) - 2Wa_{\min}Wn_{\max}}{4(Wa_{\max} - Wa_{\min})} + \frac{\bar{c}_n}{2} \tag{4.12}$$

Let us define the equilibrium set as {s*, Pa*, Pn*}.
At the equilibrium, each player's profit is the following.

$$E_n = (P_n^* - \bar{c}_n)Q_n \tag{4.13}$$

$$E_a = (P_a^* - \bar{c}_a)Q_a \tag{4.14}$$

$$\pi_c = \frac{Qa(Wa_{\max} - Pa^*)}{2} + \frac{Qn((Pa^* - s^* - Wa_{\min})/(Wa_{\max} - Wa_{\min}) * (Wn_{\max} - Wn_{\min}) + Wn_{\min} - Pn^*)}{2} \tag{4.15}$$

$$G = \alpha_a Q_a + \alpha_n Q_n - \beta(1 - Q_a - Q_b) - sQ_a \tag{4.16}$$

where π_c means the consumer surplus, which is defined as $\pi_c = \sum_i U_i$.

Let us define the utility set as {Ea, En, G, π_c} and market share set {Qa, Qn}.

Proof is in appendix D.

4.2.3. Scenario Analysis of Equilibrium and Subsidy Effect Analysis

Since there are many independent variables and the target in this section is focused on the subsidy effect on technology development. The equilibrium in each scenario according to the government subsidy policy is analysis. The interval of government subsidy/tax policy (horizontal axis) in this section is from -2000 to 500. When the policy is below 0 means the government is collecting the tariff or extra tax from the advanced manufacturer, while it is over 0 means the subsidy to the advanced manufacturer. Other parameters are set according to the survey before. The current IoV product in the market is selling around 2000RMB, therefore Wn_{max} equal to 2000RMB. Wn_{min} should be smaller than 2000RMB, we assume it as 1000RMB. Cost of normal

product are current average cost in this market. And social benefit of normal product αn is depending on the cost of transportation ministry dividend by vehicle owners in China. The parameters of advanced product are assumptions based on each scenario.

A. Scenario one: $Wa_{min}>Wn_{max}$ and lower marginal profit of the advanced product is bigger than the normal product

Within this scenario, people's WTP of the advanced product is much higher than the normal product which results in even the minimum WTP of the advanced product are higher than the maximum WTP of the normal product.

Parameters setting: Wa_{max} = 5000, Wa_{min} = 3000, Wn_{max} = 2000, Wn_{min} = 1000, $\bar{c}_a = 1500$, $\bar{c}_n = 500$, $\alpha_n = 50$, $\alpha_a = 100$, $\beta = 80$.

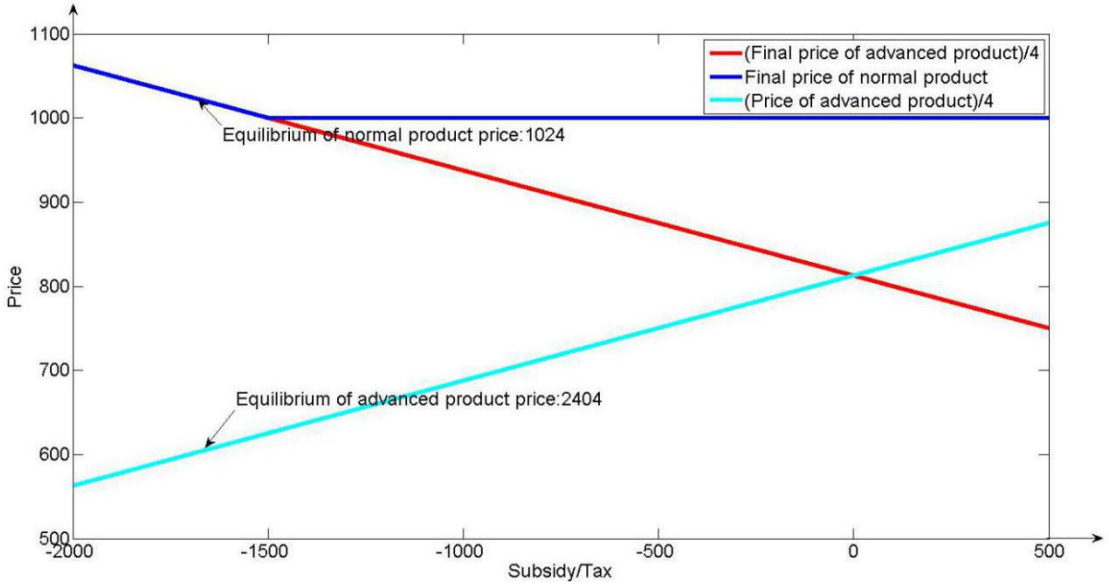


Figure 41.Best response of price in scenario one according to government financial policy

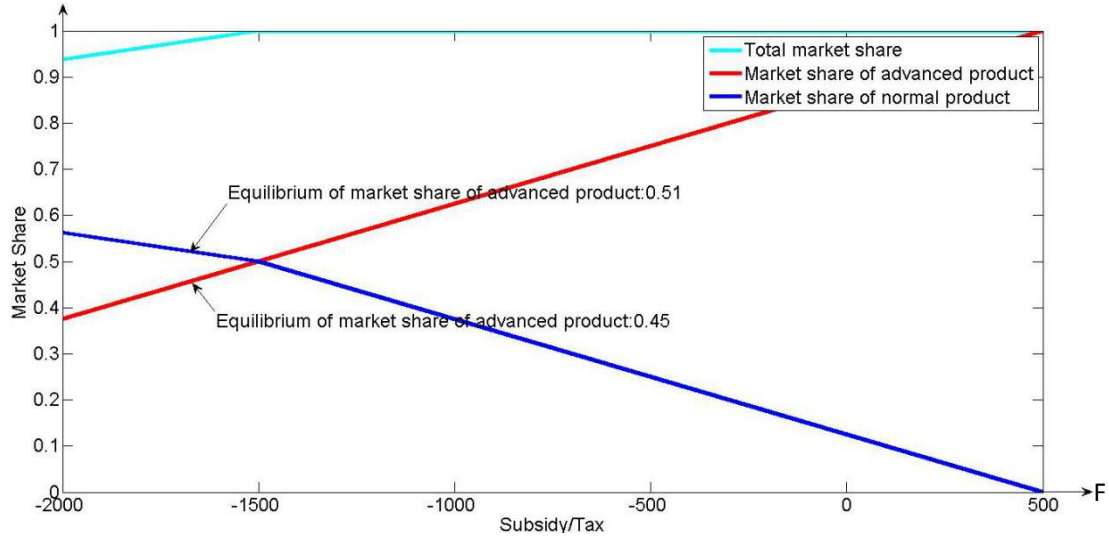


Figure 42.Best response of number of customers in scenario one according to government financial policy

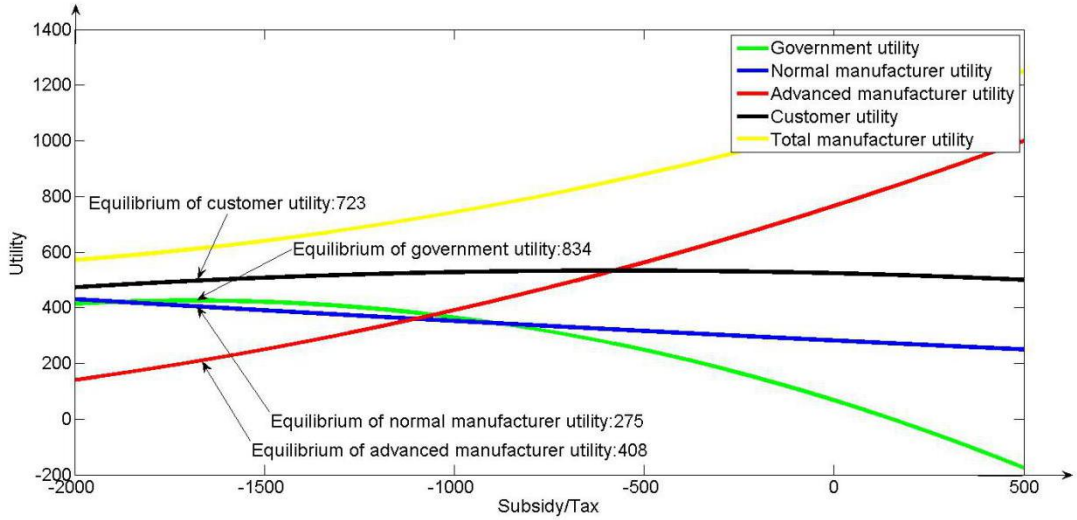


Figure 43.Best response of utilities of each side in scenario one according to government financial policy

As the equation 4.10 to 4.12, the equilibrium set can be revealed as {-1693, 2404, 1024} and the utility set is {408, 275,834,723}. They also can be seen in figure 41 and 43. As we see, the equilibrium of tax is 1693. In this scenario, the government would establish a high tax barrier which makes the final price of the advanced product very high (over 5000 in this case). Market share set of this scenario is {0.4519, 0.5214}. We can see from the market share set that even though the final price is much higher than the normal product. This results from the big advantage of customer preference, even the maximum WTP is smaller than the minimum WTP of the normal product. Because this situation is taken the government profit into account, we would discuss the policy effect on the new technology development process. In other words, reveal the sensitivity of other factors on changing subsidy or tax.

In scenario one, as shown in figure 41 and figure 43, accompanying with the decreasing tariff or increasing subsidy, the equilibrium price and market share of the advanced product are increasing heavily. By the contrary, the normal product equilibrium price and market share are decreasing. More specifically, in figure 43, the surplus of government decreases sharply while the surplus of total manufacturer increase rapidly and the surplus of the customer changing slightly if the government's tariff drops below around 1600 or turn to establish subsidy policy. Comparing with figure 43, the increasing surplus of the manufacturer is mainly contributed from the advanced manufacturer. Indeed, the surplus of traditional manufacturer decrease slightly and it nearly reaches to 0 when the government's subsidy rise to 500. In terms of the final price shown in figure 41, both of the final prices are decreasing when the tariff is decreasing, however, the final price of the advanced product decrease heavier than the normal product because of the higher marginal profit set in scenario one. In terms of total market share, the total market share is increasing all the way along the decreasing tariff and increasing subsidy and the normal product loss its share constantly in the sub-market, which means the advanced product grab the market share not only from the original people who can afford the normal product instead of advanced product one but also the people who cannot afford both at the beginning.

In terms of government, within the scenario, since the willingness of advanced product is much higher than the normal one and the marginal profit of new technology is higher than the normal one, the government's financial policy has many effects on the normal one. When decreasing tariff or increasing subsidy, the market share of the normal product is shaking and squeezed by

an advanced product even though the selling price of the normal product is decreasing until it reaches the minimum WTP of the customer, which result in the profit of normal manufacturer decrease sharply and be out of market easily. Regardless of budget and from the view of advanced product development, within this scenario, the active policy on advanced product development is useful.

In terms of different target of the government, the different policy would be established. In this scenario, in order to maximize the utility of customer, the government should establish a related lower tax around 600RMB. At this point, the market is fully occupied with 75% of the advanced product and 25% of the normal product. However, at this point, since the market is already fully occupied, the government need not continue to decrease the tax. Therefore, by contrast, considering the promotion of technology development, the government should only take actions until the whole market reach to 1, which means in this scenario, the government should take the tax around 1500RMB to make sure that the total market share reaches to 1. After that point, market share would not increase any more accompanying with the decreasing tax and this action would result in the decrease of the utility of government. Though the profit of advanced manufacturer increases, the utility of the normal manufacturer is decreasing. If the government takes the current employment into account, the government should take a higher tax from the advanced manufacturer in order to make the normal manufacturer profitable and prevent them from bankrupting.

In terms of manufacturer, the advanced manufacturer should persuade the government to give more financial support on this technology.

B. Scenario two: $Wa_{min}>Wn_{max}$ and marginal profit of the advanced product is smaller than the normal product

Within this scenario, though people's WTP of the advanced product is much higher than the normal product, the marginal profit of the advanced product is smaller than the normal product.

Parameters setting: Wa_{max} = 5000, Wa_{min} = 3000, Wn_{max} = 2000, Wn_{min} = 1000, Ca = 3500, Cn = 500, α_n = 50, α_a = 100, B = 80

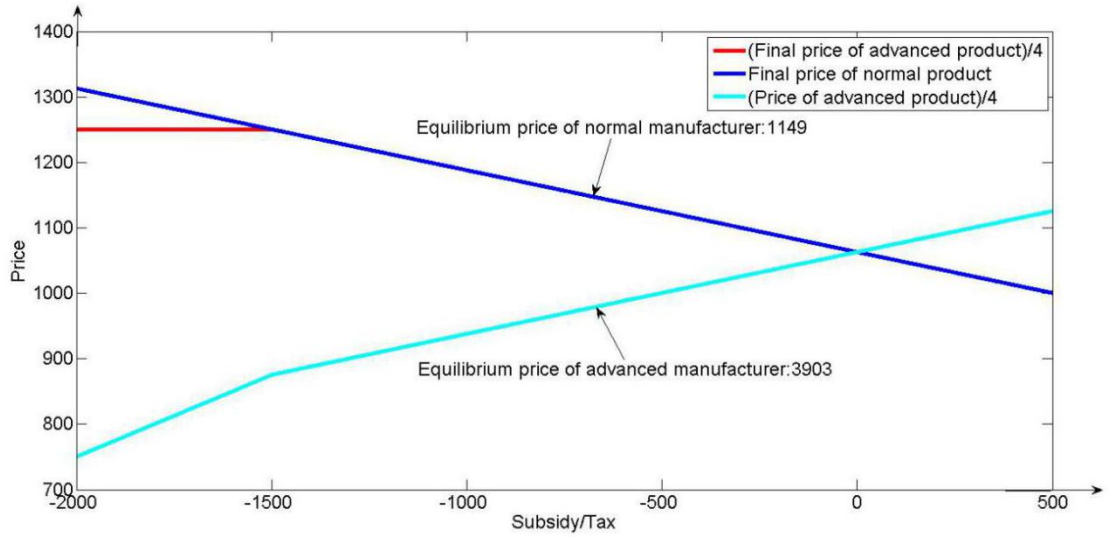


Figure 44.Best response of price in scenario two according to government financial policy

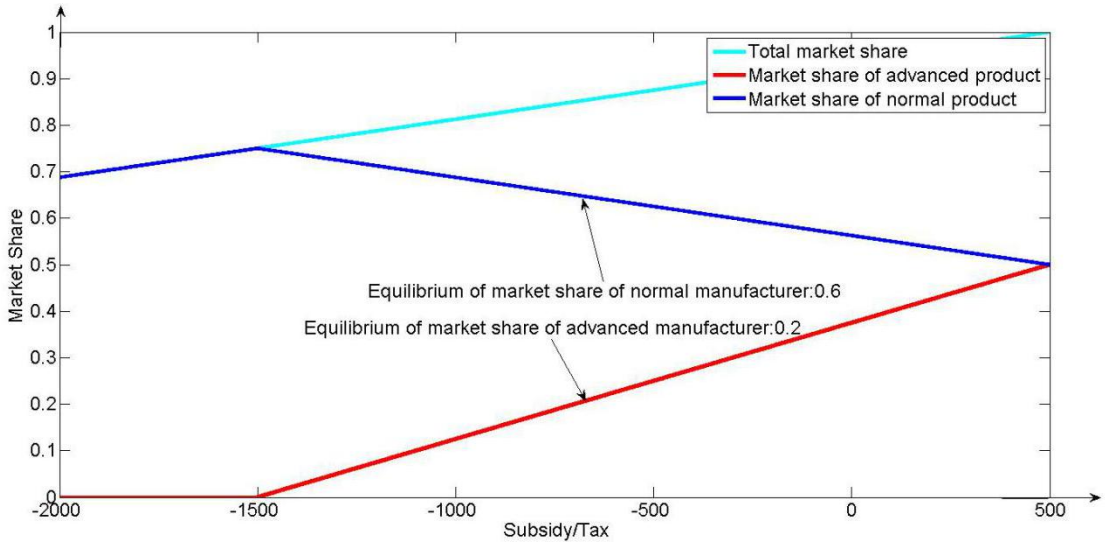


Figure 45.Best response of the number of customers in scenario two according to government financial policy

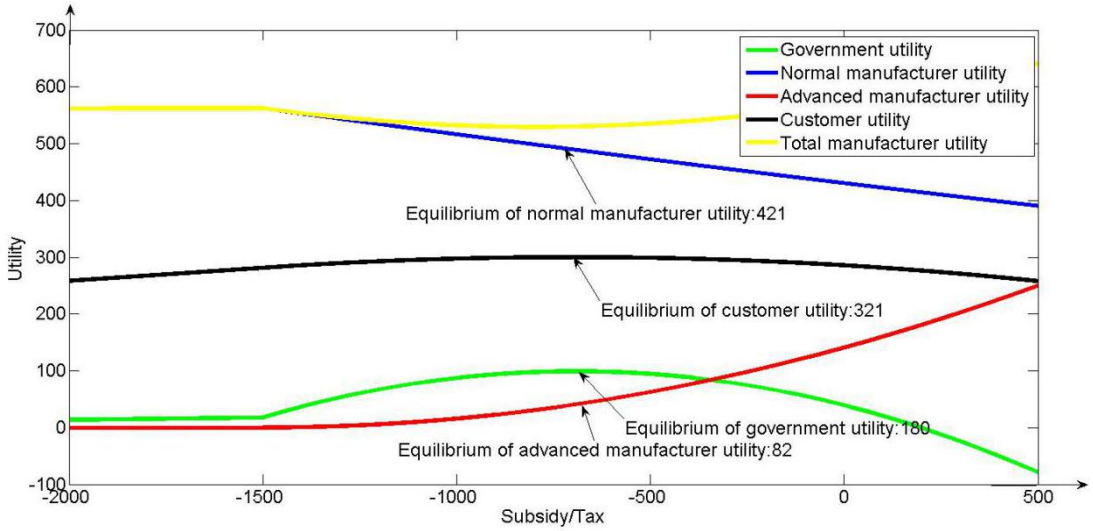


Figure 46.Best response of utilities of each side in scenario two according to government financial policy

As the equation 4.10 to 4.12, the equilibrium set can be revealed as {-693, 3903, 1149} and the utility set is {82, 421,180,321}. Market share is {0.2, 0.6}.They also can be seen in figure 44 and 46. Increasing the cost of the advanced manufacturer which means decreasing the profitability of the advanced manufacturer is great news to the normal manufacturer. Both the market share and price of normal product are increasing which result in the big rise in profit of the normal manufacturer. However, the government utility is decreasing heavily since the tax equilibrium is dropping down. Though the WTP of advanced product is still high, the decreased profitability push the final price of the advanced product to 3903, much higher than before. That is the core reason why the market drops down sharply. In terms of the total market, compared with the previous one, more people cannot afford both of the products, which means in this scenario, the government would make more effort on technology promotion. If we release the government's Nash equilibrium and the best response of other factors according to the subsidy, things will change as follow:

As figure 44 to figure 46 shows, when the government's tariff drop below 500 or even establish the subsidy policy, the tendency of each equilibrium parameters is the same as the previous scenario. The only difference is the exact value of each parameter corresponding to the same

financial policy. The tariff is extremely high at the beginning. If the government's tariff is going higher, the tendency would be changed. Because of the high tariff, the final price of the advanced product is higher than all the people who can afford them before which shown in figure 44. The market share of the advanced product would become zero. During that period, in figure 45 and 46, the market share of the normal product is increasing because of the dropping selling price and the profit of the normal manufacturer is stable. In terms of the total profit of the manufacturer, in the beginning, because of zero market share of the advanced product and the stable profit of the normal product, the total profit is stable. When the market share of the advanced product initiated, the total profit of the manufacturer would be affected mainly by the normal product at the beginning. That is because the marginal profit of the advanced product is smaller than the normal one, the total profit of the manufacturer is still decreasing along with the increasing sellings of the advanced product. Only the decremented profit of the normal product is less than the incremental profit of advanced product, the total profit of the manufacturer would increase.

In terms of government policy, within the scenario, since the marginal profit of the advanced product is smaller than the normal one, the lower bound of the advanced product's price is higher than the previous scenario, with the same financial policy, the equilibrium point of the market share of the advanced product is much lower than before and the selling price is also much higher than before. Even at some point, the market share of the advanced product may decrease to 0. The effect of government fiscal policy is bigger on advanced product development. Even with the same financial policy, the market share of the advanced product would increase slower, which strengthen the resilience of the normal product. The government is more powerful if the advanced product is imported. It can improve the competitive power of the domestic company by setting a higher tariff.

In terms of manufacturer, comparing with scenario one, the advanced manufacturer should improve its cost structure which takes advantage of marginal profit. For the normal manufacturer, one way is to develop the advanced product and the other is to save the cost.

In terms of subsidy effect and target of the government, in this scenario, the cost structure of the advanced product is worse than the normal product. If the government wants to increase the market share of this product, it should take more effort on this. In this scenario, government subsidy would reach to 500RMB instead of taking the tax from the advanced manufacturer if the government wants to promote this technology. If the government considers its utility and customer utilities, it would establish a lower tax plan around 600RMB. At this point, the utility of the normal manufacturer is much bigger than the advanced manufacturer, but the total market share is 0.85 and the market share of the normal product is nearly twice as the advanced product. This action is not good for technology development.

C. Scenario three: $Wa_{min} < Wn_{max}$ and marginal profit of the advanced product is bigger than the normal product

Within this scenario, people's WTP of the advanced product is slightly higher than the normal product which results in some people who cannot afford the advanced product before can make the payment on the advanced product now.

Parameters setting: Wa_{max} = 5000, Wa_{min} = 2000, Wn_{max} = 3000, Wn_{min} = 1000, Ca = 1500, Cn = 500, α_n = 50, α_a = 100, B = 80

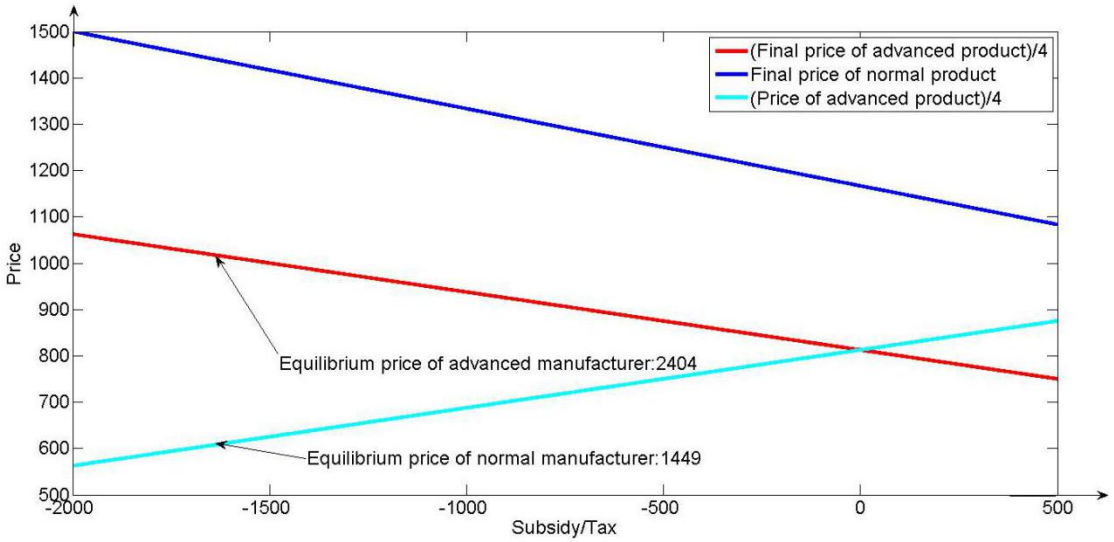


Figure 47.Best response of price in scenario three according to government financial policy

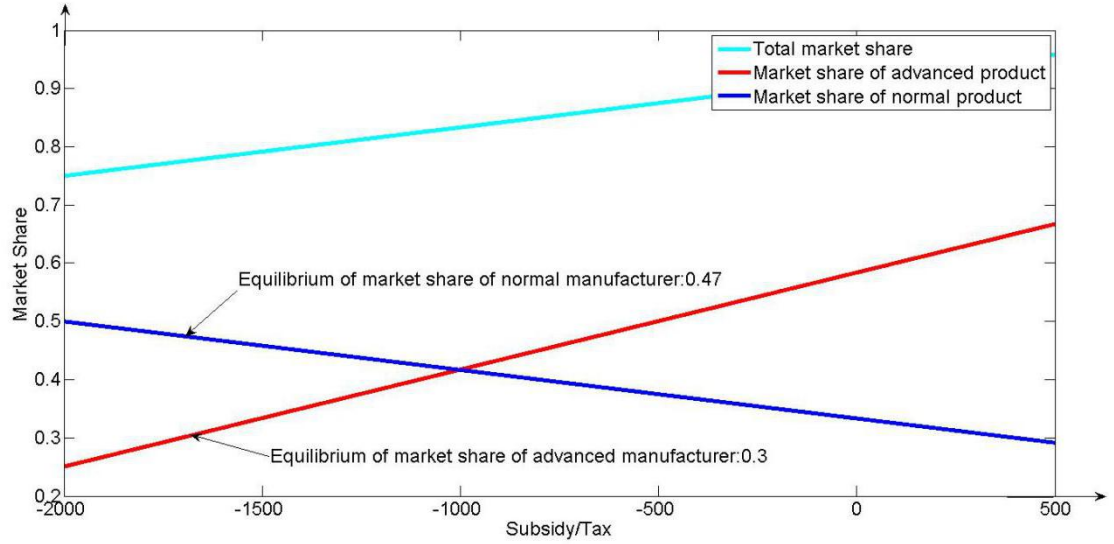


Figure 48.Best response of number of customers in scenario three according to government financial policy

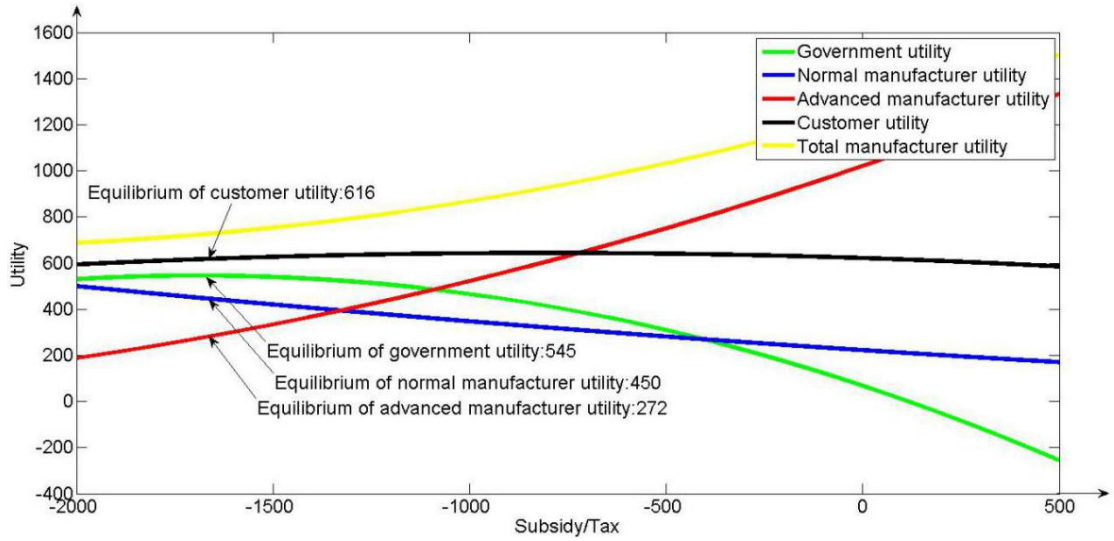


Figure 49.Best response of utilities of each side in scenario two according to government financial policy

As the equation 4.10 to 4.12, the equilibrium set can be revealed as {-1693, 2404, 1449} and the utility set is {272,450,545,616}. Market share is {0.30, 0.47}. They also can be seen in figure 47 to 49. Comparing with scenario one, it seems the equilibrium of Pa and s are not changed. Changing the customer preference for the normal product help increase the equilibrium price of the normal product, but the market share is drop down. The increasing price cannot offset the dropping market share results to the utility of the normal product is less than before. Because of the increasing popularity of the normal product, the market share of the advanced product is dropping. The total market share is the lowest among the three scenarios.

Comparing with scenario one, the surplus, market share of the advanced product would increase much slower than the situation in scenario one all the way along with the decreasing tariff. The elastic of the normal manufacturer parameters gets strengthen.

In terms of government policy, the government can also promote the technology industry by increasing the subsidy and in this way, the total market share of technology is also increasing.

In terms of manufacturer, similar to the situation in scenario two, normal product power has been strengthened. The difference is that the power is from the internal factor in the previous scenario, but in this scenario, the power is from the external factor. Take this into account, either the advanced manufacturer or normal manufacturer should improve the technology conscious in customers' minds, which would result in improvement of corresponding WTP.

Considering government target, this scenario is similar to scenario one, however, the degree is not the same because of the less popularity of the advanced product. If the government would promote this technology, the subsidy of the advanced manufacturer would be over 500RMB.

Go through all these scenarios, generally, in order to motivate the new technology market, the government should charge a higher tax on advanced manufacturing and encourage the advanced manufacturer to develop the technology to decrease its cost. The government also should increase the popularity of the advanced product that triggers the increasing of WTP of the advanced product.

4.2.4. Section Summary

In this section, advanced product development strategy has been discussed. A Stackelberg game model has been built among advanced product, normal product, government, and customer. Willingness to pay has been used to describe the customer needs that also link to the number of buyers. Three scenarios according to the willingness to pay and the cost of each product have been put forward. Within the situation that higher appreciation of the advanced product and better performance of marginal profit, the existence of the normal product would become a serious problem of government, even though the government collects a strict tariff from the advanced product. If the WTP of each product remains the same and the marginal profit of the normal product is higher, factors on the advanced product are more sensitive than before, especially for the market share. The incremental marginal profit of normal product improves the elastic of the normal product, though it's market share is still losing when subsidy goes up. By the contrary, if the appreciation of advanced product is slightly bigger than normal ones. Both market share and final price of advanced product are affected along with the decreasing tariff and also the elastic of normal product gets strengthen, though it also loses some market share compared with the situation of high appreciation with the same financial policy.

Generally, in order to motivate the new technology market, the government should charge a higher tax on advanced manufacturing and encourage the advanced manufacturer to develop the technology to decrease its cost. The government also should increase the popularity of advanced product that triggers the increasing of WTP of advanced product.

4.3. Summary

In this chapter, the relationships among customers, manufacturers, and government are discussed. The models of advanced product development with fixed technology level have been put forward. One normal manufacturer, one advanced manufacturer, government and customers are included to build the game. The government would only subsidy or put a tariff on the advanced manufacturer and leaves the normal product alone in this chapter.

The model simulates the situation with a linear cost function. Generally, in order to motivate the new technology market, the government should charge a higher tax on advanced manufacturing and encourage the advanced manufacturer to develop the technology to decrease its cost. The government also should increase the popularity of advanced product that triggers the increasing of WTP of advanced product.

In terms of policy analysis, three scenarios discussed in this part: 1. if Wamin>Wnmax and marginal profit of the advanced product is bigger than the normal product, government's financial policy has many effects on the normal product. 2. if Wamin>Wnmax and marginal profit of the advanced product is smaller than the normal product, The government's effect for advanced product and normal product are more reflected on the market share instead of price. 3. if Wamin < Wnmax and marginal profit of the advanced product are bigger than the normal product, the elastic of normal product performs better than the advanced product. The tendency of each parameter is nearly the same as the situation in scenario one.

5. Generalized Model of Subsidy Effect on New Technology Development with Multiple-attributes

In this chapter, a general model with two manufacturers, one government and one set of customer have been built to simulate a more complicated situation. The technology levels of attributes are changeable to meet the optimal utilities. According to the general model, a more specific model has been put forward to reveal the characters of the model. At last, a case based on the data in the previous chapter has been conducted and the Nash equilibrium points of the case have been calculated.

5.1. Changeable Technology Level Game

In this chapter, We also consider a game-theoretic model comprising two manufacturers, customers, and the government, in which one manufacturer produces new products with advanced technology and the other manufacturer produces products also with new technology. However, because of the brand names, the WTP of the products with the same technology levels produced by the different company may not be the same and also the inferior company can get higher WTP by choosing to produce the product with higher technology level. Here, decisions are modeled as a three-stage game. As presented in Figure 50, The government first makes a decision about subsidy, the two manufacturers make their decisions of the product price at the same time, and then customers make their decisions of purchasing products.

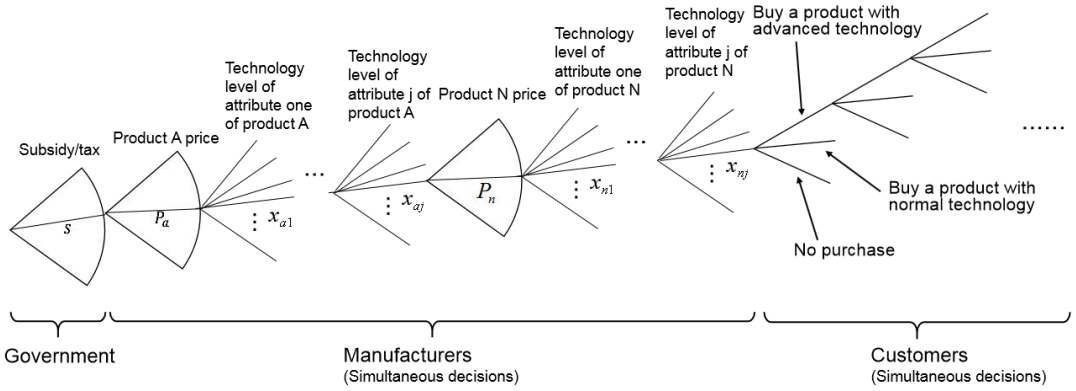


Figure 50.The game tree of changeable technology level model

5.1.1. Definition of Player

Manufacturer: In this chapter, there are two manufacturers called manufacturer A and manufacturer N. Each manufacturer can change its technology level of attributes of the product, which means the price of the normal product might be higher than the advanced product because of its higher technology level. However, there is still some difference between them. For

the product with the same technology level of attributes, just produced by different manufacturers, the WTP is still different from each other because of the brand premium.

Government: Government's definition is similar to the previous chapter. The difference is that financial tool in this chapter for government is subsidy only. Tax is not a consideration anymore. Because both manufacturers can offset competitors' advantage of WTP by changing the technology level, the dominant position does not belong to advanced manufacturer only. Another difference from the previous chapter is that government can give subsidy to both manufacturers if they meet the corresponding requirement of technology level.

Customer: Definition of the customer is mainly the same.

5.1.2. Definition of Strategy

Strategies mean what options each side can choose. In this chapter, the aim is to find out the best response to new technology on each side.

Manufacturer: for a manufacturer, they determine the price and technology level. However, this is depending on the willingness to pay of customer, government's policy and the competitors' price. in this chapter, there are two manufacturers, how to set price and technology level for each of the manufacturers are the key strategies.

Government: new technology is hi-tech which can improve social welfare in different ways. The government would guide the technology to improve some specific welfare first. To awake customers' conscious, the government usually give an additional payment to the manufacturer if one target new technology has been sold to the customer. In this chapter, the strategy of the government is how much and whether the subsidy of each technology level of attributes would be given to the manufacturers.

Customer: Customer do not know the technologies in details, they only know whether it is valuable for them to buy one new technology. In this chapter, the strategies of the customer are whether to buy the new technology.

5.2. General Model of Changeable Technology Level Game

In this section, a general model of changeable technology level game is put forward. This model has three stages, one is the sequential game that government's subsidy structure is proposed first and followed with the second stage that is a simultaneous game. In the second stage, Nash equilibrium points of price and technology of each attribute of each new technology would be determined. Finally, it is still a simultaneous game for the customer.

5.2.1. Model

Manufacturer

Consider an industry with two manufacturers, manufacturer A and manufacturer N, each corresponding product of which is called product A and product N, respectively. They plan to adopt a new technology, which consists of $\bar{j}$ kinds of attributes. Manufacturer *i*'s attribute *j* is described

by technology level, $x_{ij} \in \{1, \ldots, \bar{x}\}$. The different technology level has different performance, which is reflected in the customer's WTPs. Here, the manufacturer $i \in \{A, N\}$ decides a technology level on each attribute, defined by $x_i = (x_{i1}, x_{i2}, \ldots, x_{i\bar{j}})$ as a vector of levels. In addition, each manufacturer decides product price, P_i. For the sake of convenient description, P_i is separated into sup-prices on respective attributes: $p_{i1}, p_{i2}, \ldots, p_{i\bar{j}}$, assuming that $P_i = \sum_{j \in J} p_{ij}$ in which *J* means the set of attributes.

The manufacturer i's profit is simply defined as:

$$E_i = P_i Q_i - c_i(Q_i) \quad i \in \{A, N\} \tag{5.1}$$

where $c_i(\cdot)$ and Q_i are the production cost and sold quantity respectively. The amount of the quantity depends on the prices and technology levels of both manufacturers, so that Q_i is formally described as $Q_i(P_A, P_N, X_A, X_N)$ but we express it as Q_i for simplicity. The cost function is assumed to be a linear function as $c_i(Q_i) = \bar{c}_i Q_i$, where $\bar{c}_i$ means the production cost per unit and a function of X_i. We assume that $\frac{\partial \bar{c}_i}{\partial x_{ij}} \geq 0$ and $\frac{\partial^2 \bar{c}_i}{\partial x_{ij}^2} \geq 0$ for any *i* and *j*.

Each manufacturer decides price and technology level to maximize their own profit.

Government

Government is a policymaker to promote new technology. We model the government as a decision-maker about subsidy. We assume a subsidy is given on a technology attribute. Now, the subsidy is defined as S, which is a vector of subsidies on respective attributes: $S = (sb_1, sb_2, \ldots, sb_{\bar{j}})$. Herein, sb_j signifies a sub-subsidy on attribute *j* and means the amount per attribute level. Therefore, the total amount of subsidy per product unit is described as $S_i = \sum_{j \in J} sb_j x_{ij} (i = A, N)$. Similar to the simple model, the subsidy, S_i, is directly reflected on the manufacturer's product price. It is reasonable to assume that the subsidy is less than its cost, that is, $sb_i < \bar{c}_i$. Accordingly, customers face with the price of $P_i - S_i$. Now, defining $\bar{P}_i = P_i - S_i$, we can derive that $\frac{\partial \bar{P}_i}{\partial x_{ij}} \leq 0$ and $\frac{\partial^2 \bar{P}_i}{\partial x_{ij}^2} = 0$ because sb_j is the amount of subsidy per technology level per product unit and thus S_j is a linear function of x_{ij} for any *j*.

In the model, the two roles of technology are supposed: one is to benefit consumers and the other is to mitigate a sort of social costs that the government incurs. Previously, scholars mainly focus on the total social welfare where considers manufacturer and customers only. Indeed, the government is used to improve social welfare. However, there are millions of projects for the government to decide whether to give subsidy or not and the budget of a government is always limited. Also, some kind of social benefit like environment cannot be expressed by social welfare directly. In order to manage the governmental target generally, the government profit is defined as follows:

$$G = G_b - SC - \sum_{i\in\{A,N\}} S_i Q_i \tag{5.2}$$

where G_b stands for the total customers' benefit, SC is social costs and $S_i Q_i$ means the total subsidy payment of manufacturer *i*. Herein, G_b is defined as $G_b = \alpha_A Q_A + \alpha_N Q_N$ because the benefit depends on the total sold number of both products; α_A and α_N respectively signify a coefficient, representing the amount of benefit per product, for example different performance of navigation system would help the vehicle save energy by different level, that better performance of navigation system may save more energy and protect the environment more, therefore the coefficient of the better performance navigation system would be bigger than that of normal performance navigation system; In the meantime, SC is defined as $SC = \beta(1 - Q_A - Q_N)$, implying that as the total number of both products increases, the social cost decreases. Social cost means the payment of government that caused by the situations without the products, for instance, without the navigation system, vehicles would cost more energy that would result in more payment of government on environment protection. β is the equivalent government unit cost without the product. To sum up, the manufacturers' technologies are differentiated in terms of customer's benefit, but both technologies are in the same level with respect to social cost mitigation. Under this circumstance, the government as a policy maker makes a decision about subsidy level, $S_i (i = A, N)$ to maximize the profit.

Customer

Customer is assumed as a technology user. In the model, customer's preference for technology is described by the magnitude of WTP for each product. Unlike the simple model, we define WTP for each attribute: W_{ij}^k represents customer *k*'s WTP on attribute *j* by manufacturer *i*, assuming that $W_i^k = \sum_{j\in J} W_{ij}^k$, that is, the total sum of WTP values of all attributes means WTP for a product. Customer *k*'s utility is defined as

$$U_i \begin{cases} W_A^k - P_A & (purcha\sin g \quad manufacturer \quad A \quad techno\log y) \\ W_N^k - P_N & (purcha\sin g \quad manufacturer \quad N \quad techno\log y) \\ 0 & (purcha\sin g \quad nothing) \end{cases} \tag{5.3}$$

Customers respectively have different WTP values on respective attributes and we assume that

for a certain product produced by manufacturer *i*, W_i^k is uniformly distributed in $\left[W_i^{\min}, W_i^{\max} \right]$ with respect to *k*. Here, $W_i^{\min}$ and $W_i^{\max}$ are determined independently for each product, and also we make the following assumption.

Assumption 1: for any *j*, *k* and k', $W_{Aj}^k < W_{Aj}^{k'}$ is satisfied if and only if $W_{Nj}^k < W_{Nj}^{k'}$.

This assumption means that a customer with higher WTP on a certain attribute has always higher WTP on the same attribute for any products. Under this circumstance, customers decide one among purchasing a product A, a product N, or nothing in order to maximize their profit.

Before we discuss the sold quantity Qi, we additionally make several definitions.
Definition 1: The interval of the distribution of WTP for manufacturer i's product is defined as the length from the minimum to the maximum.

$$In_i = W_i^{\max} - W_i^{\min}$$

$$W_i^{\max} = \max\left\{ \sum_{j \in J} W_{ij}^k \mid k \in K \right\}$$

$$W_i^{\min} = \min\left\{ \sum_{j \in J} W_{ij}^k \mid k \in K \right\}$$

where *K* is the set of customers.

Definition 2: The critical point, cp, is defined to satisfy the following equation.

$$\frac{cp - P_A + P_N - W_N^{\min}}{W_N^{\max} - W_N^{\min}} = \frac{cp - W_A^{\min}}{W_A^{\max} - W_A^{\min}}$$

This equation means that the customer with the WTP of cp has a preference with no difference between products A and N.

Definition 3: Price of product N is normalized according to the rage of In_A. Then, normalized price, NP_N, is defined as

$$NP_N = W_A^{\min} + \frac{In_A}{In_N} \frac{(P_N - W_A^{\min})}{In_N}$$

Following the above definitions, some characters below can be derived clearly:

$$\begin{array}{lll} \frac{\partial NP_N}{\partial Pa} \geq 0 & \frac{\partial NP_N}{\partial In_A} \leq 0 & \frac{\partial NP_N}{\partial W_N^{\min}} \geq 0 \\ \frac{\partial^2 NP_N}{\partial Pa} = 0 & \frac{\partial NP_N}{\partial In_A} \geq 0 & \frac{\partial NP_N}{\partial W_A^{\min}} \leq 0 \end{array} \quad (5.4)$$

In the meantime, we assume the following conditions are satisfied.

$$\frac{\partial Q_A}{\partial cp} > 0 \quad \frac{\partial Q_A}{\partial NP_N} < 0 \quad \frac{\partial Q_N}{\partial cp} < 0$$
$$\frac{\partial Q_A^{\,2}}{\partial cp} = 0 \quad \frac{\partial Q_A^{\,2}}{\partial NP_N} = 0 \quad \frac{\partial Q_N^{\,2}}{\partial cp} = 0 \qquad (5.5)$$

For details of this part, the proof is in Appendix E proof 1 and proof 3.

All variables are summarized in Table 13.

Table 13. Variable lists in the model

abbreviation	descriptions
Customer side	
Qi	The number of people who buy the product produced by manufacturer i
$W_i^{\max}$	The maximum willingness to pay of product produced by manufacturer i
$W_i^{\min}$	The minimum willingness to pay of product produced by manufacturer i
$W_{ij}^{\,k}$	*Customer k*'s WTP on attribute *j* by manufacturer *i*
$W_{ij}^{\min}$	The minimum willingness to pay of attribute j of product i
$W_{ij}^{\max}$	The maximum willingness to pay of attribute j of product i
Ui	Utility of customer i
Manufacturer side	
P_i	The price of product produced by manufacturer i $i \in \{A, N\}$
$p_{i\bar{j}}$	Sup-prices on attribute j of product i $i \in \{A, N\}$
x_{ij}	Technology level of manufacturer *i*'s attribute *j* $x_{ij} \in \{1, \ldots, \bar{x}\}$
x_i	Vector of technology levels of product i $i \in \{A, N\}$
$c_i(\cdot)$	Production i's cost $i \in \{A, N\}$
$\overline{c}_i$	Production i's cost per unit $i \in \{A, N\}$
Ei	The utility of manufacturer i $i \in \{A, N\}$
Government side	
Si	Total amount of subsidy per product i
sb_j	The amount per attribute j level
G_b	Total government's benefit
SC	Social cost that the government incurs

α_i	Coefficient of amount of benefit per product produced by manufacturer i
β	Coefficient of social cost that the government incurs

5.2.2. Nash Equilibrium

Because this model is a three-stage game, Nash equilibrium is obtained by means of backward induction. First, let us consider the best response of customers at the third stage. As stated in the model part, number of customers for each product can be described as $Q_i(P_A, P_N, X_A, X_N)$ $i \in \{A, N\}$.

Second, we consider the manufacturer's best response $P_i^* = [P_A^*, P_N^*]$ and $x_i^* = (x_{i1}^*, x_{i2}^*, \ldots, x_{i\bar{j}}^*)$ $i \in \{A, N\}$ denotes the Nash equilibrium of the second stage corresponding to the specified first-stage subsidy profile $S = (sb_1, sb_2, \ldots, sb_{\bar{j}})$.

Assuming the interior optimum and second-order conditions, P_i^* and x_i^* can be characterized by:

$$\frac{\partial E_i}{\partial P_i} = 0 \quad \frac{\partial E_i}{\partial x_i} = 0 \qquad i \in \{A, N\} \tag{5.6}$$

Third, we derive the best response of the government. Similarly to the manufacturer's case, it is obtained by solving the following first-order condition, substituting the best response prices and the purchased quantities in the government profit function.

$$\frac{\partial G}{\partial S} = 0 \tag{5.7}$$

Since the solution cannot be solved analytically, simulation on a specific case would be put forward.

5.2.3. Subsidy Effect on Price and Technology Level

In this section, I analyzed how manufacturer A and N's price and corresponding technology level at the second-stage best response react to a change in the established subsidy unit S by the government in the first-stage game of the generalized model. Within this purpose, let $p_A f(S) = \frac{\partial P_A}{\partial S}$, $p_N f(S) = \frac{\partial P_N}{\partial S}$, $x_A f(S) = \frac{\partial X_A}{\partial S}$, $x_N f(S) = \frac{\partial X_N}{\partial S}$. Assume the possible solution area of second-stage is shown as:

$$\begin{pmatrix} \frac{\partial E_A}{\partial P_A} = 0 & \frac{\partial E_A}{\partial X_A} = 0 \\ \frac{\partial E_N}{\partial P_N} = 0 & \frac{\partial E_N}{\partial X_N} = 0 \end{pmatrix} \tag{5.8}$$

And each item in this matrix should be checked as follows:

$$\frac{\partial E_N}{\partial P_N} = Q_N + (P_N - \bar{c}_N)(\frac{\partial Q_N}{\partial cp}\frac{\partial cp}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N}\frac{\partial S_N}{\partial P_N} + \frac{\partial Q_N}{\partial NP_N}\frac{\partial NP_N}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial Sa}\frac{\partial S_N}{\partial P_N}) = 0 \tag{5.9}$$

$$\frac{\partial E_N}{\partial X_N} = -\overline{c}'Q_N + (P_N - \bar{c})(\frac{\partial Q_N}{\partial cp}(\frac{\partial cp}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N}\frac{\partial S_N}{\partial X_N} + \frac{\partial cp}{\partial W_N^{\min}}\frac{\partial W_N^{\min}}{\partial X_N} + \frac{\partial cp}{\partial In_N}\frac{\partial In_N}{\partial X_N}) + \frac{\partial Q_N}{\partial NP_N}(\frac{\partial NP_N}{\partial W_N^{\min}}\frac{\partial W_N^{\min}}{\partial X_N} + \frac{\partial NP_N}{\partial In_N}\frac{\partial In_N}{\partial X_N} + \frac{\partial NP_N}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N}\frac{\partial S_N}{\partial X_N})) = 0 \tag{5.10}$$

$$\frac{\partial E_A}{\partial P_A} = Q_A + (P_A - \bar{c}_A)\frac{\partial Q_A}{\partial cp}\frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}\frac{\partial S_A}{\partial P_A} = 0 \tag{5.11}$$

$$\frac{\partial E_A}{\partial X_A} = -\overline{c}_A'Q_A + (P_A - \bar{c}_A)(\frac{\partial Q_A}{\partial cp}(\frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}\frac{\partial S_A}{\partial X_A} + \frac{\partial cp}{\partial W_A^{\min}}\frac{\partial W_A^{\min}}{\partial X_A} + \frac{\partial cp}{\partial In_A}\frac{\partial In_A}{\partial X_A}) + \frac{\partial Q_A}{\partial W_A^{\min}}\frac{\partial W_A^{\min}}{\partial X_A} + \frac{\partial Q_A}{\partial In_N}\frac{\partial In_A}{\partial X_A}) = 0 \tag{5.12}$$

Assume the second order condition of second-stage game is satisfied. Pi, Xi can be characterized by the following matrix:

In terms of effect on selling price, according to equation 5.11, $p_A f(S)$ can be calculated by

$$p_A f(S) = \frac{-1}{(\frac{\partial Q_A}{\partial cp}\frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}\frac{\partial S_A}{\partial P_A})}\frac{\partial Q_N}{\partial cp}(\frac{\partial cp}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N} + \frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}) + \frac{Q_N}{(\frac{\partial Q_A}{\partial cp}\frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}\frac{\partial S_A}{\partial P_A})^2}(\frac{\partial Q_A}{\partial cp}\frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}\frac{\partial S_A}{\partial P_A})\Big/\partial S \tag{5.13}$$

According to 5.5 and 5.4, referring to the relationship between $\overline{P}_A$ and S_A within P_A, the following equation would be 0:

$$\partial(\frac{\partial Q_n}{\partial Td}\frac{\partial Td}{\partial Pn}\frac{\partial Pn}{\partial SPn^N})\Big/\partial sb = 0 \tag{5.14}$$

following would be satisfied:

$$\frac{\partial Q_A}{\partial cp}\frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}\frac{\partial S_A}{\partial P_A} < 0 \tag{5.15}$$

Therefore, the sign of $p_A f(S)$ would be determined by $\frac{\partial cp}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N} + \frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}$ and let this equation represented by symbol Δ and be defined as the critical point effect (CPA). Since the sign of $\frac{\partial cp}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N}$ and $\frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}$ are opposite to each other according to 5.4 and 5.5. $\frac{\partial cp}{\partial \overline{P}_i}\frac{\partial \overline{P}_i}{\partial S_i}$ stands for the degree of effect of subsidy of product i on the critical point.

If $\Delta > 0$, therefore $p_A f(S) < 0$, which means the best response of price of product A would decrease accompanying the increasing subsidy unit and vise versa.

In terms of the effect on technology level, according to equation 5.11, $x_A f(S)$ can be calculated by

$$x_A f(S) = \frac{\partial \overline{c}_A}{\partial S}\Big/\frac{\partial \overline{c}_A}{\partial X_A} = -p_A f(S)\Big/\frac{\partial \overline{c}_A}{\partial X_A} \tag{5.16}$$

Referring to equation 5.16, the sign of $x_A f(S)$ is opposite to. $p_A f(S)$

If $\Delta > 0$, therefore $p_A f(S) > 0$, which means the best response of technology level of product A would increase accompanying the increasing subsidy unit and vise versa.

Similar to the situation of firm A, effect on firm N can be revealed as follows:

In terms of effect on selling price, according to equation 5.9, 5.4 and 5.5:

, $p_N f(S)$ can be calculated by

$$p_N f(S) = {-\partial Q_N / \partial S} \Big/ {\sigma} + {Q_N} \Big/ {\sigma^2} \left(\frac{\partial \sigma}{\partial S}\right) \tag{5.17}$$

$$\sigma = \frac{\partial Q_N}{\partial cp}\frac{\partial cp}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N}\frac{\partial S_N}{\partial P_N} + \frac{\partial Q_N}{\partial NP_N}\frac{\partial NP_N}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N}\frac{\partial S_N}{\partial P_N} < 0 \tag{5.18}$$

$$\frac{\partial Q_N}{\partial S} = \frac{\partial Q_N}{\partial cp}\left(\frac{\partial cp}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N} + \frac{\partial cp}{\partial \overline{P}_A}\frac{\partial \overline{P}_A}{\partial S_A}\right) + \frac{\partial Q_N}{\partial NP_N}\frac{\partial NP_N}{\partial \overline{P}_N}\frac{\partial \overline{P}_N}{\partial S_N} \tag{5.19}$$

According to 5.4 and 5.5, referring to the relationship between $\overline{P}_N$ and S_N within P_N, the following equation would be 0:

$$\frac{\partial \sigma}{\partial S_i} = 0 \tag{5.20}$$

Therefore, the sign of $p_N f(S)$ would be determined by 5.19. Let us define 5.18 as, ζ, the inferior population effect (IPA).

If $\Delta > 0$, therefore $p_N f(S)$, which means the best response of price of product N would increase accompanying the increasing subsidy unit.

If $\Delta < 0$ and IPA is over 0, the price of product N would also increase accompanying with the increasing subsidy unit, $p_N f(S) > 0$.

Only if $\Delta < 0$ and IPA is below 0, the price of product N would decrease accompanying with the increasing subsidy unit, $p_N f(S) < 0$.

In terms of the effect on technology level, according to 5.9, $x_N f(S)$ can be calculated by

$$x_N f(S) = \frac{\partial \overline{c}_N}{\partial S} \Big/ \frac{\partial \overline{c}_N}{\partial X_N} = -p_N f(S) \Big/ \frac{\partial \overline{c}_N}{\partial X_N} \tag{5.21}$$

Referring to 5.16, the sign of $x_N f(S)$ is opposite to $p_N f(S)$.

As the previous stated, it is easy to verify that government can guide the technology level and selling price of manufacturers according to CPA and IPA. Let us make a short summary here. If $\Delta > 0$ met, $p_A f(S) < 0$, $x_A f(S) > 0$, $p_N f(S) > 0$ and $x_N f(S) < 0$ would be definitely satisfied regardless of the sign of ζ. In other words, an increase in subsidy by the government

unambiguously increase the equilibrium technology level of customer preferable firm (firm A) and decrease the equilibrium price of firm A. For firm N, the status is totally opposite. In contrast, if $\Delta < 0$ met, for firm A, $p_A f(S) > 0$ and $x_A f(S) < 0$ would be satisfied, which means an increase in subsidy by the government unambiguously decrease the equilibrium technology level of customer preferable firm (firm A) and increase the equilibrium price of firm A. However, for firm N, it is not always the case because of effect of ζ , sign of $p_N f(S)$ and $x_N f(S)$ cannot be determined. If both $\Delta < 0$ and $\zeta > 0$ met, $p_N f(S) > 0$ and $x_N f(Si) < 0$ would be held. I will say accompanying with increasing subsidy by the government, the equilibrium technology level of firm N is decreasing while the price of firm N is increasing. On the other hand, If $\Delta < 0$ and $\zeta < 0$ met, $p_N f(S) < 0$ and $x_N f(S) > 0$ would be held. That is increasing government subsidy would increase the technology level of firm A and decreasing the selling price at the same time.

5.2.4. Section Summary

In this section, some characters of changeable technology level game have been revealed in the general model. The best response of technology level and price can be modified by the government's subsidy policy. Two technical items have been defined as the government's policy including inferior effect factor $\frac{\partial Q_a}{\partial cp}(\frac{\partial cp}{\partial P_A}\frac{\partial P_A}{\partial S_A}+\frac{\partial cp}{\partial P_N}\frac{\partial P_N}{\partial S_N})+\frac{\partial Q_a}{\partial NP_N}\frac{\partial NP_N}{\partial P_A}\frac{\partial P_A}{\partial S_A}$ (IPA) and critical point effect factor $\frac{\partial cp}{\partial P_A}\frac{\partial P_A}{\partial S_A}+\frac{\partial cp}{\partial P_N}\frac{\partial P_N}{\partial S_N}$ (CPA). The physical meaning of IPA is the subsidy effect on the quantity of inferior product and CPA is the subsidy effect on the critical point. The direction of the subsidy effect on manufacturers is determined by both of the two factors The main conclusions of my analysis are succinctly summarized in table 14, where a "+", "-" means the increasing and decreasing function respectively. Generally, there are four situations, for example, critical conditions of situation 1 are CPA and IPA bigger than 0 that means accompanying with the increasing subsidy, the number of inferior products and critical point is increasing. If both of these conditions are satisfied, increasing subsidy would increase the technology level of product N and decrease the price of product N, while product A has the opposite performance.

Table 14.Subsidy effect summary

Index	Critical Conditions		Technology Level		Selling Price	
	CPA	IPA	Firm N	Firm A	Firm N	Firm A
1	>0	>0	+	-	-	+
2	>0	0<	+	-	-	+
3	0<	>0	-	-	+	+
4	0<	0<	-	+	+	-

5.3. Scenario Analysis of Changeable Technology Level Game

In this section, I discuss a specific model which all the assumptions are satisfied with the last section.

5.3.1. Inputs Preparation

We assume there are two firms A and N and each product has two attributes p and q in the scenario section. Also, each attribute has three technology levels, represented by 1, 2, 3. The lowest technology level is 1 and the highest technology level is 3 respectively. Besides the definition and assumption in the general model, in order to simulation calculations, other three constrains are specified as follow:

$$\frac{\partial(W_{ij}^{\max} - W_{ij}^{\min})}{\partial x_{ij}} = a_{ij} > 0$$

$$\frac{\partial^2(W_{ij}^{\max} - W_{ij}^{\min})}{\partial x_{ij}^{\ 2}} = 0$$

$$W_{ijx_{ij}}^{\min} = j * b_{ij} + W_{ij1}^{\min}$$

This assumption means the WTP interval of attribute is a linear function of technology level and the minimum WTP of attribute j with attribute level of x_{ij} of product i is a linear function of minimum WTP of the same attribute with attribute level of 1 (lowest attribute) of the same product. $W_{ijx_{ij}}^{\min}$ represented for minimum WTP of attribute j with attribute level of x_{ij} of product i.

And also the cost function per product unit is defined as $\overline{c}_i = c_{ip}x_{ip} + c_{iq}x_{iq}$,

where c_{ip} and c_{iq} are the cost per unit of attribute p and q respectively.

Therefore the parameters list in the scenario section can be shown in table 15.

Table 15. Variable lists in the model

abbreviation	descriptions
Customer side	
$W_{ij1}^{\max}$	The maximum willingness to pay of the lowest technology level of attribute j of product i. $i \in \{A, N\}$, $j \in \{p, q\}$
$W_{ij1}^{\min}$	The minimum willingness to pay of the lowest technology level of attribute j of product i. $i \in \{A, N\}$, $j \in \{p, q\}$
b_{ij}	The gap between minimum willingness to pay of attribute j of product i per technology level. $i \in \{A, N\}$, $j \in \{p, q\}$
Manufacturer side	

c_{ij}	cost per unit of attribute j of product i per technology level $i \in \{A, N\}$, $j \in \{p, q\}$
Government side	
α_{ij}	Coefficient of amount of social benefit of attribute j of product i per technology level $i \in \{A, N\}$, $j \in \{p, q\}$
β	Coefficient of social cost that the government incurs

5.3.2. Identical Manufacturer Scenario

In this section, a special case in which two manufacturers are totally the same would be calculated analytically.

The uniform function of WTP of each product is the same Therefore, both of the two manufacturers have no difference between each other.

Since both manufacturers are identical with each other, this kind of situation is similar to Bertrand game. The lower ratio of the final price to the corresponding price interval, the whole market would be taken by that product because of higher utility. The best responses of manufacturers are:

$$\begin{cases} x_{Ap} = x_{Np} \\ x_{Aq} = x_{Nq} \end{cases} \text{ or } \frac{x_{Ap} - x_{Np}}{x_{Aq} - x_{Nq}} = \frac{c_{Ap} - sb_p - b_{Aq}}{c_{Aq} - sb_q - b_{Ap}}$$

Proof in appendix E named proof 1 and 2.

5.3.3. Scenario Analysis

In this section, an extra assumption is made which is that the subsidy for both attributes per technology level is changing from 0 to 1000 and the interval is 50. Each attribute has three technology levels. For a certain subsidy plan, there might be several best response of each manufacturer because of the different combination of price and technology level, during the analysis in this section, the best response of each manufacturer at a certain subsidy plan is picked up according to the maximum utility of government at the certain subsidy plan.

scenario 1: Cost unit c_{ij} of different product with the same specific technology level is the same, which means two manufacturers are totally identical. Parameters in this scenario are listed in table 16 below.

Table 16.The corresponding values of parameters in this section

Parameters	Values in this paper	Parameters	Values in this paper
Customer side			
$W_{Np1}^{\min}$	1250RMB	$W_{Np1}^{\max}$	1600RMB
$W_{Nq1}^{\min}$	1400RMB	$W_{Nq1}^{\max}$	1800RMB

$W_{Ap1}^{\min}$	1250RMB	$W_{Ap1}^{\max}$	1600RMB
$W_{Aq1}^{\min}$	1400RMB	$W_{Aq1}^{\max}$	1800RMB
b_{Ap}	600RMB	b_{Aq}	900RMB
b_{Np}	600RMB	b_{Nq}	900RMB
Manufacturer side			
c_{Np}	400	c_{Nq}	700
c_{Ap}	400	c_{Aq}	700
Government side			
α_{Ap}	15	α_{Aq}	20
α_{Np}	15	α_{Nq}	20
β	30		

In this scenario, the model is simplified as model 1. The best response is shown in table 17.

Table 17.The picked up best response point of scenario 1

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3310	3310	0	0	135	5	5	2295	0.5	0.5
3	3	3	3	3310	3310	50	300	-915	5	5	2820	0.5	0.5
3	3	3	3	3310	3310	150	550	-1965	5	5	3345	0.5	0.5
2	3	2	3	2910	2910	1000	100	-2180	5	5	3170	0.5	0.5
2	3	2	3	2910	2910	800	300	-2380	5	5	3270	0.5	0.5
2	3	2	3	2910	2910	450	650	-2730	5	5	3445	0.5	0.5
3	2	3	2	2610	2610	100	1000	-2185	5	5	3145	0.5	0.5
3	2	3	2	2610	2610	200	900	-2285	5	5	3195	0.5	0.5
3	2	3	2	2610	2610	350	750	-2435	5	5	3270	0.5	0.5

Table 18.Nash equilibrium of scenario 1

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3310	3310	0	0	135	5	5	2295	0.5	0.5

We can see from table 18, the best action for the government is to take no actions and the equilibrium technology level of both manufacturers would be the highest technology level. Since they are totally the same as each other, they will share the market at their corresponding costs. If we change the subsidy profile of government, the best response of manufacturers can be changed.

As the previous section stated, scenario 1 simulated the identical manufacturer. Both of the identical manufacturers would cut down its price until it reaches to its cost. However, as table 18 shows, P_A and P_N, indeed, do not equal to their corresponding cost no matter which technology

level it is. They are both 10 RMB higher than its corresponding cost at a certain technology level. That is because the parameter setting of the incremental price is 10.

As table 17, considering both technology promotion and the current payoff of government, there is no doubt that the government would choose 0 subsidies. The options of the best response to technology level are 3 instead of 2. According to the assumption of uniform distribution of WTP, in this scenario, customer's decision can be simplified as the decision of customer who has minimum WTP of product. Referring to this specific customer, the utility of this customer is (W_{imin} - c_i). As the equations in section 2 and parameters set in section 3, incremental of W_{imin} is higher than c_i when technology level is higher. For example, for the product with a technology level of 2, the utility of customer with minimum WTP is 1950. For a product with technology level of 3, the utility of customer with minimum WTP is 2350 that is bigger than the product with a technology level of 2. According to the assumption of uniform distribution of WTP other customer's utility would also bigger if he or she choose product technology level of 3.This results in that the utility of higher technology level is higher than lower technology level ones. From computation aspect, this scenario resulted from the incremental cost is lower than incremental minimum WTP along with increasing technology level.

As result shows, the best response of technology level are {2,3,2,3} or {3,2,3,2} (Xi = {x_{np},x_{nq},x_{ap},x_{aq}}) instead of {3,3,3,3}. That is because under the corresponding subsidy plan the cost would be below its subsidy that is impossible in reality. For instance, the best response point {2,3,2,3}, the subsidy plan for this is 1000RMB per unit for attribute p and100RMB per unit for attribute q. If this is {3,3,3,3}, the total subsidy for any product is 3300 that is equal to its corresponding cost 3300. By contrast, under current scenario, the cost for {2,3,2,3} is 2900 and subsidy is 2300.

In terms of government, the more subsidies established, the fewer payoffs they got and it has no effect on the market. All subsidies are benefiting to the original customer who will buy any of the product without subsidy. Therefore, the best action for the government in this scenario is taking no actions. The subsidy effect can be seen in table 42.

Similar to the simple model, the first scenario is also simulating the very begging stage of the new technology market that are two similar manufacturers with indifference quality and brand reputation. From the result we can see, the competition is very strong; both of the manufacturers would choose the same technology level and same price.

scenario 2: Cost of product is also the same, but there is some brand premium for manufacturer A especially for the price sensitive taker which result in the decreasing of minimum WTP of product N. Comparing with table 16, the changed parameters are listed in table 19.

Table 19.scenario 2: the changed parameter value comparing with table 16

b_{Np}	500RMB	b_{Nq}	800RMB

In this scenario, some picked up best response and Nash equilibrium are shown in table 20 and 21 respectively.

Table 20.thepicked up best response of scenario 2

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3300	3690	50	300	-915	0	390	2630	0	1

3	3	3	3	3300	3690	150	550	-1965	0	390	3155	0	1
3	2	3	2	2600	2890	100	1000	-2185	0	290	3005	0	1
3	2	3	2	2610	2900	150	1000	-2335	0	300	3075	0	1
3	2	3	2	2600	2890	250	900	-2435	0	290	3130	0	1
2	3	2	3	2900	3190	1000	100	-2180	0	290	3030	0	1
2	3	2	3	2900	3190	850	300	-2480	0	290	3180	0	1
2	3	2	3	2900	3190	900	350	-2730	0	290	3305	0	1

Table 21.Nash equilibrium of scenario 2

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3300	3690	0	0	135	0	390	2105	0	1

This scenario gives an outline of one of the ongoing situations of the beginning stage. As time goes by, the different quality between the two manufacturers has appeared. People think the worse performance product N should be sold at a lower price than product A with the same technology level.

The first row in table 21 is the Equilibrium of this case, the government's best action still leaves free to the market. However, because of the preference of product N, manufacturer A would take the whole market. The competition between both manufacturers is heavy since the price of manufacturer N is decreasing to its cost. However, the preference with same cost structure would make product A more competitive.

As the result shows, the brand premium is crucial for the product even though they are totally the same in terms of common usage. The decreasing of minimum WTP unit (b_{Ap} and b_{Aq}) of product a result in 400RMB difference between minimum WTP of product A and product N if they all choose technology level of 3. That is why even the price of product N is decreasing to its cost, price of product A would have additional 390RMB to hold the best response. The reason why is 390 instead of 400 is that if the gap is 400RMB, it means the profitability of product N and product A are the same as scenario 1. They will hold both halves of the market. However, this is the best response in scenario 1 because both of them reaches their cost. In scenario 2, this is not the case. For the higher minimum WTP, when the price of product N reaches to its cost and hold the equal utility of product A, the price of product A would 400RMB higher than its cost. Therefore, manufacturer A would choose to continue to decrease its price. According to the parameter setting, after 10RMB decreasing, product A would take the whole market and there is no motivation to decrease its price anymore. That is what table 20 shows. Changing the minimum WTP unit is more like a 'level' shift to the market that means every best response is preferred to the higher minimum WTP product. Because according to the uniform distribution assumption changing the minimum WTP means for every customer, the WTP would change the same value no matter which technology it picked up. This scenario is more like a parallel shift.

In terms of other parameters, similar to scenario 1, the government's subsidy would not help to increase the total market share. The best actions for the government still do nothing and leave the market alone.

In terms of subsidy effect, comparing with the first and seventh best response and second and fifth best response, we can figure out increasing the subsidy unit of one attribute would result in decreasing technology level of the other attribute. Since the product A has already occupied all the market share, in order to promote this technology development, the government should not give subsidy to any attribute to hold the highest technology level of product A. The subsidy effect

can be seen in table 42.

scenario 3: Cost of product is also the same, but there is some brand premium for manufacturer A especially for the technical sensitive taker which result in the increasing of maximum WTP of product A. In this scenario, a smaller change of maximum WTP of product a is taken. Comparing with table 16, the changed parameters are listed in table 22.

Table 22.scenario 3: the changed parameter value comparing with table 16

$W_{Ap1}^{\max}$	1700RMB	$W_{Aq1}^{\max}$	1900RMB

In this scenario, some picked up best responses are shown in table 23.

Table 23.some picked up best response of scenario 3

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3500	3700	100	600	-1965	67	267	1467	0.33	0.67
3	3	3	3	3500	3700	150	900	-3015	67	267	1642	0.33	0.67
2	3	2	3	2990	3190	1000	100	-2180	36	174	1456	0.4	0.6
2	3	2	3	3160	3280	1000	100	-2180	62.4	289	1251	0.24	0.76
2	3	2	3	3160	3280	1000	250	-2630	62.4	289	1305	0.24	0.76
3	2	3	2	2690	2890	100	1000	-2185	36	174	1443	0.4	0.6
3	2	3	2	2800	2950	100	1000	-2185	60	245	1297	0.3	0.7
3	2	3	2	2860	2980	250	900	-2435	62.4	289	1265	0.24	0.76

Table 24.Nash equilibrium of scenario 3

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3500	3700	0	0	135	67	267	1117	0.33	0.67

This scenario gives an outline of another ongoing situation of the beginning stage. As time goes by, the different quality between the two manufacturers has appeared. People think the better performance product A should be sold at a higher price than product N with the same technology level.

Similar to previous scenarios, the equilibrium of government is still 0. Changing the maximum WTP would change the WTP interval of each product. This results in scaled WTP of product A comparing with product N. From the aspect of both payoff of government and technology, the best practices of government is subsidy nothing. Comparing with the technology level of {3,3,3,3}, the higher subsidy drives the best response to lower technology level. This scenario results from the lower product premium for the product of lower technology level. For example, assume the subsidy unit for attribute p and q are 0. For the product with the technology level of {3,3}, the product premium is 2350, but this for the product with the technology level of {2,2} is just 1950. This scenario would be worse if more subsidy is invested into since higher technology level means higher subsidy which would increase the product premium. Comparing with scenario 2, interval changing in scenario 3 is more like a 'curve' shift which means by changing the interval every individual's WTP is scaled instead of parallel changes. Scaled WTP would change the individual's WTP differently. For instance, if someone wants to buy a product for 5RMB, scaled by 1.1, he wants to buy this product for 5.5. The difference between them is 0.5. Other customer wants to buy the same product for 6RMB, scaled by 1.1, he would pay for 6.6 for this product. The difference is 0.6 instead of 0.5. This difference results in changing the price of Nash equilibrium point would trigger the market share changing in scenario 3. However, this would not be changed

if only minimum WTP is changed in scenario 2.

In terms of subsidy effect, comparing with the first and seventh best response and second and eighth best response, similar to the previous scenario, increasing subsidy would decrease the technology level. Without subsidy, they would hold the equilibrium at the highest technology level. At that point, the total market share is 1. Though the market share for each manufacturer is not the same, they picked the highest technology level. In terms of technology promotion, the government should not do anything. The subsidy effect can be seen in table 42.

scenario 4: Cost of product is still the same, combined scenario 2 and 3 together, scenario 4's changing is listed in table 25.

Table 25.scenario 4: the changed parameter value comparing with table 16

b_{Np}	500RMB	b_{Nq}	800RMB
$W_{Ap1}^{\max}$	1700RMB	$W_{Aq1}^{\max}$	1900RMB

In this scenario, the picked up best responses are shown in table 26.

Table 26.the picked up best responses of scenario 4

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3840	4570	50	400	-1215	159	896	1191	0.3	0.7
3	3	3	3	3840	4570	450	600	-3015	159	896	1455	0.3	0.7
3	2	3	2	2840	3520	100	1000	-2185	92.8	564	1300	0.4	0.6
3	2	3	2	3040	3620	100	1000	-2185	140	693	1212	0.32	0.68
3	2	3	2	3370	3790	100	1000	-2185	164	936	1128	0.21	0.79
2	3	2	3	3150	3820	1000	100	-2180	95	570	1305	0.38	0.62
2	3	2	3	3150	3820	950	300	-2680	95	570	1400	0.38	0.62
2	3	2	3	3150	3820	900	350	-2730	95	570	1410	0.38	0.62

Table 27.Nash equilibrium of scenario 4

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3840	4570	0	0	135	159	896	992	0.3	0.7

Since this scenario combined the previous two scenarios together, the results also show both of the effects. First, the market share is changing by the price. Second, the price difference between product N and product A at Nash equilibrium point is bigger than scenario 3.

In terms of subsidy effect, comparing the fourth to the sixth best response, the subsidy is the same, however, the price is not the same, which results in changing of the utility of customer and corresponding manufacturer. The final utility of government would be determined by manufacturers.

All the scenarios above are external motivation that is mainly affected by customers. It is more uncontrollable. By contrast, the following scenarios would change the parameters of manufacturers which is also called inner factor and more controllable.

In this scenario, the government takes the most advantage, because at Nash equilibrium though two manufacturers shared the market, they choose the highest technology level and the market is fully occupied. If any subsidy is given, though market structure would change, the best strategy for one of the manufactures is decreasing its technology level.

scenario 5: Cost is the main inner factor of manufacturer. In this scenario, cost unit of product A

would be increased comparing with scenario 1. In this scenario, the altitude of cost changing would result in the changing of product premium. scenario 5's changing is listed in table 28.

Table 28.scenario 5: the changed parameter value comparing with table 16

c_{Np}	600	c_{Nq}	1050

In this scenario, some picked up best responses are shown in table 29.

Table 29.some picked up best responses of scenario 5

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
2	3	3	3	4350	4750	0	50	-15	0	1450	1125	0	1
3	3	3	2	5050	3170	150	1000	-2605	27.5	413	1110	0.27	0.73
3	3	3	2	5050	3200	150	950	-2468	25	450	1066	0.25	0.75
3	3	2	3	5050	3620	750	400	-2684	14	618	1011	0.14	0.86
3	3	2	3	5050	3600	800	400	-2819	17.6	576	1049	0.18	0.82
3	3	2	3	5050	3530	950	150	-2483	27	460	1099	0.27	0.73
3	3	2	3	5100	3550	950	150	-2450	35	497	1061	0.23	0.77
3	3	2	3	5240	3620	950	150	-2373	44	610	993	0.15	0.85

Table 30.Nash equilibria of scenario 5

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
2	2	3	3	3300	4800	0	0	135	0	1500	1125	0	1
2	3	3	3	4350	4750	0	0	135	0	1450	1125	0	1
3	2	3	3	3900	4800	0	0	135	0	1500	1125	0	1
3	3	3	3	4960	4760	0	0	135	0	1460	1125	0	1

Different from the previous four scenarios, this situation gives a story of the product of different attributes. Firm N choose to develop some attributes with more cost. For example, firm A chooses to develop the Navigation and well-being attribute of IoV since the lower manufacturer cost while firm N choose to develop safety and entertainment attribute of IoV.

In this scenario, there are 4 equilibria shown in table 30. As we see, no matter, what the technology level of product N changes (the inferior profitability product in this case), the equilibrium technology level of product A is always 3, which is the highest technology level. That is because the accompanying with the increasing technology level, the cost advantage is more obvious. And because of the advantage of cost structure, manufacturer A can use price strategy to squeeze the market of product N until its disappearance. That is why at any equilibrium, price of product N is always equal to its cost.

As the result shows, changing the cost structure would not trigger the payoff structure of the government. From the view of payoff, the government would still refuse to give subsidy. However, in the previous scenarios, there is only one best response if the government refuse to give subsidy. In scenario 5, there are many best responses with such a subsidy plan. There are also multiple best responses including the fifth one that meets both the maximum government profit and manufacturer A. But no matter which best response it is, for manufacturer N, which technology level it chose has no effect since the market share of product A is 0 if manufacturer A choose the highest technology level. In this scenario, the manufacturer with a lower cost has the absolute advantage of the other one.

Comparing the second and the third best responses, hold other parameter fixed and if the

changed subsidy would not result in the change of best response price, the subsidy would only increase the payoff of the manufacturer. However, accompanying with the increasing subsidy as the sixth and seventh best response shows, if the changed subsidy results to price changing which drive the market share change at the same time, the payoff of any interest sides would be affected. Take the sixth and seventh as an example, the incremental 50RMB subsidy unit of attribute q results to the 50RMB relative payoff of product N because of the higher technology level of attribute q it chooses. This change results in the 30RMB decremented of product A and 0.08 percent market share loss. This means subsidy of any attribute would promote the motivation of the development of higher technology level.

Comparing with the last pair, the pair of the eighth and ninth best responses shows that if the incremental subsidy is not enough to change the market share. The negative effect of incremental subsidy would be absorbed all by lower technology level picker which in the example, the incremental 50RMB of subsidy unit of attribute p would directly drag down the same amount of price of product A.

In terms of the last three best responses, the subsidy units of each attribute are the same, changing the price would change the market share of each manufacturer. For example, increasing the price of product N would push up the manufacturer N's price, though the increasing price cannot stop manufacturer N's dropping market share.

In terms of government policy, it is better to do nothing, because the market is taken by manufacturing A wholly and also it is Nash equilibrium of this scenario with the highest technology level of product A.

In terms of subsidy effect on technology development, if increasing the subsidy of any attribute, manufacturer A would choose the lower technology level instead of the highest technology level. Though the market share of product N would increase accompanying increasing subsidy, the major market is still product A. Therefore, increasing the subsidy would decrease the market share of high technology product. As technology promotion, the government should not give subsidy to the manufacturing.

scenario 6: In this scenario, product can make bring more government benefit. The changes is listed in table 31.

Table 31.scenario 6: the changed parameter value comparing with table 16

α_{Ap}	150	α_{Aq}	200
α_{Np}	150	α_{Nq}	200

In this scenario, some picked up best responses are shown in table 32.

Table 32.Nash equlibrium of scenario 6

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3310	3310	0	0	1080	5	5	2295	0.5	0.5

In this scenario, there is only one Nash equilibrium and both manufacturing start to produce the product with higher social benefit at the beginning.

As table 32 shows, equilibrium of technology level, price, market share are the same with scenario one, however, the government payoff changed a lot. That is resulted from the increasing benefit factors. But the equilibrium point of subsidy is still 0. Till now, some key factors we have

tests, equilibrium point of subsidy is always 0. That is because the equilibrium points are always around the cost and also in all scenarios $W_i^{\min} > \bar{c}_i$ is always hold, which means because of high competition all customer can afford one of the product at least. Therefore, for government, Q_A and Q_N can met a specific market market share {0.5, 0.5} ({ Q_A , Q_N }) at equilibrium in this case regardless of subsidy. Therefore, without increasing in Q_A or Q_N , increasing subsidy has always negative effect on government. From the mathematical view, $\frac{\partial G}{\partial S} = -Q_i$ which means no matter how to change α_{ij} subsidy always have negative affect on the utility of government. So does β .

Scenario 7: In this scenario, based on the parameters setting in scenario 6 and we assume the more popular product A among customer has a lower cost structure, which means for the same technology level, cost of product A would be lower than that of product N. Changed parameters are listed in table 33.

Table 33.scenario 7: the changed parameter value comparing with table 16

α_{Ap}	150	α_{Aq}	200
α_{Np}	150	α_{Nq}	200
c_{Np}	600	c_{Nq}	1050
b_{Np}	500RMB	b_{Nq}	800RMB
$W_{Ap1}^{\max}$	1700RMB	$W_{Aq1}^{\max}$	1900RMB

Some picked up best responses of scenario 7 is listed in table 34.

Table 34.some picked up best responses of scenario 7

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
1	1	1	2	2010	2270	50	0	363	31	77	230	0.84	0.16
1	1	1	2	2060	2320	100	0	313	343	85	230	0.84	0.16
1	1	2	1	2080	2220	150	0	230	379	85	169	0.88	0.12
3	1	2	3	3160	4730	200	0	400	90	1300	760	0.29	0.71
1	1	1	1	1980	1800	0	50	330	267	133	190	0.81	0.19
1	1	2	3	2850	5650	0	200	330	0	2750	1200	0	1

Table 35.Nash equilibrium of scenario 7

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	1	3	3	3250	5660	0	0	1084	133	1874	938	0.3	0.7

This is a combination scenario with previous 3 scenarios. Take both of the advantages of cost and popularity, product A is like a priority product. At Nash equilibrium, highest technology level of

product A would give more benefit to manufacturer A since the relative advantage, $(W_i^{\max}+W_i^{\min})/2-\bar{c}_i$,is increasing for same technology level. For product N, in order to decrease the relative disadvantage, it will also raise up its technology level. If not,there would be no market share for product N. However, if S=(0, 0) and $x_N=(1,1)$ the market share of Q_N would be 0. That is why $X_N=(3,1)$ is determined.

Accompanying the increasing sb, the advantage of cost appears. Let us see the second and third best response, at this point, even the market share is majorly holding by product N, however, its utility is less than product A. That is resulted from higher profit per unit. If the subsidy goes higher and higher, product A would take advantage of subsidy by technology level differentiation. This shows, within this scenario, when the government has a lower subsidy, product A would like to take the profitability advantage to increase the price. If the government's subsidy goes high, product A can choose higher technology. This situation is also efficient for product N.

In terms of subsidy effect on technology development, from table 34, increasing the subsidy would increase the technology level of the manufacturer. If the subsidy is small, the market share is mainly occupied with the product N and the technology level of product N would be the lowest. Only give a related bigger subsidy to the manufacturer, the market share would change from product N to product A and also manufacturer A would choose the higher technology level because of both advantages of cost structure and higher WTP. But comparing with Nash equilibrium, the government also should not give any subsidy to the manufacturer.

Scenario 8: In this scenario, based on the parameters setting in scenario 6, we assume the more popular product A among customer is from its quality which resulted from higher cost of the same product level than product N. Changed parameters are listed in table 36.

Table 36.scenario 8: the changed parameter value comparing with table 16

α_{Ap}	150	α_{Aq}	200
α_{Np}	150	α_{Nq}	200
c_{Ap}	600	c_{Aq}	1050
b_{Np}	500RMB	b_{Nq}	800RMB
$W_{Ap1}^{\max}$	1700RMB	$W_{Aq1}^{\max}$	1900RMB

Some picked up best responses of scenario 8 is listed in table 37.

Table 37.some picked up best responses of scenario 8

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
1	1	2	3	2800	5500	0	150	480	0	1150	1200	0	1
1	1	2	3	2850	5650	0	200	330	0	1300	1200	0	1
1	1	3	3	3650	8650	0	1000	-1920	0	3700	1425	0	1
1	1	3	2	2850	5200	50	150	430	0	1300	1175	0	1

1	1	3	2	3650	7600	850	150	-1970	0	3700	1175	0	1

Table 38.Nash equilibrium of scenario 8

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
3	3	3	3	3950	4950	0	0	1080	650	0	1775	1	0

In this scenario, we consider both manufacturers change to develop the product with higher social benefit and firm A choose the product with higher cost and WTP attribute to develop.

In this scenario, there is only one equilibrium which all manufacturing choose the highest technology level. Comparing with scenario 7, because of the cost structure advantage, product N have a bigger elastic , $\frac{W_i^{\min} - \overline{c}_i}{In_{-i}}$, towards its cost if both product has same technology level, where -i means other product except i. If $x_N = (3,3)$, the elastic is equal to 0.68 while with same technology level, elastic of A is 0.31. This means product N has more advantage of price priority strategy because of the cost benefit. And also a higher technology level would increase its elastic. That is why product A would choose higher technology level to offset its weakness in the cost side.

Accompanying the increasing subsidy, compared with scenario 7, it should give more subsidies to meet the best response conditions of manufacturing. Because there is part of the subsidy is used to offset the cost disadvantage of product A.

In terms of subsidy effect on technology development, if the government does not give any subsidy, both of the two manufacturers would choose the highest technology level, however, total market would be occupied by product N because of the better cost structure performance. If any subsidy initiated, the whole market would change to product A and the manufacturer N would choose the lowest technology level, though it does not matter to the technology promotion because of the 0 market share of product N. Product A would choose higher technology level accompanying with the increased subsidy. Therefore, the best practice for government is stopping the subsidy.

Scenario 9: In this scenario, we released the government subsidy assumption and let the range of subsidy from (-500, 0). And other Changed parameters are listed in table 39.

Table 39.scenario 9: the changed parameter value comparing with table 16

$W_{Ap1}^{\max}$	1700RMB	$W_{Aq1}^{\max}$	1900RMB

Some picked up best responses of scenario 9 is listed in table 40.

Table 40.some picked up best responses of scenario 9

X_{Ap}	X_{Aq}	X_{Np}	X_{Nq}	P_A	P_N	S_p	S_q	G	E_A	E_N	Pai	Q_A	Q_N
3	3	1	1	3490	1350	-250	-300	1651	168	28	1165	0.88	0.11
3	3	1	3	3600	2750	-300	-250	1663	242	48	1020	0.80	0.19
2	3	1	1	3080	1390	-300	-350	1584	148	50	880	0.85	0.17
1	3	1	1	2650	1270	-350	-300	1259	127	25	767	0.85	0.15

Table 41.Nash equlibrium of scenario 9

X_{Ap}	X_{Aq}	X_{Np}	X_{Nq}	P_A	P_N	S_p	S_q	G	E_A	E_N	Pai	Q_A	Q_N
3	3	1	1	3490	1390	-300	-300	1753	162	41	1101	0.85	0.14

3	3	1	1	3500	1400	-300	-300	1753	171	42	1101	0.85	0.14
3	3	1	1	3510	1410	-300	-300	1753	180	44	1100	0.85	0.14

In this scenario, comparing changing the parameter value of manufacturers, we changed the government subsidy to government tax as the simple model does.

As we see from table 40, the global optimal subsidy profile for this case is sb=(-300,-300), which means the government can only take the tax from the manufacturer in order to make the maximum utility. That is partly the reason why the Nash equilibrium of the previous scenarios are always sb=(0,0). There is three Nash equilibrium that the sum of them is -600. That is because of the uniform distribution of the customer. Therefore, subsidy for a product can be seen as a whole regardless of the combination of each attribute. From the remaining best response, we can see that no matter increasing or decreasing the subsidy, the payoff of government is always going down.

In terms of subsidy effect on technology development, in this scenario, the government would take higher tax from the technology at the equilibrium. However, if the government releases its payoff, decrease the tax from the manufacturer, the technology of product N would increase. Though its market share is small, it can push this technology forward.

Table 42. The trend of parameters according to increasing subsidy

Scenario Index	Changed Parameter	sp↑						sq↑					
		Pa	Pn	Qa	Qn	Ea	En	Pa	Pn	Qa	Qn	Ea	En
scenario one	Identical	↓	↓	→	→	→	→	↓	↓	→	→	→	→
scenario two	b_{sp} ↑ b_{sq} ↑	↑	↑	→	→	↑	→	↑	↑	→	→	↑	→
scenario three	W^{max}_{Ap1} ↑ W^{max}_{Aq1} ↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↓	↑	↓
scenario four	b_{sp} ↑ b_{sq} ↑ W^{max}_{Ap1} ↑ W^{max}_{Aq1} ↑	↑	↑	↑	↓	↑	↓	↑	↑	↑	↓	↑	↓
scenario five	c_{np} ↑ c_{nq} ↑	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑
scenario six	α_{nq} ↑ α_{aq} ↑ α_{ap} ↑ α_{np} ↑	↓	↓	→	→	→	→	↓	↓	→	→	→	→
scenario seven	scenario 4 + scenario 5	↑	↑	→	→	↑	↑	–	–	–	–	–	–
scenario eight	$c_{np} \Leftrightarrow c_{ap}$ $c_{nq} \Leftrightarrow c_{aq}$	↑	↑	→	→	↑	↑	↑	↑	→	→	↑	↑
scenario nine	Negative subsidy	↑	↑	→	→	↑	→	↑	↑	→	→	↑	→

5.3.4. Discussion

As we see from these previous scenarios, each scenario represents one special situation according to different WTP or cost structure or social benefit. Through the combination of these factors, we can build the picture of the subsidy effect on new technology with multiple attributes development and it starts with the scenario one that is the beginning of this kind of technology. There are nine scenarios, the outline structure of each scenario is shown in figure 51 below.

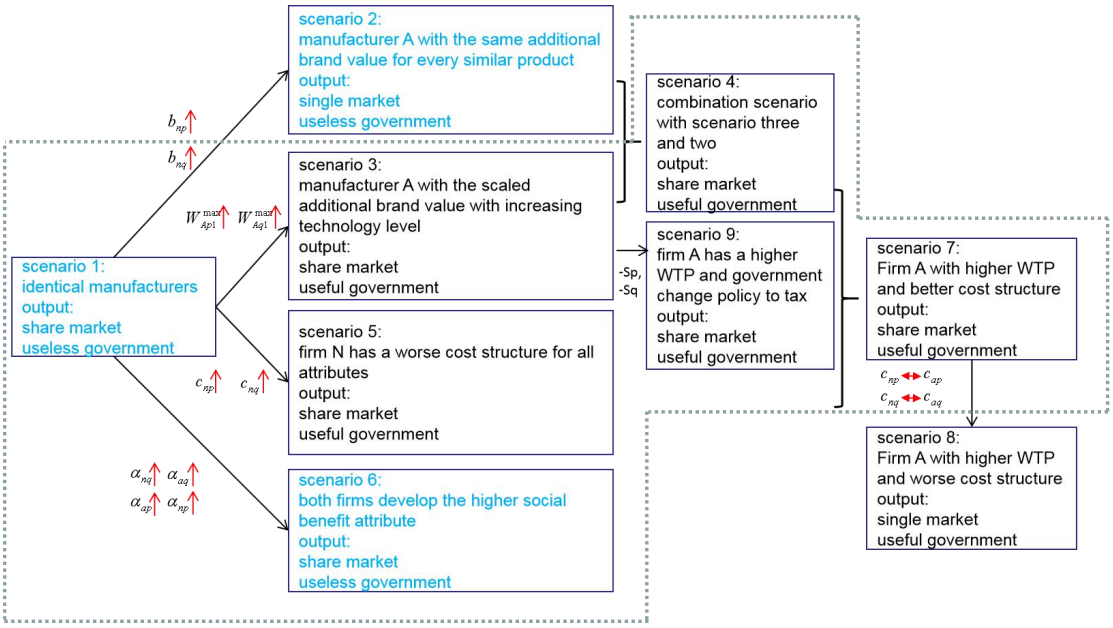


Figure 51.scenarios structure

Scenario one: identical manufacturers

In scenario one, it shows the early stage of this industry that there are only two players in this industry and they have similar technologies, brand value and other characteristics since this technology is updated from the current technology. Both of the manufacturers would take the price priority strategy and increasing sales by cutting down the price. Because there is no quality difference of each other for the product with the same technology level of the same attribute. Any advantages of any one manufacturer can be offset by producing the same product for the other one. Therefore, for the non-cooperate game, the result is the same as the Bertrand game that both manufacturers would take the price which is the same as the cost. And since in this scenario, the incremental cost per technology level is smaller than incremental WTP per technology level that means increasing technology level would improve the profit. That is why both of the manufacturers pick the highest technology level at the Nash equilibrium. At the equilibrium, manufacturers can occupy all the market without the subsidy. Government has no motivation to give the subsidy since the maximum social benefit can be gained automatically by the market force and no bankrupt risk of any manufacturer. If we release the government subsidy, it helps nothing with the market share situation.

This situation is similar to the early age of IoV product, we call it “vehicle recorder”. This product is derived from the previous navigation system and conjoint with the CCTV. Customer can use it for accident judgment after an accident. Since it is very useful for drivers, in China, WTP is higher than its cost. Though it is a new product several years ago, it installed nearly in every vehicle within a short time and without any government subsidy as promotional aids. Because the technology of vehicle recorder is not advanced enough which result in the hard competition. Finally, there are few big names in this industry remains and they share the lower profitable market without the subsidy.

Scenario two: manufacturer A has the same additional brand value for certain type of product.

In this scenario, it shows as time goes by, even this is not a revolutionary technology, accompanying the time flies, customers would build up their preference on one of the brands that result in WTP of firm A is higher than firm N for any product with the similar technology level

of attributes. This kind of incremental WTP just resulted from the brand value. Since there is no quality difference, therefore the WTP is increased parallel for every product A by brand value comparing with scenario one. With this situation, both manufacturers would also take the price priority strategy until the cost since there is no quality difference. However, the case is not going as the previous one, because of the WTP gap. At the corresponding cost of a similar product, customer utility of product A is bigger than product N. With the same cost structure, firm A would take advantage of brand value to occupy the whole market. Therefore, firm N would be bankrupt for lack of orders. The government can do nothing to help firm N because any subsidy for the industry would benefit both manufacturers at the same degree. With the same strategy, firm N would also lose the game unless the government gives subsidy to firm N only.

Scenario three: manufacturer A has the scaled additional brand value with the increasing technology level

In some industries, the brand value is increasing accompanying with the increasing technology. These industries majorly gain their reputation from their higher technology level product. Because of the higher technological maturity, even at the same technology level, product A may have better performance. This kind of performance difference would increase with the increasing technology level. Therefore, the WTP difference between two products would increase with the increasing technology level. Since the cost structure is also the same, compared with scenario 1 at the Nash equilibrium, both of the manufacturers would choose the highest technology level. However, the market share is no longer full occupied by firm A. Because of the different additional WTP for a product with different technology level, the best practices of firms might not be price priority anymore. That is why in this scenario, the market is shared by both firms over their costs. If the subsidy condition is released, the market share would change by changing the subsidy unit. The best choice for manufacturers might choose the lower technology level. Therefore, in this situation, the government would better do nothing.

This situation is similar to the earphone market. In this market, Sennheiser always represented the reputation. For a higher technology level product, Sennheiser has much higher WTP than other brands like Shure. By contrast, for the lower technology level product, most produced by OEM, has similar WTP with other brands.

Scenario four: combination scenario with scenario three and two

This scenario combined the previous two scenarios together. Therefore, it has a conjoint result with the previous two results. At Nash equilibrium, the market is shared by two firms and firm A occupied more with higher price compared with scenario two. If release the subsidy limitation, firm A would occupy more at any corresponding technology level.

Scenario five: firm N has a worse cost structure for all attributes

In this scenario, firm N has a worse cost structure. This may result in two reasons. One is that during the diffusion, firm A shows better cost management. The other is firm N decide to develop the attributes with higher cost. Not matter which reasons, at the Nash equilibrium, firm A would definitely take all the market share. Because of the worse cost structure, firm A has an advantage at every technology level. Hold other parameters constant, compared with scenario one, firm A can decrease more price in price priority strategy when the WTP of both firms are the same, which means the firm with lower cost would have more profit margin to decrease. In terms of technology level, comparing with scenario one, the technology level of firm A is still the highest since it has a better cost structure according to the WTP structure at a certain technology level.

But this is not the case for firm N, the cost structure of firm N is worse than WTP structure at the higher technology level. That is at some Nash equilibria technology level of firm N might be lower technology level though there is no market for it. If we release the subsidy condition, accompanying with the changing subsidy, firm N might have some minor market share and firm A might change its strategy to develop the lower technology level product.

Scenario six: both firms develop a higher social benefit attribute

In this scenario, both firms choose to develop a higher social benefit attribute. Since the parameters around manufacturers are not changed. Therefore, comparing scenario one, technology level and price would not change at the Nash equilibrium. The only changed factor is the utility of government. The utility of government increased a lot.

Scenario seven: Firm A with higher WTP and better cost structure

In this situation, this is similar to the conjoint situation with scenario 4 and scenario 5. From scenario 4, we revealed that both firms would share the market with product A's major occupation and from the scenario 5, we found the technology level of firm N at Nash would be lower technology level. Therefore, the result of this situation is a combination of the two scenarios.

This kind of situation is similar to the cell phone situation in China. Comparing with the iPhone and some kind of local brands, the iPhone has a better cost structure and higher WTP. Therefore, iPhone occupied the higher technology smartphone market while others take the remain lower technology level phone market.

Scenario eight: Firm A with higher WTP and worse cost structure

In this situation, the cost structure is the opposite of scenario 7. However, the result is totally different. At the Nash equilibrium, firm N would take all the market share by setting a really low price because of the better cost structure. For firm A, it would choose the highest technology level at an equilibrium since the worse cost structure can be offset by incremental WTP comparing with scenario one at a certain technology level. For firm N, the better cost structure as scenario one drives it to pick the highest technology level at Nash. If we release the subsidy, the situation would turn around. All market share shift from firm N to firm A because with the increasing subsidy, the weakness of cost structure can be offset by the increased subsidy. That is to say, if a firm develops a product with higher WTP and cost, it can win the market with the help of the government subsidy.

This kind of situation represented the green power vehicle. It has a higher WTP among the customer because its technology and battery enhance its cost. Without the help of the government, it is hard to be accepted by the customer because of the high price. When the government begins to give subsidy, the market is changed.

Scenario nine: firm A has a higher WTP and government change policy to tax

In this scenario, compared with scenario 3, we change the government policy to tax from the subsidy. Therefore, the subsidy item would become negative. We found that though this is a new technology, the government would still take some tax from it at the equilibrium. Two firms nearly occupied the whole market at the equilibrium, firm A with higher WTP would choose to pick up the highest technology level. However, firm N would no longer choose the highest one. They would choose the lowest instead because of the lower WTP comparing with the sum of the cost and tax at a certain technology level. In terms of government, it cannot continuously increase the tax, since that would depress the manufacturer to improve the technology level which would

result in the decreasing of social benefit.

This situation often happened in imported technology like carbon fiber. China cannot produce high quality of carbon fiber. Therefore, it imports these kind of materials from abroad. In order to encourage local manufacturers, the Chinese government would take some tariff from these import products.

5.3.5. Section Summary

According to the target of government which is to make the maximum payoff of the utility function, comparing all the scenarios above, if the reality follows all the assumptions, no matter from the outer or inner aspects, the best action of government is leaving the business to the market and establish nothing about the subsidy.

In this section 9 scenarios have been put forward to tests each of the major parameters alone and combination effect is also tested. It shows that the government's subsidy within these scenarios would be a negative effect on governments payoff. And minimum WTP would give a level shift of best response while changing maximum WTP would display a curve shift of best response.

5.4. A Case Study: Development of IoT Technologies in Automotive Industries

5.4.1. Data Source From Previous Chapter

Table 43.Expected WTP from chapter three

The product identification	Expected WTP
HMM	3190
MHM	3288
MMH	3586
HHM	3619
HMH	3647
MHH	3790
HHH	4126

As chapter three mentioned, by simple computation of expected WTP of each product in table 43, the WTP of every technology level of each attribute can be calculated. Again, HMM means high quality of moving management, middle quality of well-being, and middle quality of safety. In this case study, we would pick two attributes data as inputs including moving management and well-being. There are three technology levels in each attribute. WTP of each technology level of moving management attribute can be calculated by remainder of subtraction of expected WTP of MHM from expected WTP of HHM. That is 3619-3288=331; let us round about it as 330. This is

the value of b_{Ap} , similar with moving management; each technology of WTP of attribute well-being can be calculated by HHM and HMM, which is 3619-3190=429. Let us round about it as 430, b_{Aq} . WTP of IoV product is starting from 2600, which is equal to $W_{Ap1}^{\min} + W_{Aq1}^{\min}$. Social cost coefficient β is derived from the ministry of Transportation that the general cost of vehicle management last year divided by the total number of vehicles in China. Since there are two firms in this case and IoV industry is at its beginning stage of industry, we assume the value of each parameter is slightly different from each other.

5.4.2. Original Case

Followed with last section, value of each parameter used in the case study are listed below in table 44.

Table 44.The corresponding values of parameters in the case

Parameters	Values in this paper	Parameters	Values in this paper
Customer side			
$W_{Ap1}^{\min}$	1275RMB	$W_{Ap1}^{\max}$	1700RMB
$W_{Aq1}^{\min}$	1325RMB	$W_{Aq1}^{\max}$	1900RMB
$W_{Np1}^{\min}$	1250RMB	$W_{Np1}^{\max}$	1600RMB
$W_{Nq1}^{\min}$	1300RMB	$W_{Nq1}^{\max}$	1800RMB
b_{Np}	200RMB	b_{Nq}	250RMB
b_{Ap}	330RMB	b_{Aq}	430RMB
Manufacturer side			
c_{Ap}	800	c_{Aq}	900
c_{Np}	600	c_{Nq}	800
Government side			
α_{Np}	15	α_{Nq}	20
α_{Ap}	18	α_{Aq}	23
β	30		

Since there are many Nash equilibrium points, some of them are shown in table 45 below according to the unique technology level combination with highest government's utility.

Table 45. Picked up Nash equibrium of case

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
1	3	1	1	3020	2140	0	0	87.8	223	9.9	470	0.49	0.51
1	1	1	1	1580	1740	0	0	66.6	10.7	132	620	0.73	0.27
1	2	1	1	2210	1850	0	0	78.6	68.6	5.4	475	0.54	0.46
2	1	1	1	2000	1770	0	0	76.4	28	0	462	0.6	0.4
2	2	1	2	2810	2060	0	0	85.5	180	5	473	0.5	0.5
3	1	1	1	2610	1980	0	0	82.8	143	5	474	0.49	0.51

Also, some best response are shown in table 46.

Table 46. Picked up best response of case

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
2	1	1	1	2010	1780	0	100	-23.6	32	6	480	0.6	0.4
2	2	1	1	2070	1810	0	150	-74.95	60.5	31.5	531	0.45	0.55
2	2	1	1	2150	1850	0	200	-126	112.5	37.5	675	0.25	0.75
1	3	1	1	3100	2620	50	0	60.2	52	57	499	0.57	0.43
1	2	1	1	3060	2160	100	0	-13	243	28	488	0.47	0.53
1	1	1	1	2230	1870	200	0	-121.4	77	16	516	0.54	0.46

As table 45 shows, at Nash equilibrium, government should better leave the market alone, give nothing to any manufacturers. Generally, this market would be occupied by both of the manufacturers. However, for the manufacturer A, lower technology level strategy seems better. Because the higher cost of product A with same technology level comparing with product N, results in that customers cannot get higher utility from the product A with higher technology level. At Nash equilibrium, product A always choose the lowest technology level, manufacturer N also does not develop both attributes with the highest technology level. Indeed, if manufacturer N chooses the lower technology level, it would gain more market share shown in the second equilibrium.

This situation is a piece of good news for the government because they do not need to subsidy anything and they will benefit from the competition between the two manufacturers.

In terms of subsidy effect on IoV technology development, it is shown in table 46, accompanying with the increasing subsidy, the technology level of product A is always lowest. However, changing subsidy of attribute p (moving management) would decrease the technology level of product N. Since the technology level of attribute p has already been the lowest, therefore the technology level of attribute q would decrease. By contrast, changing subsidy of attribute q (well-being) would increase the technology level of product N. From table 46, we can see hold the technology level of attribute p constant, the technology level of attribute q would increase. However, with the increasing technology level of attribute q of product N, the market share of product N is also decreasing. At the current situation, the government should give some subsidy to well-being attribute to make sure product N would choose higher technology level in order to promote IoV technology.

5.4.3. Numerical Evidence of Subsidy Effect on Price and Technology Level

In terms of CPA and IPA, the best responses with identical technology level along with the increasing subsidy unit are listed in table 46 below, the results provide the evidence of the situation 3 in table 14 that the critical conditions are CPA=-3.703703704<0 and IPA=0.000257649>0.

Table 47.Subsidy effect test

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q
1	1	1	3	1420	3500	300	0
1	1	1	3	1430	3560	350	0
1	1	1	3	1440	3610	400	0
1	1	1	3	1460	3670	450	0
1	1	1	3	1410	3780	0	250
1	1	1	3	1410	3830	0	300
1	1	1	3	1420	3880	0	350
1	1	1	3	1430	3940	0	400

When IPA >0 and CPA < 0, increasing either Sp or Sq, both of price of product A and N would be increasing. This is perfectly satisfied with the general model results.

5.4.4. How Can We Initiate the Subsidy

In order to find out how to initiate the subsidy. We started from the data of case study and released the range of subsidy to (-500,0). We revealed the following Nash equilibrium.

Table 48. Maximum utility of government without limitation of subsidy

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
1	1	1	1	1500	1700	-500	-500	1071	0	100	450	0	1
1	1	1	1	1500	1700	-550	-500	1058	0	94.4	401	0	0.94
1	1	1	1	1500	1700	-500	-550	1058	0	94.4	401	0	0.94

We can see from table 48, if government has an option of taking tax in the case study, it will choose to take total tax of 1000RMB because of maximization of its utility.

In order to figure out how to initiate the government subsidy. We changed some parameters according to the parameters setting in the case study as below.

Table 49.Changed parameters comparing with table 44

α_{np}	150	α_{nq}	200
α_{ap}	180	α_{aq}	230
β	300		

c_{ap}	1500RMB	c_{aq}	1600RMB
c_{np}	1500RMB	c_{nq}	1600RMB

The Nash equilibrium points are listed below:

Table 50. Nash equilibrium of last scenario

X_{Np}	X_{Nq}	X_{Ap}	X_{Aq}	P_N	P_A	S_p	S_q	G	E_N	E_A	Pai	Q_N	Q_A
1	1	1	1	3600	3640	100	300	111.6	0	14.4	64.8	0	0.36

From table 50, we can find out that both social benefit coefficient and cost can motivate government to initiate the subsidy. However, what is the relationship among them would help us use the subsidy policy to manage the IoV technology.

5.4.5. Sensitivity Analysis

As section 5.4.4 shows, only cost or social benefit satisfied with minimum value conditions, the government would give subsidy. Therefore, we want to reveal the relations between subsidy and cost or social benefit. To solve this question and check the Nash equilibrium robustness of cost and social benefit related parameters, in this section, we conducted the sensitivity analysis. The variables we used in the sensitivity analysis are social benefit related factors including α_{aq} , α_{nq} , cost related factors including $c_{nq}, c_{np}, c_{aq}, c_{ap}$. To simplify the computation, we assume the value of α_{aq} is equal to α_{ap} , so as product N.

The values of α_{aq} in sensitivity analysis are 20, 200, 2000. The values of each cost are 1, 1.5 and 2 times of the original case study. Since the dimension of results are too high, we only list and analysis the situation (c_{nq}, c_{np}) = (800, 600) here. The remaining results are shown in Appendix F.

Table 51.sensitivity analysis of case study

Cap \ Caq		900																				1350							
	αa \ α n	15								150								1500								15			
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	3	2150	3060	0	0	1	1	1	3	2150	3060	0	0	3	2	3	1	4230	2650	300	100	1	1	1	1	2150	1950	0	0
	200	1	2	1	1	2610	1720	0	50	1	2	1	1	2610	1720	0	50	3	2	3	1	4230	2650	300	100	1	1	1	1	2150	1950	0	0
	2000	3	3	1	1	5110	1800	250	350	3	3	1	1	5110	1800	250	350	3	3	3	3	5400	4500	350	350	3	3	1	1	8470	4000	500	950
1200	20	1	2	1	1	3010	2160	0	0	1	2	1	1	3010	1900	0	0	2	3	3	3	5100	4800	100	350	1	1	1	1	2550	2300	0	0
	200	1	3	1	1	3940	2100	0	50	1	3	1	1	3940	2000	0	50	2	3	3	3	5100	4800	100	350	1	1	2	1	2610	2860	50	0
	2000	1	3	1	1	3930	2040	0	150	1	3	1	1	3930	2040	0	150	2	3	3	3	5100	4800	100	350	1	1	2	1	2610	2860	50	0
1600	20	1	3	1	1	4310	2230	0	0	1	3	1	1	4310	2300	0	0	2	3	3	3	5900	5700	200	550	1	1	1	2	2950	3400	150	200
	200	1	3	1	1	4300	2230	0	0	1	3	1	1	4310	2300	0	0	2	3	3	3	5900	5700	200	550	1	1	1	1	2950	2600	0	0
	2000	1	3	1	1	4300	2200	0	150	1	3	1	1	4310	2200	0	150	2	3	3	3	5900	5700	200	550	1	1	1	1	2950	2600	0	0

1350																1800															
150								1500								15								150								1500							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2150	1950	0	0	3	1	3	3	3750	5140	500	600	1	1	2	1	2600	2750	0	0	1	1	2	1	2600	2750	0	0	3	1	3	3	4200	5590	500	600
1	1	1	1	2150	1950	0	0	3	1	3	3	3750	5140	500	600	1	1	2	1	2600	2750	0	0	1	1	2	1	2600	2750	0	0	3	1	3	3	4200	5590	500	600
3	3	1	1	8470	4000	500	950	3	3	1	1	8470	4000	500	950	3	1	1	1	4270	2380	100	0	1	1	2	1	2600	2750	0	0	1	1	3	3	2730	5610	400	550
1	1	1	1	2550	2300	0	0	2	3	3	3	6450	6300	250	700	1	1	1	1	3000	2600	0	0	1	1	1	1	3000	2600	0	0	1	1	3	3	3000	5800	400	550
1	1	2	1	2610	2860	50	0	2	3	3	3	6450	6300	250	700	1	1	1	1	3000	2600	0	0	1	1	1	1	3000	2600	0	0	1	1	3	3	3000	5800	400	550
1	1	2	1	2610	2860	50	0	2	3	3	3	6450	6300	250	700	1	1	1	1	3000	2600	0	0	1	1	1	1	3000	2600	0	0	1	1	3	3	3000	5800	400	550
1	1	1	1	2950	2600	0	0	1	1	3	3	2950	5900	450	600	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0	1	1	3	3	3400	6200	400	550
1	1	1	1	2950	2600	0	0	1	1	3	3	2950	5900	450	600	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0	1	1	3	3	3400	6200	400	550
1	1	1	2	2950	3400	150	200	1	1	3	3	2950	5900	450	600	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0	1	1	3	3	3400	6200	400	550

As we can see from table 51, mainly one Nash equilibrium set represented within one black boundary cell can be expressed as (X_{ap}, X_{aq},X_{np},X_{nq},Pa,Pn,Sp,Sq) where each item represents technology level of attribute p of product A, technology level of attribute q of product A, technology level of attribute p of product N, technology level of attribute q of product N, price of product A, price of product N, subsidy unit of attribute p and subsidy unit of attribute q respectively. One Nash equilibrium set can be divided into three parts including technology area (green), price area (red) and subsidy area (blue and yellow). The color in each area are changed from light to dark along with the increasing number. The number in each cell is the value of corresponding factor at a certain condition. The Nash equilibrium set within the red boundary cell is the case study result.

In terms of robustness, starting from equilibrium of the case study, when there are moderate changing of α_n (15 to 150), equilibrium set shows strong robustness and this is also happened if α_n is small and there is big change of Caq from 1200 to 1600. In terms of other variables, equilibrium does not show strong robustness.

In terms of social benefit coefficient, holding the cost of product N constant (Cnp, Cnq) = (600, 800), increasing either α_n or α_a would initiate the government's subsidy and the number of subsidy is increasing with the increasing social benefit coefficient.

In terms of cost, product A would get the highest subsidy when the cost of it is at a middle rank (Caq, Cap) = (1350, 1200). If the cost is lower than that, government has not any motivation to give subsidy to manufacturer A because of profitable industry status. Also the cost could not be too high as (Caq, Cap) = (1800, 1600). Because government has its own budget, it cannot give any infinite subsidy. Therefore, with subsidy ceiling of attribute q, manufacturer A should develop the higher technology level with middle rank cost attribute instead of middle technology level of higher rank cost. In this way, manufacturer A can gain more subsidy from attribute q.

5.4.6. Discussion

At the current situation, technology IoV industry is a profitable industry, though this industry is a fresh market, the popularity of IoV (WTP) is very high. Also, the picked up two attributes, well-being and moving management, are lower cost attributes. This two situations made the merits of this industry. Without the subsidy, IoV industry can be developed automatically. This is at the beginning stage of this industry. Indeed, some of the attributes like moving management is deriving from the current driving system like navigation. Because of this, these attributes can be updated easily without too much investment. This is also the reason why the government would not give any subsidy to any attribute at the equilibrium. However, at equilibrium, the technology level of product N is always the lowest. That of product A is changeable. Considering the technology promotion, if government give some subsidy to well-being attribute, it will motivate manufacturer A to choose the higher technology level comparing with the equilibrium point. Therefore, taken only these two attributes into account, the best way for the government to do is giving moderate subsidy to well-being attribute in order to promote technology development.

Generally, in terms of initiation of the subsidy at the equilibrium, for this case, this is a special case that,

even if it is a new technology, it is very popular among customers which results to minimum WTP is higher than its cost at the beginning. This might result from the characters of IoV is derived from the traditional vehicle, in other words, it is not new enough. As the section 5.4.4 shows, it seems government would not a subsidy to the IoV until two conditions are satisfied: the first one is that this industry is not profitable enough make the cost is around the maximum WTP of the customer. The second one is the technology with higher social benefit should be developed.

In terms of improvement of this case, for the first condition, the manufacturer should invest more in attributes which is very costly. The costly attribute can be divided into two types. One is the attribute is well-known among the customers with higher cost. The higher cost should be higher enough to prevent some customers from buying because of beyond capability. For example like safety attribute, this attribute connects to the vehicle system. It needs the support of vehicle component and many kinds of sensors that would raise up the cost this attribute. The incremental cost would go beyond the customer's WTP even the maximum WTP that means no one can afford it without subsidy. In the meantime, the government would initiate the subsidy to benefit the civilians. Therefore, the government would give you a subsidy to offset the cost of adopting the stage because of the lack of customers. For the second one, manufacturers should produce more products related to social benefit improvement. Taken the case as an example, if a manufacturer chooses safety attribute instead of well-being as its main development area. The government would give subsidy to the manufacturer.

In terms governance issues, with the current WTP distribution and the constant cost of product N, we make a simple suggestion table below:

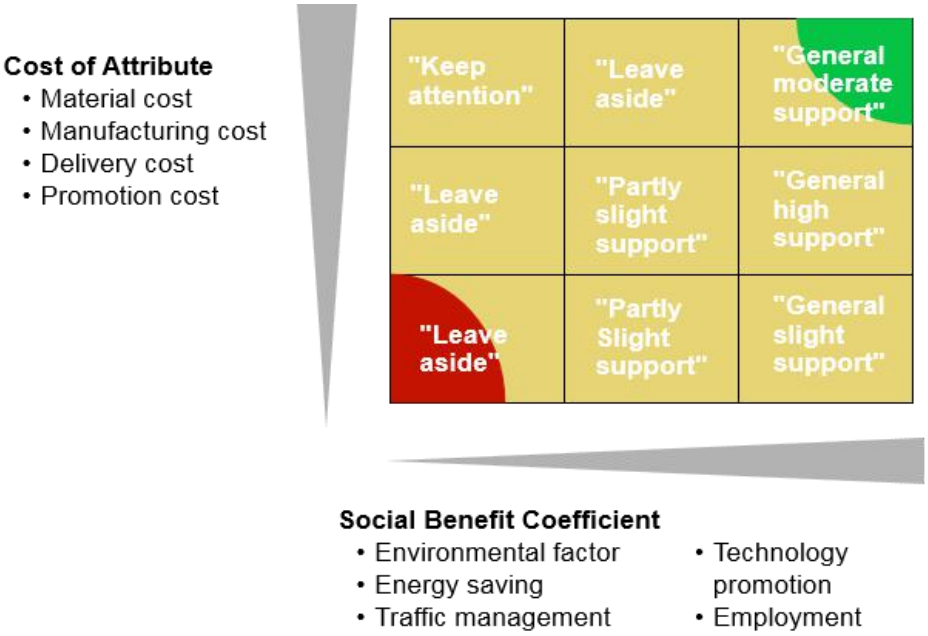


Figure 52.Subsidy strategy of the government

As figure 52 shows, according to the value of cost and value of social benefit coefficient, the subsidy strategy of government can be divided into nine areas. Each area represents one situation defined by social benefit and cost qualitatively. Each area contains many equilibria. The strategy definition is listed as follow:

Leave aside: government need not give any subsidies.

Keep attention: slight subsidy (< 400 for each attribute) would be given to minor equilibria.
Partly slight support: slight subsidy (< 400 for each attribute) would be given to related half of the equilibria.
General moderate support: moderate subsidy (> 400 and < 700 for each attribute) would be given to major equilibria.
General high support: high subsidy (> 700 and < 1000 for each attribute) would be given to major equilibria.
General slight support: slight subsidy (< 400 for each attribute) would be given to major equilibria.
Also, from table 55, we can figure out that with the higher subsidy, manufacturer would develop the higher technology level with higher possibility. The subsidy is more sensitive to social benefit than cost especially when the cost is related low.
According to these, we can continue to derive some local government policies. For example, central government currently emphasis the environmental factor as an KPI of local governance. However, different part of China would has different environmental issues. Also the social benefit of environment also followed marginal decline principle with increasing capital investment. In the Northern part of China, environmental issue is more crucial, α_n or α_a in that area should be bigger than that in Southern part of China, which would result in the different policy strategy according to figure 52.
In terms of highly development city like Beijing, Shanghai, except for environment issues, the traffic jam is also a tough problem. To deliver the IoV product precisely, IoV product in these cities should develop the moving management related attribute while in other small cities, accidents are happened more frequently because of lack of consciousness. The local government should promote the safety related attribute. These different target drive the different cost of IoV product and results in different policy strategy according to figure 52.

5.5. Summary

This chapter proposed a game model with the multiple-attribute product. Give the generalized description; we derived a specific application on IoV industry. Use the data from part 1, we finally get the Nash equilibrium of this industry according to the current materials. Also, several scenarios are proposed to tests the effect of major parameters. Finally, we derived out that for the new technology relative to IoV, the government would give subsidy when the product is not popular among customers and this product should improve the social benefit.

6. Conclusion and Expectation

6.1. Conclusions and Suggestions

6.1.1. Conclusions

In this research, we aim to solve a problem with the new technology of multiple-attributes and each attribute can be classified into several technology levels. How subsidy effect would be initiated by this type of product. A special case of the internet of the vehicle industry(IoV) in the auto field is also used to simulate the real practice.

In order to solve these issues, this research would firstly solve the customer preference and technology of IoV. This part aims to figure out the customer preference and technology of IoV industry and reveal the relative quantity and quality data as the input of the further case study chapter. Followed with the subsidy effect analysis built on a game theoretical model to reveal its effect on the technology development process.

The specific conclusion in each chapter is shown below:

A. Customer preference of IoV product and customer

Culture shock between the traditional understanding of vehicle and the new definition of the vehicle is still exited even in the young generations. They take safety and essential driving as their most important consideration. And the advanced technologies like the high level of entertainment and smart connection that recognized as the trend among youth are less attractive. And most customers would like to pay less than 5000RMB for any types of IoV product. IoV technologies have been checked and clustered into 6 groups and 11 sub-groups. These groups are technical fields defined by different students from corresponding departments. According to these technical fields, from the expert view, IoV technology is mainly supported by communication, vehicle, and algorithm.

B. The simple model of subsidy effect

In the first game model, the government's subsidy can give positive power in product promotion within some range. When beyond this limitation, the extra subsidy would be absorbed by the manufacturers. And in order to find out an equilibrium point among manufacturer customer and government. The utility unit of social welfare offered by the government would satisfy the minimum terminal within most situations. If not, there would be no agreement among them even this game is an information complete game.

C. The general model of subsidy effect

In this part, a general model based on game theory has been put forward to characterize the multiple-attributes product. Several scenarios are put forward to reveal the characters of this model. Finally, in the case study of the second game, according to the real data in China has been conducted. The model has been calculated by quadratic function solving. The result shows, the government would not give any subsidy except two conditions satisfied. One is the manufacturer should develop the product

with the higher social benefit and the other is the product with the less profitable attribute or even negative profit product. Also, we find out the tendency of technology level and price determination along with the increasing subsidy by sensitive analysis. The more subsidy government give to manufacturers, the higher technology level manufacturers would decide to develop. This situation would be more obvious when the social benefit coefficients are high. Base on all of these, we proposed a governmental policy strategy matrix to help government make decisions on technology management.

6.1.2. Suggestions

In this research, the relationships on IoV products have been discussed. Each interests side has its own rational considerations without system view. Under the frame of this paper, some suggestions are put forward to each interest side, mainly in government side:

A. Suggestions for the customers

Customer should learn to accept the fresh concept of hi-tech and have a try with the new function of the product. As we know, the currency will increase the value during its payment transmission. Only trigger the consumption desire, the society would be in the innovation process. Customer should try some small creative things from the beginning and understand the innovation would change our lives. The first step, customers should go first.

B. Suggestions for the government

The government should improve the law on innovation protection, enforce the law strictly. Though in China, some laws on patents protection have been published, however, some items in them are still vague. The description words are not specific which may go against the protection. The same with the enforcement of the law, currently, the punishment of patents violation is just financial punishment and the number is still low, which make the cost of law-breaking low.

The government should improve the promotion policy, especially on directly subsidy. Currently, the government publishes the general subsidy or tax exemption policy, however, they are all general guide, not so specific. Only some local government like Liaoning province has published some specific items like income tax exemption for the first two years. However, as shown in this paper, directly grant may be more effective on the company's R&D cost. And also, sometimes, financial support may not always be efficient. As stated in chapter 5, the government leave the market to the market itself under some conditions, which may gain better results.

The government also should guide the customer to welcome the hi-tech product and drive the customers' consumption desire. No matter what the product is, only the most acceptable product among customer is the best. If the government would use the benefit of IoV product, the government should push these products. Increasing the ways of advertisement, increasing the education of hi-tech from childhood, the conscious would change from the beginning.

In terms of technology management, according to figure 52, highly developed cities in Northern part of China like Beijing should establish a general slight subsidy plan to gain more social benefit with moving management attribute oriented IoV product; highly developed cities in Southern part of China like Shanghai should leave the market alone; developing small cities in Southern part of China like Ningbo

should keep attention on some special combination of cost and social benefit to drive the manufacturer improve its technology level; developing small cities in Northern part of China like Baotou should establish a general moderate subsidy plan to gain more social benefit with safety attribute oriented IoV product.

C. Suggestions for the manufacturers

As we know, technology would drive customer and research drive the technology, which means only increasing the research cost would win the market all the time. As we can see in the model, the advanced product would have the right to set the price first. If he wants to eliminate the normal manufacturer, he can use the lower price strategy because the marginal profit is bigger than the normal manufacturer. By this way, he can win the market even it will non-profitable at the beginning.

The manufacturer also should consider the general usage of the product. For example, some technology of the IoV product can also use to collect data from any other fields. Make the product be a platform and modularization.

In terms of subsidy initiation, the manufacturer should develop more products that can bring more social benefit while it is very fresh among the customer.

6.2. Main Contribution

There are several contributions to this paper, which listed below:

Contribution 1: open a new gate of using willingness to pay and CVM in the hi-tech field

This research shows that WTP and CVM can be well used in the hi-tech field on future product. As stated in chapter 1, in the recent 5 years, the application of willingness to pay all focused on the current product or service. No one uses this method to reveal future product. Even in the present products researches, most researchers use them in customer preference and technology and health fields. The application in the engineering field is less than 10 percent. The same as the CVM, because of the number of attributes of IoV products, there would be over 100 combinations of pictures to compare if the discrete choice method is used though that would be more precise. Therefore, CVM is picked up and the combination products in the survey decrease to 8.

Contribution 2: give a new way to technology management research from attribute point of view

Before a future product come to a commercial, there are two researches should be done. One is the relevant technologies should be developed which solve the problems that we called how. The other is the subsidy effect of the product which solve the problems that we called why. However, fewer researcher focus on the specific character of the product. Previous works are more related to some general characters, for example, durable products. Other researchers give up product side, they do research on external factors like adoption time. For the application of IoV is also the first. From 2012 when the concept of IoV has been proposed, many researchers all around the world have rushed into this field, but no one focuses on the subsidy effect of this product. All aimed to solve the technical problems without commercial considerations. This paper is the first one to do the research on subsidy effect of this product. And two different game models have been developed to explain the roles of each interest side.

Contribution 3: demonstrate the possibility of taking government as an internal player of the game by

proposing a unique governmental profit function instead of social welfare as usual

In the major previous researches, they mainly refuse to consider the cost of government. We always consider the government has unlimited budget or resources. Therefore we can focus on the relationship between customer and manufacturer. However, if we do research on government subsidy effect, we should take the government budget into account. We should consider the cost of the government before the government promotes some technology. Actually, in some situations, the government need not give any subsidy. The market can be fully occupied automatically.

6.3. Expectations

6.3.1. The Limitation of This Paper

We consider the subsidy effect on the price of the product and attribute technology level of product. This model cannot be used as the service product model since the attributes of service can be changed from one to another. There is no clear objective distinguish from one attribute to the other. Therefore, this model can only be used in the product with the physical entity and the definition of each attribute can be accepted commonly. This model mainly focused on the product with multiple attributes and subsidy can be given to each attribute separately. The subsidy is only directly given to the manufacturer according to the quantity of selling by the government. In terms of technology level, each attribute of the product should be classified into several ranks by technology level (the higher level means better performance) and each technology level has a clear definition. For example, the navigation system can be classified by resolution. Navigation system with level 1 technology can be located within 1 meter while that with level 2 technology can be located within 1 centimeter. The customer makes decisions only by price and corresponding WTP. Though there are kinds of products since any combination of attributes with different technology level, for a certain product, the number of customers according to price is followed a uniform distribution. Also, there are only two manufacturers in the game. There are still many limitations in this paper and it will be listed below:

A. In chapter 2, more surveys can be done in this chapter, for example, the survey on the normal IoV product, though the product has been widely used now, the price distribution is still vague. The price range of the survey can be wider and the interval should be bigger. The IoV product contains more sensors or devices in it, the price may be more expensive than what the survey stated. And the interval is also an issue, the interval of the bid can be bigger. The standard of field definition is subjective which may result in the error of the following research and the rank of each field should be supported by some numerical analysis.

B. In chapter 4, since the cost is used in this chapter, however, it is a fixed one. In practice, the cost of the manufacturer is combined variable one and fixed one together. And there is still another type of relationships, for example, two manufacturers may not be the master and slave. They are both have their own advantages in some areas. In this term, the substitution item should be used. Also, other games like Cournot game can be discussed. In chapter 5, the details of government subsidy mechanism can be discussed into details.

C. As the whole, maybe under other subsidy effect, other interest side would be inserted in. In reality, the information data supplier is also an important role in the operation of IoV products.

D. This model main considers only two manufacturers and also it focuses on the product with multiple-attributes at the beginning. It cannot solve the product with the updating service, for example, the navigation service may be updated for free if the advanced function has been released. Also, it did not take any service into consideration. Indeed, the data supplier would be crucial for some attributes of the product.

6.3.2. Expectation

Aimed to recover the weakness mentioned above, the further research on this filed can be:

A. Arrange more surveys on customer side including other related products, reveal the whole commercial atmosphere of IoV product.

B. More policy analysis with more factors can be used to describe the government affect on IoV product.

C. Develop the scientific method like machine learning to define the technical words field and collect more corresponding data to support the rank of the fields.

D. Use more types of game methods to simulate the subsidy effect including Cournot model and use more real cost function to represent the cost.

E. From the beginning, construct a more complete model of IoV.

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Appendix A

The original technical words data statistics:

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
无线通信网络 H04	通信	通信硬件	6	RSU（微波读写天线）
			1	PHY（物理层：与外部接口的芯片）
			10	路由
			6	中继
			5	计算机
			3	GPS
			10	服务器
			3	采集卡
			1	计时器
			1	GNSS（全球卫星导航系统）
			7	can总线
			10	传感器
			1	检测器
			1	obu（车载单元）
			1	esim
			1	sim
			3	MCU（微控单元）
			1	UART（通用异步收发报机）
		通信技术	14	网络
			26	通信
			1	无线通信
			1	蜂窝数据
			1	数据包
			48	联网
			1	DSRC（专用短程通信技术）
			1	WIFI
			1	局域网
			1	UHF（特高频无线电波）
			1	RFID（无线射频技术）
		通信协议	2	MAC（介质访问控制层）
			1	RTSP(实时流传输协议)
			1	MQTT（消息队列遥测传输）
			1	GSM（全球移动通信系统）
	算法	算法应用	3	路径
			1	位置匹配
			1	信息库
			2	导航
			1	定位
			3	信息系统
			2	数据库
			2	策略
			1	指纹
			2	图像识别
			1	博弈
			1	巡航
		算法框架	12	算法
			1	概率模型
			1	函数
			5	模型
			1	状态机
			1	SVM（支持向量机）
	高科技硬件		1	便携设备
			1	可穿戴设备
	汽车零部件	汽车电子	6	控制器
			2	显示终端
			3	电控系统
			1	OBD（车载诊断系统）
			1	etc（不停车电子收费系统）
			1	单片机
			2	芯片
		新能源组件	1	电池
			2	充电
		传统组件	1	引擎
			1	车窗
			1	轮胎
	文娱传媒		1	视频
			1	语音
			1	音频
			1	娱乐
			1	摄像头
	汽车整机厂		1	卡车
			6	电动汽车
			1	工程机械

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
信号装置 G08	通信	通信硬件	1	卫星
			5	采集卡
			4	计算机
			3	服务器
			2	收发器
			5	处理器
			1	雷达
			4	传感器
			2	信息管理模块
			2	RSU
			1	GPS
			3	服务器
			1	北斗
			1	can总线
		通信技术	1	wifi
			10	通信
			21	联网
			1	4G
			1	红外
			1	GPRS（通用分组无线服务技术）
		通信协议	1	数字证书
	算法	算法应用	6	定位
			1	导航
		算法框架	3	算法
	汽车零部件	汽车电子	1	ECU（行车控制单元）
			1	自动驾驶
			1	显示终端
			4	电控系统
		新能源组件	2	充电
		传统组件	1	转向
			1	弹簧
			1	仪表盘
	汽车整机厂		1	公交车
			1	电动汽车

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
计算，计数，推 G06	通信	通信硬件	1	缓存
			3	计算机
			2	存储器
			2	服务器
			1	计数器
			1	处理器
			1	传感器
		通信技术	7	联网
			2	RFID
			1	UHF
			2	网络
			2	通信
			1	蓝牙
			1	wifi
			1	GPRS
		通信协议	1	MAC
			1	RSS(建议信息聚合)
	算法	算法应用	3	数据库
		算法框架	5	算法
			2	神经网络
			2	API
	汽车零部件	汽车电子	1	芯片
		新能源组件	1	电池
	汽车整机厂		1	电动汽车
	其他		1	SSME（航天飞机主发动机）

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
车辆控制系统 B60W	通信	通信硬件	4	can总线
			4	传感器
			1	RSU
			2	采集卡
			4	处理器
			1	北斗
			1	存储器
			1	编译器
			2	中继
			1	收发器
			2	MCU
			1	服务器
			1	UART
			1	天线
			1	路由
		通信技术	14	联网
			6	通信
			3	网络
	算法	算法框架	2	算法
	汽车零部件	汽车电子	6	电控系统
			1	驱动
			1	显示终端
			1	记录仪
			1	芯片
		新能源组件	2	电池
			1	充电
		传统组件	3	发动机
			3	电机
			3	汽车座椅
			1	电平
			2	方向盘
			1	大灯
			1	雾灯
			1	变速器
	文娱传媒		1	投影
			1	摄像头
	汽车整机厂		5	汽车
			1	电动汽车

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
测试，测量 G01	通信	通信硬件	1	传感器
			2	服务器
			3	计算机
			1	陀螺仪
			1	卫星
			1	采集卡
			1	GPS
		通信技术	1	通信
			1	红外光
			1	紫外光
	算法	算法应用	1	数据库
			1	地理坐标
			3	定位
			1	导航
			1	管理系统
	汽车零部件	算法框架	2	算法
		汽车电子	1	电控系统
			1	单片机
		新能源组件	2	充电
			1	电池
			1	动力电池
	汽车整机厂		1	电动汽车

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
控制，调节 G05	通信	通信硬件	3	can总线
			2	MCU
			1	传感器
		通信技术	2	联网
			2	通信
	算法	算法应用	1	信息系统
	汽车零部件	汽车电子	1	芯片
			2	电控系统
			2	ECU
		新能源组件	1	电池
			1	燃料电池
		传统组件	1	发动机
	文娱传媒		1	摄像头

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
核算装置 G07	通信	通信硬件	1	can总线
			1	UART
			1	MCU
			1	收发器
			1	GNSS
			1	滤波器
		通信技术	1	通信
			1	WIFI
			1	联网
	汽车零部件	汽车电子	2	芯片
			1	记录仪
	文娱传媒		1	视频
			1	摄像头

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
供热，通风 F24	通信	通信硬件	1	传感器
		新能源组件	1	电池
		传统组件	1	净化器

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
发电，变电，配 h02	通信	通信硬件	1	集成电路
			1	电源
			1	电容
			1	二极管
			1	服务器
		通信技术	1	联网
		算法框架	1	算法
	高科技硬件		1	手机
	汽车零部件	汽车电子	1	显示终端
		新能源组件	1	充电
	汽车整机厂		1	电动汽车
	其他		1	电网

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
其他类目不包含h05	通信	通信硬件	1	探测器
	算法	算法应用	1	人机交互
		算法框架	1	算法
	汽车零部件	汽车电子	1	显示终端

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
音乐辅助设备G10	通信	通信硬件	1	处理器
		通信技术	1	联网
	算法	算法应用	2	图像识别
	汽车零部件	汽车电子	2	显示终端
		传统组件	1	引擎
	文娱传媒		1	视频

IPC Classification	Expert Classification : Level one	Expert Classification : Level Two	NO. Of Cited Patents	Technical Words
基本电气原件H01	通信	通信硬件	1	采集卡
			1	探测系统
		新能源组件	1	电池
			1	动力电池
	汽车整机厂		1	客车

Appendix B

In terms of private issues, name in the interview would be shaded.

Main body of first interview:

Q: Hello, Mr. Song, My name is Zhu Zheqi from University of Tokyo and I am a Ph.D student on IoV strategy. I am here today for your brilliant insight idea on the future of IoV.

A: Thanks for your interests on IoV. Actually we are the first produce the IoV products in China which we call it T-BoX and it can collect all the vehicle data with the backstage platform. It looks as the interface between vehicle and technology service supplier (TSP).

Q: AS far as I can see, [redacted] is a steel ring producer and currently it is still one of your branches. For what, your company want to add IoV product as another branch?

A: Great, it seems you do some works before. It is true that we are a traditional vehicle component manufacturer before. However, traditional component goes not well these years. Our board want to invest some new technology relevant to vehicles which can make a continuous profit with lower risk. And you see, we choose IoV product. The reason why we choose IoV is that IoV is a blank field which means if someone gets in early, he may have rights to set the rule and standard of this field. And IoV is a base instead of applications. Therefore what we would do in the future if IoV is complete is to update this platform instead of caring too much on the taste of customers.

Q: Base?

A: Yes, base. You can consider it as a land. IoV is the land, applications is like seeds. No matter how popular the seed is, it must not separate with land. What we do is to make the land more strong. For example, let it be faster, boarder.

Q: You mean the core of IoV technology is making a strong platform. If there is a better platform, the applications would use it automatically. Is that right?

A: Right. Since the IoV is just beginning, the company should consider the IoV technology itself more instead of the application technology based on the IoV.

Q: You just mentioned the IoV technology itself. So, what do you think the basic technologies that affect IoV most. Or another saying, what technologies, as your company, should develop in order to promote IoV.

A: Actually, there are many technologies affect IoV. However, we choose the communication hardware as the entrance of IoV products. Of course, communication hardware is the core technologies that link to IoV directly. As you see, IoV is an application of internet. Internet, essentially is a communication tool. No matter what we use it for. For car, for food, for service, anything. But basically, it is a communication tool. Therefore, we develop the communication hardware. It is a core technologies that IoV cannot go pass without. Here is an analogy. As we all know, in American, there is a time called gold rush in California. Many people around the world go there and want to find the gold. Finally, whether the people find the gold is not important. But we can surely conclude that the people who produce the shovels are earning much. That is what we done currently. We develop the tool and offer the tool and care nothing about the target what you use it for.

Q: It is so nice of you and your explanation which give me a brief idea on what you done currently. And do

you think there are some other technologies that affect the IoV most?

A: Yes, since every company has its own strategy and resources, it cannot develop all the core technologies of IoV. Indeed, [redacted] also have a selection of which core technologies go first.

Q: What technologies do you think are core technologies too, though [redacted] did not develop.

A: It is hard to say which one is more premier, however I can give you some hints. As far as I know, the platform of IoV operation system is still very crucial. It is like windows or IOS, there is thousands of software, but for the operational system, you can count it by fingers. Actually, [redacted] is beginning to construct a platform of IoV and currently it did well. We try to combine the communication hardware and system together.

Q: You mean the system. Can I taking system as algorithm technologies or programming?

A: You can, indeed, the core of system is programming and algorithm.

Q: You just mentioned [redacted] is trying to integrate the hardware and system. Is that normal in this filed that a company develop more than one technology at a time?

A: It is normal and in any fields this is a normal strategy. Actually, for [redacted], the integration mentioned before is to integrate the downstream of hardware. This can improve the customer stickiness of our products.

Q: [redacted] choose developing hardware first, why? The order can be changed?

A: As I said before, system is embedded in the hardware, though it is a little bit late than hardware, it is still the core and from some aspects it is the reason why clients choose us not others. I do not think there is order between them. Though it will cost much more development fee at the beginning, it worth.

Q: But if you choose to develop the hardware only, hard ware technology may go better.

A: As you say “may”, yes, that is the strategy. It may go better. But we choose this way, we should respond for any opportunity lost.

Q: So much thanks for your explanation. And one more question, except for algorithm and communication hardware, what do you think would be the core technologies one company wants to develop first?

A: It seems like commercial secret. But it is fine, for my own opinion, I think vehicle electronic is also core of IoV. We call it IoV instead of IoA, IoB, IoC. Because it is the application of vehicles or monitor of vehicles, maybe. It is not only the internet. That is why the extension of vehicle is also very important. And the interface of vehicles, data of vehicles mainly come from vehicle electronics.

Q: Could you please give me some hints on advantages and disadvantages of communication technology, vehicle electronic and platform development?

A: Well, this is hard to say. From the development process, communication technology is the foundation; platform comes later and last is vehicle electronics. The former is the base of the latter. This explains the time cost, which means if you develop the latter first. You may wait for the former product to be commercial. However, the development cost of former is higher than the latter.

Q: Thanks very much for your precious time and you make me more clear on this field.

A: I hope my idea can help you and let us make a progress on this field.

Second interview:

Q: Thank you for your time on this interview and my name is Zhu Zheqi, from University of Tokyo on strategy. Previously, I saw your report on CCTV and you do not think Tesla would be the next Apple, Could

you please give me some ideas on that?

A: I am pleasure to talk to the student on this field since you know technology is the future. And I am happy to see you are curies on my previous report. I do not think Tesla would be the next Apple, because Tesla did not have the core technology like Apple does. The people in China buying the Tesla is because they what to feel the high-tech and the acceleration. Totally, we call it the future car feeling. However, this is not unique, actually, many Chinese vehicle company have done the same following the Tesla and did well too in this field like BYD. And from industry aspect, vehicle industry especially for the vehicle company does not look like a component company. It has many heavy assets and it is a system work which considers security first. This is culture shock with the hi-tech company which take feeling over security. And last, basically, the supply chain cannot afford enough capability for Tesla since many Tesla's hi-tech are closely related to state securities. State would not let it grow freely.

Q: How critical thinking you make. And you just mentioned state. Do you think state would keep an eye on the IoV as Tesla does?

A: Of course, it does, why state would monitor the Tesla, because it has OTA system, which can collect the vehicle data anytime and anywhere. That is the core of IoV. Indeed, Tesla would be monitored, not because of its new energy vehicle but because of its IoV application may affect the state security directly.

Q: Cool, Great, That is the point. You mean the IoV would be supported by Chinese corporation instead of others at least at the beginning of the IoV construction.

A: Yes, IoV is like new energy car. Its booming needs the help of the government, especially for IoV. It links to automotive and infrastructure directly, which only government can push them advance. This point is totally different from other countries. In western countries, Japan included, they are like to prove a thing is good and persuade many sides before this technology come to commercial. This is not the same in China since China has huge population. We cannot wait a so long discussion. In China, government set the policies first if they feel this is good for the society. Of course, good has been proved by some top scientists. Because of the policy pushing, technology can be developed quickly. That is why new energy vehicles and automotive can be quickly developed in China, better than American in some aspect, even though we are starting lately.

Q: It is true there is a huge difference between west and east culture and style of government. As you said, in China, government can affect the technology. So considering this, what specific technology field would a company choose to develop if it wants to win in the IoV field?

A: Specific technology field?

Q: I am sorry for misleading. Specific technology field means the core technology which supports the IoV like communication technology.

A: Well, Yes, which one to be developed is really an issue? Actually government can make a good atmosphere of this field, however, they cannot point out which one is basic than others at the beginning. That is why there are many different companies which supply different IoV products. But for my opinion, communication technology, as you said, is the most important one. Indeed, China would make 5G commercial next year. There is a big application of 5G is IoV. The core improvement of 5G is that short the delaying of transmission and broad the bandwidth, which are the key criteria of IoV if it comes to be commercial using. That is why we think 2018 and 2019 would be a booming year of IoV since the foundation is well improved.

Q: You mentioned IoV products. Are there any commercial products in the market?
A: No, we call them IoV products, but in fact, they are not, and they are just some simple applications of internet like navigation.
Q: What key technology in communication technology field and do they developed separately such as communication contract, communication hardware, communication technic.
A: You did a good pre-job before interview.
Q: Thanks
A: And yes, in communication technologies, there are still many branches like you said. However, many of them can be done in one company. For example, Huawei is Chinese communication hardware manufacturer before. Since it did well in hardware and has deep understanding in communication field, Chinese government also let it join in the Chinese communication contract draft. Actually, many vehicle related companies are focused on many fields, not only on its original products after its growing. Because it can trigger synergistic effect. A communication technic research institution must know how to change the hardware to make the technic more effective.
Q: So you mean in the vehicle industry, many company develop many technologies in the same field at the same time?
A: Yes, for another instance, Bosch, as the global top 1 vehicle component corporation, based on its ECU, they developed many ADAS products like AEB, ACC.
Q: I see. Thanks. And do you think other technologies would be the choice of company to develop like platform?
A: Yes, of course, communication technology is just one example of choice. Actually many hi-tech companies choose to develop the application of IoV for instance the smart home link. These technologies can expand the IoV.
Q: Except for the applications or hi-tech companies, what do you think the traditional vehicle company would develop into?
A: I think, vehicle electronic would be their first choice since this choice has lower risk with more profit and typically other type companies can hardly enter in.
Q: Could you please give me some hints on advantages and disadvantages of communication technology, vehicle electronic and platform development?
A: Well, communication technology is more like a social welfare which may be supported by government. The others may lack of this. And since the vehicle electronic is expansion of traditional vehicles, the development cost would be lower than others. For platform, it is based on the algorithm; it can benefit other field though it cannot be used in IoV currently. Therefore, algorithm development has lowest risk.
Q: Have you ever heart about the PriceWaterhouseCooper Ltd. report on IoV application? They predict the attributes of IoV in the future. They are Moving Management, Vehicle Management, Entertainment, Well-being, Autonomous driving, Safety and Home integration.
A: Yes. I have read that report before.
Q: Previously I have done a survey among customers that let them pick up top 3 attributes they want to buy. According to the statistics, top 3 are safety, moving management and well-being. For your opinion, among these three attributes, which technology would support each most among communication, algorithm and vehicle electronics.

A: This is an interesting issue. From my view, I think communication affect moving management most, followed by well-being and last is Safety. And this order is totally different from vehicle electronics. From aspect of algorithm, moving management comes first, followed by safety and last is well-being.

Q: It is so nice of you to share your busy time and you advise help me a lot.

A: It is my pleasure and you can feel free if you have other questions in the future.

Appendix C

Table 52. State policy on advanced manufacturing

Index	Date	Name of Policy	Policy Core Content
1	May-15	Made in China 2025 strategy	To accelerate the fusion development of the new generation of information technology and manufacturing technology. Regard intelligent manufacturing as the main direction of the deep integration of the two. Strive to develop intelligent equipment and intelligent products and promote intelligent production process.
2	Jul-15	The State Council's guiding opinion on actively promoting the action of "Internet Plus"	Artificial intelligence is listed as one of its 11 priority actions. Specific actions are as follows: cultivate and develop emerging artificial intelligence industries, promote innovation of intelligent products in key field, improve the intelligent level of terminal products. The main goal is to speed up the core technology breakthrough of artificial intelligent to promote the application of artificial intelligence in field of intelliget home, intelligent terminal, intelligent car, robot, etc.
3	Mar-16	The synopsis of the 13th five-year plan for the development of People's Republic of China's national economy and social development	To accelerate the development and application of new information network technology. Focus on breaking through key technologies of big data and cloud computing, autonomous controllable operating system, senior industry and large-scale management software and artificial intelligence technology in emerging field. Artificial intelligence written in the 13th Five-Year Plan synopsis.
4	Apr-16	Robot industry development planning (2016-2020)	By 2020, the annual output of industrial robots in our own brand will reach 100,000 units, and the annual output of six-axis industrial robots will be more than 50,000 units. The annual sales income of service robots will exceeded 30 billion yuan. The main technical indexes of industrial robot will reach the level of similar products in foreign countries, and the key parts such as servo motor and driver of precision reducer for robot will make great breakthrough.
5	May-16	The "Internet Plus" three-year action implementation Program for artificial	By 2018, artificial intelligence basic resources and innovation platform will be built. Artificial intelligence industrial system will be basically established. Basic core technology will make breakthrough. overall technology and industrial development will keep pace with international statistics. Application and

		intelligence"	system-level technology will be partly in the leading state.
6	Jul-16		To develop the new generation of information technology, in which in aspect of artificial intelligence, focus be settled on the development of quasi-artificial intelligence technology methods driven by big data , make great breakthrough in the field of quasi-artificial intelligence based on big data analysis.
7	Sep-16	Special action for innovation and development of intelligent hardware industry (2016-2018)	To focus on the development of intelligent wearable devices, intelligent vehicle-borne equipment,intelligent medical and health equipment, intelligent service robots, industrial intelligent hardware equipment, etc.
8	Nov-16	The 13th Five-Year Plan for the development of national strategic emerging industries	To develop artificial intelligence, cultivate the customer preference and technology of artificial intelligence industry and promote the comprehensive integration and infiltration of artificial intelligence technology into various industries, including: speeding up the construction of artificial intelligence support system; promoting the application of artificial intelligence technology in various fields. Encourage all industries to strengthen their cooperation with artificial intelligence and gradually realize intelligent upgrade.
9	May-17	Government work report of 2017	Artificial Intelligence is firstly written into national government work report.
10	Jul-17	Notice of the state Council on printing and distributing the development plan of the new generation of artificial intelligence	To determine the strategic objectives of the three-step development of the new generation of artificial intelligence and artificial intelligence has been risen to the national strategic level. By 2020, artificial intelligence technology and its application will be synchronized with the world's advanced level and the scale of the core industry of artificial intelligence will exceeded 150 billion yuan while the scale of related industries will exceeds 10 trillion yuan. By 2025, the basic theory of artificial intelligence will make a great breakthrough, some technologies and applications will reach the world's leading level, and the scale of core industries will exceed 400 billion yuan while the scale of related industries will exceeds 10 trillion yuan. By 2030, the theory, technology and application of artificial intelligence will reach the leading level in the world and the scale of the core industry will be more than 1 trillion yuan while the scale of related industries will exceed 10 trillion yuan.
11	Oct-17	19th CPC National	Artificial intelligence is written into 19th CPC National Congress

		Congress report	report,which will promote the deep integration of internet, big data, artificial intelligence and real economy.
12	Dec-17	(Three-Year action plan for the development of a new generation of artificial intelligence industry 2011-2022)	From the perspective of promoting industrial development, the "Action Plan", combined with "made in China 2025 stategy", refine and implement the relevant tasks of the "New generation artificial intelligence development plan,". With the deep integration of information technology and manufacturing technology as the main line, focusing on the industrialization and integrated application of new generation of artificial intelligence technology, to promote the deep integration of artificial intelligence and real economy.

Table 53. State IoV relevant policy

Index	Time	Relevant departments	Name of Policy	Key policy points
1	Dec-17	Ministry of industry and information technology	Guidelines for the construction of a national industrial standard system for automobile networking (intelligent networked automobile)	By 2025, the system will form an intelligent networked automobile standard system that capable of supporting high-level autonomous driving. More than 100 intelligent networked automobile standards will be developed, covering intelligent automatic control, the cooperative decision-making technology of network connection and the technical requirements and evaluation methods related to the performance of autonomous driving function in typical scenarios to promote the development of integration of "Intelligent + networking" connection for intelligent automobile and comprehensive promotion and popularization of technology and products.
2	Dec-17	Ministry of Industry and Information Technology	Three-year implementation plan on promoting the development of the new generation of artificial intelligence industry	By 2020, more than 10 key enterprises will complete the industrial Internet demonstration construction covering the whole production process, and the networked automobile network facilities in key region will be initially completed.
3	Jul-17	Development and reform commission,	The implementation Scheme of	The purpose of this paper is to promote a wider and deeper level integration of traffic and Internet , to speed up the process to get traffic

		ministry of communications	promoting the "Internet plus" convenient traffic to promote the development of intelligent transportation	informational and intelligent to promote the modernization of China's transportation industry.
4	Jul-17	The Sate Council	Development plan of the new generation artificial intelligence	In terms of intelligent delivery vehicles, we should strengthen the integration and matching of technologies, such as vehicle-borne perception, automatic driving, networked automobile, internet of things and develop an intelligent sensing traffic system. In terms of network infrastructure, we should develop and support the intelligent industrial internet, networked automobile facing to unmanned driving, etc.
5	Apr-17	Development and reform commission, ministry of industry and information, ministry of science and technology	Medium- and long-term development plan for automobile industry	By 2020, we will complete the construction of manufacturing innovation center in automobile field like intelligent networked automobile and realize the good operation. The intelligent networked automobile will develop synchronously with the international market. By 2025, the intelligent networked automobile will enter the advanced ranks in the world.
6	Jan-17	Ministry of industry and information technology	Development planning on internet of things .(2016-2020)	To promote the rapid growth of networked automobile, smart home and other applications in consumer field. To carry out the demonstration of new technology application of networked automobile, including automatic driving, safety and energy saving, emergency rescue, anti-collision, illegal vehicle detection and cracking down on vehicle-related criminals and other applications.
7	Sep-16	National development and reform commission, ministry of industry and information	Special action on the development and innovation of intelligent hardware industry(2016-2018)	In the aspect of intelligent automobie equipment, the special action requires the development of intelligent vehicle-mounted radar, intelligent rearview mirror, intelligent recorder, intelligent vehicle-mounted navigation and so on so as to promote the information service of China's vehicle networking.

		technology		
8	Jul-16	National development and reform commission, ministry of communications	Implementation plan to promote the "Internet plus" convenient transportation to promote the development of intelligent transportation	To build a national wireless technology verification platform of vehicle networking to promote the test verification and industrialization of vehicle networking technology.To build a third-party testing platform which can evaluate and detect the performance indexes such as data specification, interactive interface, opening capability, safety protection and the like of the vehicle networking big data and the cloud platform. To construct acertification platform of vehicle networking network data security, user personal information protection rating and software evaluation.
9	May-16	National development and reform commission, ministry of industry and information, ministry of science and technology	Three-year action implementation plan of the "Internet plus" artificial Intelligence	To carry out the pilot project of intelligent vehicle in places with conditions. To build a safe and intelligent network system of integrated vehicle with cloud network to promote the typical application of intelligent vehicle.
10	Mar-16	China Automobile Industry Association	Suggestions on the development planning of the 13th five-year plan for the automobile industry	During the 13th five-year plan period, the automobile industry innovation system should be set up. The intelligent network couplet automobile should be developed actively and the vehicle with driving assistant function should be put forward. The penetration rate of new car should reach 50%.
11	Jul-15	The Sate Council	The State Council's guiding opinion on actively promoting the action of "Internet plus"	The guiding opinion requires to promote the application of intelligent technology such as vehicle networking, and to speed up the standardization of subdivision fields such as vehicle networking, intelligent special equipment and so on.
12	May-15	The Sate Council	Made in China 2025 strategy	By 2020, it is necessary to master the total technology and key technologies of intelligent assisted driving and establish the independent R & D system and production supporting system of the

				intelligent networked joint automobile preliminarily.

Table 54. Local policy on AI industry

Index	Provinces and cities	Policy Name	Policy content
1	Guizhou Province	Guizhou province's "Internet plus "artificial intelligence special action plan.	It will promote the integration of Internet and robotics, smart home, intelligent terminal, intelligent monitoring, intelligent medical treatment and other fields. To accelerate the research and breakthrough of artificial intelligence core technology, and foster and develop the new industry of artificial intelligence further.
2		Intelligent Guizhou development plan (2017-2020)	By 2020, the development of intelligent Guizhou will make phased progress. The framework of intelligent Guizhou's development will be established initially and the intelligent application infrastructure and artificial intelligence industry chain will form initially.
3	Jiangxi Province	Notice on the measures about accelerating the development of artificial Intelligence and Intelligent Manufacturing	The main direction of development of Jiangxi's artificial intelligence industry will be established as four fields: artificial intelligence products, intelligent manufacturing equipment, artificial intelligence and intelligent equipment application and services. Centre on the four main areas above, measures propose 11 further measures to promote the industrial development.
4	Shandong Provence	The 13th Five-Year Plan for scientific and technological innovation in Shandong Province	To research the key technologies of artificial intelligent models and algorithms, processing chips and cognitive system software to promote the application of artificial intelligence technology in the fields of intelligent manufacturing, public safety, health care, smart home, unmanned aerial vehicle, etc.
5	Shaanxi Province	Implementation advice on actively promote the action of "Internet plus" of the people's Government of Shaanxi Province	To accelerate the core technology breakthrough of artificial intelligence. To promote the coordinated development of big data and artificial intelligence to promote the extensive application of artificial intelligence in smart home, intelligent terminals, intelligent automobiles and robots.
6	Jilin Province	Implementation advice on actively promoting the Action of "Internet plus" in Jilin Province of Jilin Provincial people's Government	To promote the extensive application of artificial intelligence in the fields of smart home, intelligent terminals, intelligent automobiles and robots.

7	Heilongjiang Province	The 13th Five-Year Plan for scientific and technological innovation in Shandong Province	To improve the independent development capability of the new generation of key information technologies and core industries and focus on the research and development of the new generation of information technologies and systems, including the Internet of things, big data, artificial Intelligence and Virtual reality.To speed up to promote the tansfoemation apllication of artificial intelligence, virtual reality and augmented reality in fields of industry, medical treatment, culture, health, life, entertainment to cultivate emerging idustries.
8	Shanghai	Implementation advice on promoting the development of new generation artificial Intelligence in this city	By 2020, the connotation of artificial intelligence application will be deepened. 6 or so artificial intelligence innovative application demonstration areas will be created. 60 or so artificial intelligence deep application scenes will be formed. More than 100 artificial intelligence application demonstration projects will be built. The research and development capabilities of frontier theories and key technologies will be significantly improved, reaching the global advanced level in some key areas. 10 or so artificial intelligence innovation platforms will be built. 5 or so artificial intelligence characteristic industrial agglomeration areas will be built. To cultivate about 10 artificial intelligence innovation benchmark enterprises. Artificial intelligence key industry scale will exceed 100 billion yuan
9	Beijing	Guiding opinions on speeding up science and technology innovation and cultivating artificial intelligence industry in Beijing	By 2020, all the technology and application of the new generation of artificial intelligence in Beijing will reach the world advanced level, and some key technologies will reach the world leading level, forming a number of major original basic theory and landmark achievements of cutting-edge technology.
10	Chongqing	Special briefings of major themes on artificial intelligence	Chongqing has launched a major theme of artificial intelligence. In the next three years, it's planned to attract all social innovation entities to invest hundreds of billions of yuan to carry out artificial intelligence technology innovation and application demonstration.
11	Guangdong Provwince	Implementation advice on promoting the development of big data in Guangdong Province (2016-2020)	To support artificial intelligence technology innovation of natural language understanding, machine learning, deep learning, etc.

12	Zhejiang Province	Development Planning of New Generation artificial Intelligence in Zhejiang Province	By 2022, Zhejiang will make important progress in the fields of basic theory, core technology, supporting platform, innovative application and industrial development of artificial intelligence. The overall technology and industrial development level of artificial intelligence will be leading the country and keep pace with that world' s leading level. Specifically, in terms of technology research and development, more than 500 core invention patents will be obtained and more than 10 leading or participating in the formulation of artificial intelligence technical standards and norms. In terms of industrial scale, The scale of the core industry of artificial intelligence will be more than 50 billion yuan, the scale of the core industry of artificial intelligence is more than 50 billion yuan to drive the relevant industry scale get more than 500 billion yuan. In terms of application, artificial intelligence technology will be used to take the lead in application and promotion in field of manufacturing, transportation, finance, health care, education and government.
13	Anhui Province	Development planning of artificial intelligence industry in Anhui province (2017-2025) (draft for comments)	By 2018, it will strive to expand the scale of the core industry of artificial intelligence to 8 billion yuan, driving the scale of related industries to 30 billion yuan. by 2020, it will strive to expand the scale of the core industry of artificial intelligence to 13 billion yuan, driving the scale of related industries to 45 billion yuan. By 2025, it will strive to expand the scale of artificial intelligence core industry to 35 billion yuan, driving scale of related industries to 220 billion yuan.

Table 55.Local policy on IoV relevant industry

Provinces and cities	Date	Policy name	Policy key content
Jilin Province	Jan-18	Implementation opinions of the implementation of the development plan about the new generation of artificial intelligence	To strengthen the integration and matching of vehicle perception, automatic driving, automobile networking and internet of things. To develop traffic intelligent perception system to form automatic driving platform technology system and product assembly capability. To develop unmanned vehicle networking
Hubei Provinc	Dec-1	The 13th five-year plan development and	To further develop the fusion technology of vehicle and network information. To accelerate the construction of

e	7	construction planning of innovation ability of Hubei province	national base of innovation demonstration area of intelligent networked automobile and intelligent transportation. Relying on the Wuhan national economic and technological development zone of networked automobile demonstration area, to cultivate industry customer preference and technology where intelligent automobile develop integratedly with intelligent transportation.
Zhejiang Province	Dec-17	Development planning of the new generation of artificial intelligence in Zhejiang Province	To break through the new energy vapor gas vehicle "vehicle network fusion" technology and the on-board intelligent operating system, high-precision map and positioning, intelligent perception, intelligent decision-making and control and other key technologies To promote research & development and application of intelligent auxiliary driving, complex environment perception, tehicle-mounted intelligent equipment and other products. Planning to build a intelligent network test ground.
	May-17	Suggestions on deepening the Integration Development of Manufacturing Industry and Internet	Accelerate the development of wearable electronics, network terminals, smart home, medical electronics, car networking and other networked, intelligent products.
	May-16	The 13th Five-Year development plan of the new energy automobile industry in Zhejiang Province	To build two demonstration bases for the intelligent transportation of 5G cars in Wuzhen, Tongxiang and Yunxi, Hangzhou. To speed up the technological breakthroughs and large-scale applications in such aspects as the intelligent operation of new energy vehicles and the system of vehicle networking.To build a unified intelligent information platform and form a new energy vehicle interconnection and sharing pattern.
Liaoning Province	Dec-17	The development planning on Liaoning's new generation of artificial intelligence	In the field of intelligent transportation, we should focus on the technology of automatic driving and vehicle networking to build an intelligent transportation integrated service platform and promote the application of artificial intelligence in road passenger transport management service.
Sichuan Province	Sep-17	Guiding opinions on the development of the 13th five - year plan auto industry in Sichuan province	To speed up to promote the demonstration of intelligent networked car.To take the oppotunity of Sino-German cooperation in building test and verification pilot demonstration of intelligent networked automobile and vehicle networking standards to vigorously promote the first intelligent networked car and

			car networking promotion demonstration.
Fujian Province	Sep-17	Development planning of new energy automobile industry in Fujian province(2017-2020)	To speed up the development of automatic driving technology. To speed up the application of intelligent interconnection internet plus in car. To seek the application of big data in enterprise and car networking value-added services to realize the car networking service secondary sales.
Guangdong Province	Jul-17	Cooperation framework agreement of the Guangdong provincial people's government of the Ministry of industry and information technology	To carry out the application pilot of networked car. To support Guangzhou and other cities to participate in development and application of the pilot in the national car network and intelligent network automotive industry. To promote safe, shared and convenient new applications of intelligent networked vehicles.
Anhui Province	Feb-17	Development plan of automobile and new energy automobile industry in the 13th five - year plan of Anhui province	To actively develop vehicle networking communication technology and integrated supply. To speed up the layout and development of industry chain in car network and intelligent transportation system. To basically build independent, high-end intelligent auto industry chain and intelligent transportation system by 2020 and possesse more than 80 percent of independent facilities .
Yunnan Province	Dec-16	Development planning of automobile industry in Yunnan province（2016-2020）	Focus on developing mobile internet industry like mobile car networking. Focus on supporting emerging services projects in the environment of the mobile internet, internet of things and the car network.
Hunan Province	Nov-16	Development plan of new industrialization in Hunan province during the 13th five - year plan	The plan put forward that we should accelerate the growth of emerging industries and actively cultivate the network intelligent gas vehicle.To support automobile enterprise and internet enterprise to cooperate on developing networked smart cars including unmanned cars. To build industry cluster of network linked automobile.
Jiangsu Province	Sep-16	Development plan of Jiangsu automobile during industry 13th five - year plan	To promote the cross-border development of integration of automobile.To deepen the application of the internet.To encourage cooperation of industry chain and accelerate the application of car networking. To establish Cooperative mechanism of intelligent network car, intelligent transportation network, intelligent electric fence and smart city. To explore multidomain-connected mode of innovative development of dynamic intelligent network connection automobile.

Appendix D

Stage four:

Under this situation, the number of customers who want to buy the products would be listed below:

$$Qa = Fa = 1 - \frac{Pa - s - Wa_{\min}}{Wa_{\max} - Wa_{\min}}$$

$$Qn = \frac{Pa - s - Wa_{\min}}{Wa_{\max} - Wa_{\min}} - \frac{Pn - Wn_{\min}}{Wn_{\max} - Wn_{\min}}$$

Stage three:

The utility function of advanced manufacturer is $E_a = (Pa - c_a)Q_a$ and substituted this equation by the functions above. This expression can be rewrite as $E_a = (Pa - c_a)(1 - \frac{Pa - s - Wa_{\min}}{Wa_{\max} - Wa_{\min}})$ and it can be simplified as $E_a = \frac{-Pa^2}{Wa_{\max} - Wa_{\min}} + (\frac{c_a + s + Wa_{\max}}{Wa_{\max} - Wa_{\min}})Pa - (\frac{s + Wa_{\max}}{Wa_{\max} - Wa_{\min}})c_a$. In this function, the symmetry axis is $\frac{c_a + s + Wa_{\max}}{2}$ and the two real roots are Ca and s+$Wa_{max.}$

Therefor, the best response of advanced manufacturer is:

$$Pa = \frac{c_a + s + Wa_{\max}}{2}$$

Stage two:

After the solution of advanced manufacturer price, the normal manufacturer price can be revealed as follow:

The utility function of advanced manufacturer is $E_n = (Pn - c_n)Q_n$ and substituted this equation by the functions above. This expression can be rewrite as $E_n = (Pn - c_n)(\frac{Pa - s - Wa_{\min}}{Wa_{\max} - Wa_{\min}} - \frac{Pn - Wn_{\min}}{Wn_{\max} - Wn_{\min}})$.

Substituted Pa by the expression calculated above and simplified as:

$$E_a = \frac{-Pn^2}{Wn_{\max} - Wn_{\min}} + (\frac{c_a - s - 2Wa_{\min} + Wa_{\max}}{2(Wa_{\max} - Wa_{\min})} + \frac{Wn_{\min} + c_n}{Wn_{\max} - Wn_{\min}})Pn - (\frac{c_a - s - 2Wa_{\min} + Wa_{\max}}{2(Wa_{\max} - Wa_{\min})} + \frac{Wn_{\min}}{Wn_{\max} - Wn_{\min}})c_n$$

The symmetry axis is

$\frac{(Wn_{\max}-Wn_{\min})(c_a-s)+Wa_{\max}(Wn_{\max}+Wn_{\min})-2Wa_{\min}Wn_{\max}}{4(Wa_{\max}-Wa_{\min})}+\frac{c_n}{2}$ and the two real roots are Cn

and $\frac{(Wn_{\max}-Wn_{\min})(c_a-s)+Wa_{\max}(Wn_{\max}+Wn_{\min})-2Wa_{\min}Wn_{\max}}{2(Wa_{\max}-Wa_{\min})}$.

If $\frac{(Wn_{\max}-Wn_{\min})(c_a-s)+Wa_{\max}(Wn_{\max}+Wn_{\min})-2Wa_{\min}Wn_{\max}}{4(Wa_{\max}-Wa_{\min})}+\frac{c_n}{2}\geq 0$:

The best response of normal manufacturer is

$$Pn=\frac{(Wn_{\max}-Wn_{\min})(c_a-s)+Wa_{\max}(Wn_{\max}+Wn_{\min})-2Wa_{\min}Wn_{\max}}{4(Wa_{\max}-Wa_{\min})}+\frac{c_n}{2}$$

If $\frac{(Wn_{\max}-Wn_{\min})(c_a-s)+Wa_{\max}(Wn_{\max}-Wn_{\min})-2Wa_{\min}Wn_{\max}}{4(Wa_{\max}-Wa_{\min})}+\frac{c_n}{2}\leq 0$:

The best response of normal manufacturer is $Pn=0$, since if Pn = 0, the payoff of normal product manufacturer would be negative. However, this is a contradiction. Because the payoff would be positive in the chart when Pn equal to 0. Therefor, the best response of normal manufacturer is

The best response of normal manufacturer is

$$Pn=\frac{(Wn_{\max}-Wn_{\min})(c_a-s)+Wa_{\max}(Wn_{\max}+Wn_{\min})-2Wa_{\min}Wn_{\max}}{4(Wa_{\max}-Wa_{\min})}+\frac{c_n}{2}$$

Stage one:

Since the payoff of government can be described as $G=A_aQ_a+A_nQ_n-B(1-Q_n-Q_a)-sQ_a$, by combining similar terms, $G=(A_a+B-s)Q_a+(A_n+B)Q_n-B$. Substituted Qa and Qn by the expression in proposition 1 and continuously substituted Pa and Pn by the expression in proposition 2. Finally, the expression can be simplified as:

$$G=\frac{-s^2}{2(Wa_{\max}-Wa_{\min})}-(\frac{A_n-B-2A_a-2c_a+2Wa_{\max}}{4(Wa_{\max}-Wa_{\min})})s-B-\theta-\frac{c_a-Wa_{\max}}{2(Wa_{\max}-Wa_{\min})}$$

which $\theta=(\frac{c_a-2Wa_{\min}+Wa_{\max}}{2(Wa_{\min}-Wa_{\max})}+\frac{\lambda+(4Wn_{\min}-2c_n)(Wa_{\max}-Wa_{\min})}{4(Wa_{\max}-Wa_{\min})(Wn_{\max}-Wn_{\min})})(A_n+B)$ and

$\lambda=c_aWn_{\max}-c_aWn_{\min}-2Wa_{\min}Wn_{\max}+Wa_{\max}Wn_{\min}+Wa_{\max}Wn_{\max}$.

If government's payoff would be positive, then delta of function should be over 0.

$$\Delta = \left(\frac{2A_a - A_n + B + 2c_a - 2Wa_{\max}}{4(Wa_{\min} - Wa_{\max})} \right)^2 + \frac{\Phi}{Wa_{\max} - Wa_{\min}}$$ and

$$\Phi = \frac{(c_a - Wa_{\max})(A_a + B)}{(Wa_{\min} - Wa_{\max})} - 2B + \frac{(\lambda + 2c_n(Wa_{\min} - Wa_{\max}))(A_n + B)}{2(Wa_{\max} - Wa_{\min})(Wn_{\max} - Wn_{\min})}$$

The symmetry axis is $\frac{B - A_n + 2A_a + 2c_a - 2Wa_{\max}}{4}$.

If $\Delta \geq 0$ and $\frac{B - A_n + 2A_a + 2c_a - 2Wa_{\max}}{4} \geq 0$:

The best response of government is $\frac{B - A_n + 2A_a + 2c_a - 2Wa_{\max}}{4}$

If $\Delta \geq 0$ and $\frac{B - A_n + 2A_a + 2c_a - 2Wa_{\max}}{4} \leq 0$:

The best response of government is 0.

If $\Delta \leq 0$ and $\frac{B - A_n + 2A_a + 2c_a - 2Wa_{\max}}{4} \geq 0$:

The best response of government is $\frac{B - A_n + 2A_a + 2c_a - 2Wa_{\max}}{4}$

If $\Delta \leq 0$ and $\frac{B - A_n + 2A_a + 2c_a - 2Wa_{\max}}{4} \leq 0$:

The best response of government is 0.

Appendix E

Proof 1:

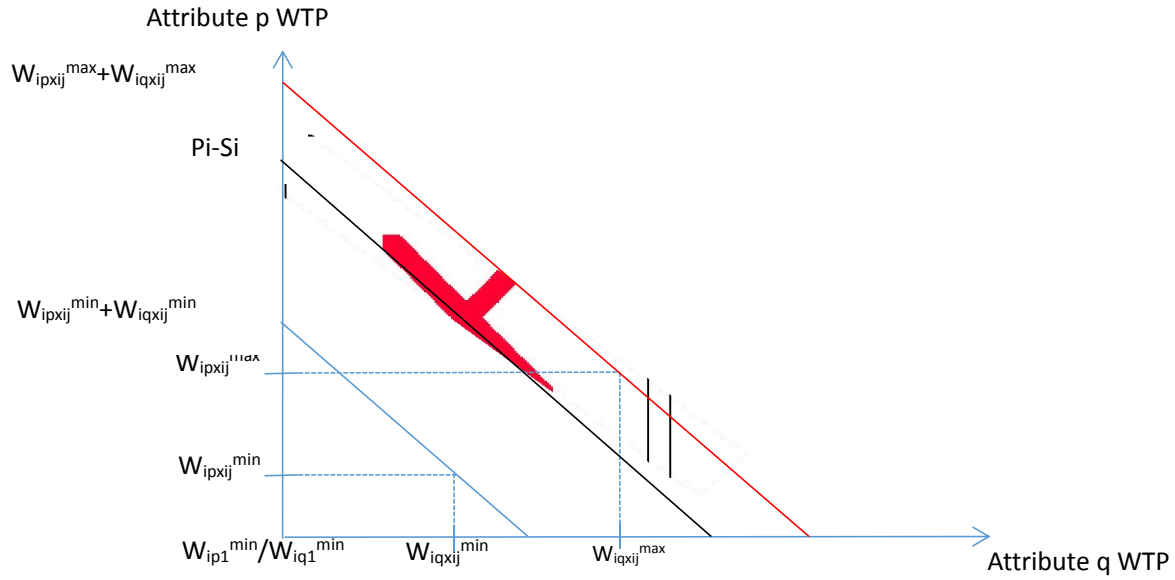

Figure 1. The number of the people who can afford the product i

As figure 1 shows, the origin point is the minimum WTP of first level of each attribute of product i. The blue line goes though the point (Wipxijmin, Wiqxijmin) with 45 degree, which means this line is the minimum price of product i. Therefore, the red line is maximum price of product i. Assume the black line is the selling price. The area beyond the black line is the people who can afford the new technology. Since there is a final price (red line), the area beyond the red line is the people who cannot afford. So the shade is the number of people who can afford the product and since it is uniform distributed, the number of customers who will buy the product could be expressed as follows:

$$Qi = 1 - \frac{(Pi - S_i) - W_{ipx_{ij}}^{\min} - W_{iqx_{ij}}^{\min}}{W_{ipx_{ij}}^{\max} + W_{iqx_{ij}}^{\max} - W_{ipx_{ij}}^{\min} - W_{iqx_{ij}}^{\min}} \quad (1)$$

Proof 2:

Based on the specific situation in generalized model, the interval of same attribute is constant regardless of manufacturer and technology level, which means the position of selling price of each attribute within the interval would decide the whole market. Since cost of each attribute is lower than its corresponding minimum WTP stated in assumption D, number of customers would be determined in two situations. One is selling price is higher than minimum WTP and the other is lower. First situation can be expressed as equation 2 and second is shown in equation 3.

$$\begin{cases} Q_A = \frac{P_A - S_A - W_A^{\min}}{In_A}, Q_N = 0 & W_A^{\max} - (P_A - S_A) > W_N^{\max} - (P_N - S_N) \\ Q_A = 0, Q_n = \frac{P_N - S_N - W_N^{\min}}{In_N} & W_A^{\max} - (P_A - S_A) < W_N^{\max} - (P_N - S_N) \\ Q_a = \frac{P_A - S_A - W_A^{\min}}{2In_A}, Q_n = \frac{P_N - S_N - W_N^{\min}}{2In_N} & W_A^{\max} - (P_A - S_A) = W_N^{\max} - (P_N - S_N) \end{cases} \quad (2)$$

$$\begin{cases} Q_A = 1, Q_N = 0 & W_A^{\max} - (P_A - S_A) > W_N^{\max} - (P_N - S_N) \\ Q_A = 0, Q_N = 1 & W_A^{\max} - (P_A - S_A) < W_N^{\max} - (P_N - S_N) \\ Q_A = 1/2, Q_N = 1/2 & W_A^{\max} - (P_A - S_A) = W_N^{\max} - (P_N - S_N) \end{cases} \quad (3)$$

The demand function of product A described with a step function is defined as $u((W_A^{\max} - P_A + S_A - (W_N^{\max} - P_N + S_N)) * (Q_A + Q_N))$. Since the two manufacturers are totally the same, the demand function of product N is $u((W_A^{\max} - P_A + S_A - (W_N^{\max} - P_N + S_N)) * (Q_A + Q_N))$ and at the break point $W_A^{\max} - P_A + S_A = W_N^{\max} - P_N + S_N$, $u(W_A^{\max} - P_A + S_A - (W_N^{\max} - P_N + S_N)) = 1/2$ and $Q_A = Q_N$ and $\delta(W_A^{\max} - P_A + S_A - (W_N^{\max} - P_N + S_N)) = 1/2$ should be satisfied. With the expression above, the complete information game can be represented:

$$\begin{cases} \max \Pi_1 = (P_A - \overline{c}_A) u(Tem) Q_{all} \\ \max \Pi_2 = (P_N - \overline{c}_N) u(Tem) Q_{all} \end{cases} \quad (4)$$

$$Tem = W_A^{\max} - (P_A - \overline{c}_A) - (W_N^{\max} - (P_N - \overline{c}_N)) \quad (5)$$

As the special proposition, if $W_A^{\max} - P_A + S_A \neq W_N^{\max} - P_N + S_N$, all the market share would be taken by the product with lower relevant price. Therefore

$$Q_{all} = \begin{cases} 1 - \frac{P_i - \overline{c}_i - W_i^{\min}}{In_i} & P_i - \overline{c}_i \geq W_i^{\min} \\ 1 & P_i - \overline{c}_i < W_i^{\min} \end{cases} \quad (6)$$

the solution of this game can be derived from

$$\frac{\partial \Pi_1}{\partial P_A} = 0 \text{ and } \frac{\partial \Pi_2}{\partial P_N} = 0$$

which means

$$u(Tem)\left[Q_{all}(P_A) + (P_A - \overline{c}_A) Q'_{all}(P_A)\right] = (P_A - \overline{c}_A) \delta(Tem) Q_{all}(P_A) \quad (7)$$

$$u(Tem)\left[Q_{all}(P_N) + (P_N - \overline{c}_N) Q'_{all}(P_N)\right] = (P_N - \overline{c}_N) \delta(Tem) Q_{all}(P_N) \quad (8)$$

Because regardless of position of Pi and $W_i^{\min}$, Qall is always a value without parameters, which means

the formation of solution of equation 4 would not change according to equation 6. Referring to the constraint $W_A^{\max} - P_A + S_A$ and $W_N^{\max} - P_N + S_N$, there are three situations.

Situation 1: $W_A^{\max} - (P_A - S_A) = W_N^{\max} - (P_N - S_N)$ and $P_A \geq \bar{c}_A$ and $P_N \geq \bar{c}_N$.

This situation means selling price of each productis bigger than its cost and the position of each terminal price in its corresponding WTP interval is the same.

$$\begin{cases} P_A = \bar{c}_A + \dfrac{Q_{all}(P_A)}{Q_{all}(P_A) - Q'_{all}(P_A)} \\ P_N = \bar{c}_N + \dfrac{Q_{all}(P_N)}{Q_{all}(P_N) - Q'_{all}(P_N)} \end{cases} \tag{9}$$

As the formulation of Qall expressed by P_A or P_N is the same as equation 6 stated, substituted equation 6 into equation $\frac{Q_{all}(P_A)}{Q_{all}(P_A) - Q'_{all}(P_A)}$. From the graph of equation 6, the maximum value of $\frac{Q_{all}(P_A)}{Q_{all}(P_A) - Q'_{all}(P_A)}$ is 1, which means $P_A = \bar{c}_A + \frac{Q_{all}(P_A)}{Q_{all}(P_A) - Q'_{all}(P_A)} < \bar{c}_A + 1$. Together with constraint $P_A \geq \bar{c}_A$, the only possible value of P_A is $P_A = \bar{c}_A$. Similar with P_A, P_N can also be calculated as $P_N = \bar{c}_N$. When the P_A and P_N are equal to their own corresponding cost, customers' utility of each product are determined by its cost and subsidy. Because the customers are uniform distributed and other parameters of manufacturer are the same, which means the product with relevant lower cost would take the whole market. This can be expressed as:

$$\begin{cases} Q_{all}(P_A = \bar{c}_A) = 1 \quad if\,(W_A^{\max} - P_A + S_A) > (W_N^{\max} - P_N + S_N) \\ Q_{all}(P_N = \bar{c}_N) = 1 \quad if\,(W_A^{\max} - P_A + S_A) < (W_N^{\max} - P_N + S_N) \\ Q_{all}(P_A) = Q_{all}(P_N) = \dfrac{1}{2} \quad if\,(W_A^{\max} - P_A + S_A) = (W_N^{\max} - P_N + S_N) \end{cases} \tag{10}$$

According to the additional assumption in section 6.3.1., the conditions of this expression can also be rewrite as:

$$\begin{cases} (x3 - x1)(c_{ap} - sb_p - b_{ap}) > (x4 - x2)(c_{aq} - sb_q - b_{aq}) \\ (x3 - x1)(c_{ap} - sb_p - b_{ap}) < (x4 - x2)(c_{aq} - sb_q - b_{aq}) \\ (x3 - x1)(c_{ap} - sb_p - b_{ap}) = (x4 - x2)(c_{aq} - sb_q - b_{aq}) \end{cases} \tag{11}$$

Therefore, the best response of price of manufacturers can only be got with the third situation. There are two best response of this proposition:

$\begin{cases} x3 = x1 \\ x4 = x2 \end{cases}$ or $\dfrac{x3 - x1}{x4 - x2} = \dfrac{c_{ap} - sb_p - b_{ap}}{c_{aq} - sb_q - b_{aq}}$

Situation 2: $W_A^{\max} - (P_A - S_A) > W_N^{\max} - (P_N - S_N)$ and $P_A \geq \bar{c}_A$ and $P_N \geq \bar{c}_N$.

As the definition of step function and impulse function,

if $W_A^{\max} - (P_A - S_A) \neq W_N^{\max} - (P_N - S_N)$, $\delta(W_A^{\max} - (P_A - S_A) - W_N^{\max} + (P_N - S_N)) = 0$.

Solve the equation 4,

$$P_N = \bar{c}_N - \frac{Q_{all}(P_N)}{Q'_{all}(P_N)} \tag{12}$$

However, this situation is not a stable one since manufacturer n has a positive profit while manufacturer a has no profit. Manufacturer a must decrease its price to meet the first situation.

Situation 3: $W_A^{\max} - (P_A - S_A) < W_N^{\max} - (P_N - S_N)$ and $P_A \geq \bar{c}_A$ and $P_N \geq \bar{c}_N$.

The same with situation 2, situation 3 also is not a stable one, it will drop to situation 1.
The selling price of product is the same as the cost, so as its attribute. The Nash equilibrium point of selling price of each attribute is equal to its cost since they must over or equal to its cost.

Proof 3:

Assume the interval of product A with x3 level of attribute p and x4 level of attribute q is border than the interval of product N with x1 level of attribute p and x2 level of attribute q.

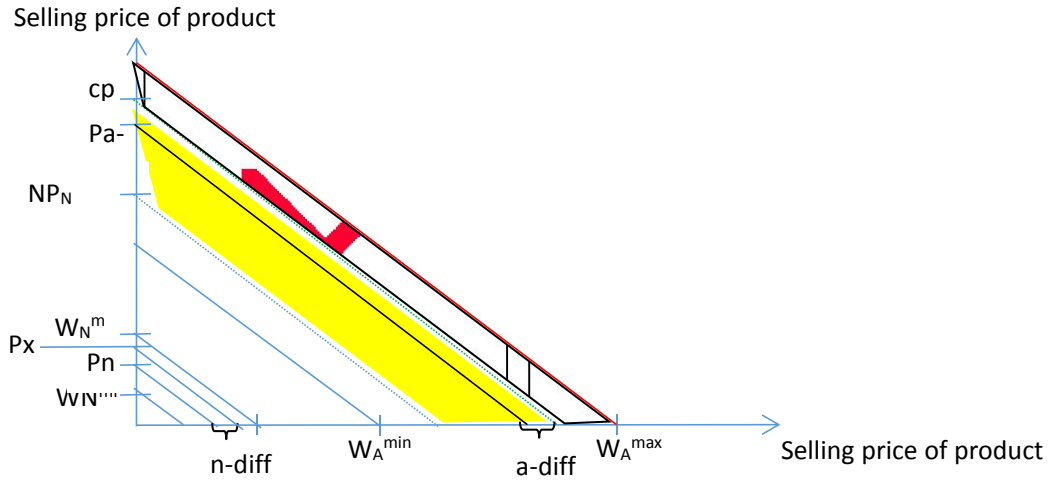

Figure 2. The number of people who will buy the producta and n

Since the higher technique the border WTP interval and product A has high technique. As figure 2 shows, the interval of WTP of product N is smaller than the interval of WTP of product A, however the area surround by each interval of the same product stands for the same number of customer which is the total samples. Because of the different scale of interval, the utilities of each productc annot be compared. According to this, the number of people who can only afford N but A is the area between NPn and (Pa-Sa). The area between (Pa-Sa) and WAmax is the number of people who can afford both. The product with higher utility would be picked up. Therefore, cp should satisfied with two conditions that one is the position of customer between WAmin and WAmax should be equal to position of customer between WNmin and WNmax and the other is utilities should be the same. The equation can be expressed as:

$$\begin{cases} \dfrac{cp - W_A^{\min}}{W_A^{\max} - W_A^{\min}} = \dfrac{P_x - W_N^{\min}}{W_N^{\max} - W_N^{\min}} \\ cp - (P_A - S_A) = P_x - (P_N - S_N) \end{cases} \tag{13}$$

Px means the cp among interval of product N. Therefore cp can be expressed as:

$$\frac{cp - (P_A - S_A) + (P_N - S_N) - W_N^{\min}}{W_N^{\max} - W_N^{\min}} = \frac{cp - W_A^{\min}}{W_A^{\max} - W_A^{\min}} \tag{14}$$

the number of people who will buy product N with x1 level of p attribute and x2 level of q attribute is shown as followed:

$$Q_N = \frac{cp - NP_N}{In_N} \tag{15}$$

And the number of people who will buy product A with x3 level of p attribute and x4 level of q attribute is shown as followed:

$$Q_{\mathrm{A}} = \frac{W_A^{\max} - cp}{In_A} \tag{16}$$

Since the all the customer is uniform function, customers' utility of product A is:

$$\pi_A = Q_A \frac{W_A^{\max} - cp}{2} \tag{17}$$

The customer surplus of product N is bit complicated since the upper terminal of price would be discounted back to product N's interval.

The utility of product N is:

$$\pi_N = Q_N \left(\frac{cp - (W_A^{\min} - W_N^{\min} T) - P_N T}{2T}\right) \tag{18}$$

Where $T = \dfrac{In_A}{In_N}$

Total surplus of customer is:

$$\pi = \pi_A + \pi_N \tag{19}$$

Appendix F

Table 56.sensitivity analysis of case study according to (Cnp, Cnq) = (600, 1200)

Caq / Cap		900																						1350							
	α n / αa	15								150								1500								15							
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	1800	1800	0	0	1	1	1	1	1900	1800	0	0	3	1	3	1	3600	3100	300	0	1	1	1	1	2150	2000	0	0
	200	1	1	1	1	1800	1800	0	0	1	1	1	1	1800	1800	0	0	3	1	3	1	3600	3100	300	0	1	1	1	1	2150	2000	0	0
	2000	3	3	1	1	5400	1910	200	750	3	3	1	1	5400	1910	200	750	3	3	1	1	5400	1900	200	750	3	3	1	1	6650	2410	250	750
1200	20	1	2	1	1	3200	2210	0	50	1	2	1	1	3200	2210	0	50	1	1	3	1	2300	3500	400	0	1	1	1	1	2550	2300	0	0
	200	1	2	1	1	3100	2210	0	50	1	2	1	1	3100	2210	0	50	1	1	3	1	2300	3500	400	0	1	1	2	1	2650	2910	50	0
	2000	2	3	1	1	5400	2000	350	850	2	3	1	1	5400	2000	350	850	2	3	1	1	5400	2100	250	800	1	3	1	1	5350	2900	0	550
1600	20	1	1	2	1	2600	2800	0	0	1	1	2	1	2600	2800	0	0	1	2	3	1	3400	3700	250	0	1	1	1	1	2950	2600	0	0
	200	1	3	1	1	4410	2500	0	0	1	1	2	1	2600	2800	0	0	1	2	3	1	3400	3700	250	0	1	1	1	1	2950	2600	0	0
	2000	1	3	1	1	4500	1800	0	900	1	3	1	1	4500	1800	0	900	1	3	3	1	4410	3500	200	150	1	3	1	1	5750	2910	0	450

1350																	1800															
150								1500								15								150								1500							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2250	2000	0	0	3	1	3	1	3750	3200	300	0	1	1	2	1	2600	2800	0	0	1	1	2	1	2600	2800	0	0	3	3	3	3	7800	6600	150	900
1	1	1	1	2150	2000	0	0	3	1	3	1	3750	3200	300	0	1	1	2	1	2600	2800	0	0	1	1	2	1	2600	2800	0	0	3	3	3	3	7800	6600	150	900
3	3	1	1	6650	2410	250	750	3	3	3	1	6650	3500	300	700	3	1	1	1	4300	2600	100	0	3	1	1	1	4300	2600	100	0	3	3	3	3	7800	6600	150	900
1	1	1	1	2550	2300	0	0	2	3	3	3	6450	6300	250	700	1	1	1	1	3000	2600	0	0	1	1	1	1	3000	2600	0	0	2	3	3	3	7800	7800	450	1000
1	1	2	1	2650	2910	50	0	2	3	3	3	6450	6300	250	700	1	1	1	1	3000	2600	0	0	1	1	1	1	3000	2600	0	0	2	3	3	3	7800	7800	450	1000
1	3	1	1	5350	2600	0	550	2	3	3	3	6450	6300	250	700	1	1	2	1	3000	3300	100	300	1	1	2	1	3000	3300	100	300	1	1	3	1	3000	4000	300	100
1	1	1	1	2950	2600	0	0	1	3	3	2	5650	5000	200	600	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0	1	1	3	3	3400	7000	400	950
1	1	1	1	2950	2600	0	0	1	3	3	2	5650	5000	200	600	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0	1	1	3	3	3400	7000	400	950
1	3	1	1	5750	2910	0	450	1	3	3	2	5650	5000	200	600	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0	1	1	3	3	3400	7000	400	950

Table 57.sensitivity analysis of case study according to (Cnp, Cnq) = (600, 1600)

Cap \ Caq		900																				1350							
	αa \ α n	15								150								1500								15			
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	2100	2200	0	0	1	1	1	1	2100	2200	0	0	3	2	3	1	5500	3800	550	500	1	1	1	1	2250	2200	0	0
	200	1	1	1	1	2100	2200	0	0	1	1	1	1	2100	2200	0	0	3	2	3	1	5500	3800	550	500	1	1	1	1	2250	2200	0	0
	2000	3	3	1	1	5400	2200	250	600	3	3	1	1	5400	2200	250	600	3	3	1	1	5400	2200	250	600	3	3	1	1	6650	2410	300	950
1200	20	1	1	1	1	2200	2200	0	0	1	1	1	1	2300	2200	0	0	1	1	3	1	2300	3900	600	0	1	1	1	1	2550	2400	0	0
	200	1	1	1	1	2200	2200	0	0	1	1	1	1	2200	2200	0	0	1	1	3	1	2300	3900	600	0	1	1	2	1	2650	2910	0	50
	2000	3	3	1	1	6800	2500	350	900	3	3	1	1	6800	2500	350	900	3	3	1	1	6800	2500	350	900	1	3	1	1	5450	2410	0	1000
1600	20	1	1	2	1	2600	2910	0	0	1	1	2	1	2700	2910	0	100	1	2	3	1	3400	3700	250	0	1	1	1	1	2950	2700	0	0
	200	1	1	2	1	2600	2910	0	0	1	1	2	1	2600	2910	0	0	1	2	3	1	3400	3700	250	0	1	1	1	1	2950	2700	0	0
	2000	1	3	1	1	4500	2200	0	700	1	3	1	1	4500	2200	0	700	1	3	1	1	4500	2300	0	600	1	3	1	1	5750	2600	0	950

1350																1800																			
150								1500								15								150								1500					
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2350	2200	0	0	1	1	1	1	2350	2200	0	0	2	1	1	1	3400	2500	0	0	2	1	1	1	3400	2500	0	0	2	1	3	1	3400	3600	200	50
1	1	1	1	2250	2200	0	0	3	1	3	1	3950	3500	350	0	2	1	1	1	3400	2500	0	0	1	1	2	1	2700	2910	0	100	2	1	3	1	3400	3600	200	50
3	3	1	1	6650	2410	300	950	3	3	1	1	6650	2410	300	950	1	3	1	1	6400	2800	150	1000	1	3	1	1	6400	2800	150	1000	2	1	3	1	3400	3600	200	50
1	1	1	1	2650	2400	0	0	1	2	3	1	3900	3700	150	300	1	1	1	1	3000	2800	0	0	1	1	1	1	3000	2800	0	0	1	3	3	2	6600	5900	300	900
1	1	2	1	2650	2910	0	50	1	2	3	1	3900	3700	150	300	1	1	1	1	3000	2800	0	0	1	1	1	1	3000	2800	0	0	1	3	3	2	6600	5900	300	900
1	3	1	1	5450	2400	0	1000	3	3	3	1	7850	4200	600	850	1	3	1	1	6700	3000	0	950	1	3	1	1	6700	3000	0	950	1	3	3	2	6600	5700	200	950
1	1	1	1	2950	2700	0	0	2	3	3	3	7250	7200	350	900	1	1	1	1	3400	2800	0	0	1	1	1	1	3400	2800	0	0	1	2	3	1	5200	4600	250	900
1	1	1	1	2950	2700	0	0	2	3	3	3	7250	7200	350	900	1	1	1	1	3400	2800	0	0	1	1	1	1	3400	2800	0	0	1	2	3	1	5200	4600	250	900
1	3	1	1	5750	2600	0	950	2	3	3	3	7250	7200	350	900	1	1	2	1	3400	3700	100	700	1	1	2	1	3400	3700	100	700	1	1	3	1	3400	4400	300	500

Table 58.sensitivity analysis of case study according to (Cnp, Cnq) = (900, 1600)

Caq / Cap		900																1350							
	αa \ α n	15								150								1500							
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	2500	2500	0	0	1	1	1	1	2500	2500	0	0	1	2	1	1	4400	2800	0	800
	200	1	1	1	1	2500	2500	0	0	1	1	1	1	2500	2500	0	0	1	2	1	1	3900	2700	0	500
	2000	3	3	1	1	5700	2500	0	850	3	3	1	1	5700	2500	0	850	3	3	1	1	5700	2500	0	850
1200	20	1	1	1	1	2500	2500	0	0	1	1	1	1	2500	2500	0	0	3	1	3	1	4900	4410	800	0
	200	1	1	1	1	2500	2500	0	0	1	1	1	1	2500	2500	0	0	3	1	3	1	4900	4410	800	0
	2000	3	3	1	1	6700	2610	500	750	3	3	1	1	6700	2610	500	750	3	3	1	1	6700	2610	500	750
1600	20	1	1	1	1	2600	2610	0	0	1	2	1	1	3900	2610	0	50	1	1	3	1	2700	4800	850	0
	200	1	1	1	1	2600	2610	0	0	1	1	1	1	2600	2610	0	0	1	1	3	1	2700	4800	850	0
	2000	1	3	1	1	4500	2500	0	550	1	3	1	1	4500	2500	0	550	1	3	1	1	4500	2610	0	450

Caq / Cap		1350							
	αa \ α n	15							
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	2450	2500	0	0
	200	1	1	1	1	2450	2500	0	0
	2000	3	3	1	1	6750	2500	350	1000
1200	20	1	1	1	1	2650	2500	0	0
	200	1	1	1	1	2550	2500	0	50
	2000	3	3	1	1	7940	2800	650	1000
1600	20	1	1	1	1	2950	2700	0	0
	200	1	1	1	1	2950	2700	0	0
	2000	1	3	1	1	5850	2800	0	950

1350																1800															
150								1500								15								150							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2450	2500	0	0	1	1	1	1	2650	2500	250	850	1	1	1	1	2700	2610	0	0	1	1	1	1	2700	2610	0	0
1	1	1	1	2450	2500	0	0	1	1	1	1	2650	2500	250	850	1	1	1	1	2700	2610	0	100	1	1	1	1	2700	2610	0	0
3	3	1	1	6750	2500	350	1000	3	3	1	1	6750	2600	250	1000	3	1	1	1	4400	2500	600	0	3	1	1	1	4400	2500	600	0
1	1	1	1	2650	2500	0	0	3	1	3	1	5050	4500	700	0	1	1	1	1	3000	2800	0	0	1	1	1	1	3000	2800	0	0
1	1	1	1	2550	2500	0	50	3	1	3	1	5050	4500	700	0	1	1	1	1	3000	2800	0	0	1	1	1	1	3000	2800	0	0
3	3	1	1	7940	2800	650	1000	3	3	1	1	7940	2800	650	1000	1	1	1	1	3100	3100	0	500	1	1	1	1	3100	3100	0	500
1	1	1	1	2950	2700	0	0	1	2	3	1	4300	4800	500	350	1	1	1	1	3400	2900	0	0	1	1	1	1	3400	2900	0	0
1	1	1	1	2950	2700	0	0	1	2	3	1	4300	4800	500	350	1	1	1	1	3400	2900	0	0	1	1	1	1	3400	2900	0	0
1	3	1	1	5850	2800	0	950	1	3	1	1	5750	2900	0	800	1	3	1	1	7100	3400	0	950	1	3	1	1	7100	3400	0	950

1800															
1500															
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
2	1	1	1	3700	2800	150	400	1	1	1	1	2700	2610	0	0
3	1	1	1	4700	2800	300	0	1	1	1	1	2700	2610	0	0
3	1	1	1	4300	2610	450	0	3	1	1	1	4400	2500	600	0
2	1	3	1	4200	4700	500	250	1	1	1	1	3000	2800	0	0
2	1	3	1	4200	4700	500	250	1	1	1	1	3000	2800	0	0
2	1	3	1	4200	4700	500	250	1	1	1	1	3100	3100	0	500
1	3	3	2	7000	6600	500	950	1	1	1	1	3400	2900	0	0
1	3	3	2	7000	6600	500	950	1	1	1	1	3400	2900	0	0
1	3	3	2	7000	6600	500	950	1	3	1	1	7100	3400	0	950

Table 59.sensitivity analysis of case study according to (Cnp, Cnq) = (900, 1200)

Caq / Cap		900																1350							
	αn / αa	15								150								1500								15							
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	2000	2100	0	0	1	1	1	1	2200	2100	0	0	1	1	1	1	2200	2100	0	0	1	1	1	1	2250	2100	0	0
	200	1	1	1	1	2000	2100	0	0	1	1	1	1	2000	2100	0	0	1	1	1	1	2200	2100	0	0	1	1	1	1	2610	2600	0	50
	2000	3	3	1	1	5500	2210	100	750	3	3	1	1	5500	2210	100	750	3	3	1	1	5500	2210	100	750	3	3	1	1	6750	2100	550	1000
1200	20	1	1	1	1	2600	2610	0	0	1	1	1	1	2200	2100	0	0	1	1	3	1	2300	4210	700	0	1	1	1	1	2550	2300	0	0
	200	1	1	1	1	2600	2610	0	0	1	1	1	1	2600	2610	0	0	1	1	3	1	2300	4210	700	0	1	1	1	1	2650	2630	0	50
	2000	3	3	1	1	6600	2210	600	800	3	3	1	1	6600	2210	600	800	3	3	1	1	6600	2200	600	800	1	1	1	1	2650	2630	0	50
1600	20	1	1	1	1	2600	2610	0	0	1	2	1	1	3600	2500	0	0	1	3	3	1	4300	4410	750	150	1	1	1	1	2950	2700	0	0
	200	1	1	1	1	2600	2610	0	0	1	1	1	1	2600	2610	0	0	1	3	3	1	4300	4410	750	150	1	1	1	1	2950	2700	0	0
	2000	1	3	1	1	4500	2100	0	750	1	3	1	1	4500	2100	0	750	1	3	1	1	4500	2210	0	650	1	3	1	1	5750	3000	0	500

1350																1800															
150								1500								15								150								1500							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2250	2100	0	0	1	1	1	1	2250	2100	0	0	2	1	1	1	3400	2500	0	0	2	1	1	1	3400	2500	0	0	3	1	1	3	4200	5200	50	700
1	1	1	1	2610	2600	0	50	1	1	1	1	2250	2100	0	0	1	1	1	1	2700	2700	0	100	2	1	1	1	3400	2500	0	0	3	1	1	3	4200	5200	50	700
3	3	1	1	6750	2100	550	1000	3	3	1	1	6610	2300	400	900	3	1	1	1	4300	2200	650	0	3	1	1	1	4300	2200	650	0	3	1	1	1	4300	2200	650	0
1	1	1	1	2550	2300	0	0	3	1	3	1	4950	4300	450	0	1	1	1	1	3000	2800	0	0	1	1	1	1	3000	2800	0	0	2	3	3	3	7800	7800	450	1000
1	1	1	1	2650	2630	0	50	3	1	3	1	4950	4300	450	0	1	1	1	1	3000	2800	0	0	1	1	1	1	3000	2800	0	0	2	3	3	3	7800	7800	450	1000
1	1	1	1	2650	2630	0	50	3	3	3	1	7850	4700	750	600	1	1	2	1	3000	3300	100	300	1	1	2	1	3000	3300	100	300	2	3	3	3	7800	7800	450	1000
1	1	1	1	2950	2700	0	0	2	3	3	3	7250	7500	650	700	1	1	1	1	3400	2800	0	0	1	1	1	1	3400	2800	0	0	1	1	3	3	3500	7710	700	950
1	1	1	1	2950	2700	0	0	2	3	3	3	7250	7500	650	700	1	1	1	1	3400	2800	0	0	1	1	1	1	3400	2800	0	0	1	1	3	3	3500	7710	700	950
1	3	1	1	5750	3000	0	500	2	3	3	3	7250	7500	650	700	1	1	1	1	3400	2800	0	0	1	1	2	1	3400	4000	400	400	1	1	3	1	3500	4910	500	400

Table 60.sensitivity analysis of case study according to (Cnp, Cnq) = (900, 800)

Cap \ Caq		900																1350							
	αa \ α n	15								150								1500								15							
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	1800	1700	0	0	1	1	1	1	1800	1700	0	0	2	1	1	1	2710	1730	250	100	1	1	1	1	2150	1900	0	0
	200	1	1	1	1	1800	1700	0	0	1	1	1	1	1800	1700	0	0	2	1	1	1	2710	1730	250	100	1	1	1	1	2150	1900	0	0
	2000	3	3	1	1	5110	1700	500	500	3	3	1	1	5110	1700	500	500	3	3	1	1	5110	1700	300	450	3	1	1	1	3810	1740	650	0
1200	20	1	2	1	1	3010	2000	0	0	1	2	1	1	3010	2000	0	0	1	3	2	3	4000	4300	500	400	1	1	1	1	2550	2300	0	0
	200	1	2	1	1	3010	2000	0	0	1	2	1	1	3010	2000	0	0	1	3	2	3	4000	4300	500	400	1	1	1	2	2560	2810	50	0
	2000	1	3	1	1	3910	2000	0	300	1	3	1	1	3910	2000	0	300	3	3	3	3	6410	5410	700	300	1	1	1	2	2560	2810	50	0
1600	20	1	3	1	1	4330	2420	0	0	1	3	1	1	4330	2420	0	0	2	3	3	3	5900	6000	500	350	1	1	1	1	2950	2600	0	0
	200	1	3	1	1	4330	2420	0	0	1	3	1	1	4330	2420	0	0	2	3	3	3	5900	6000	500	350	1	1	1	1	2950	2600	0	0
	2000	1	3	1	1	4300	2400	0	100	1	3	1	1	4330	2420	0	100	2	3	3	3	5900	6000	500	350	1	1	2	1	2950	3500	350	0

1350																1800															
150								1500								15								150							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2150	1900	0	0	3	2	1	3	5100	3900	100	250	1	1	1	2	2600	2800	0	0	1	1	1	2	2600	2800	0	0
1	1	1	1	2150	1900	0	0	3	2	1	3	5100	3900	100	250	2	1	1	1	3400	2500	0	0	1	1	1	2	2600	2800	0	0
3	1	1	1	3810	1760	650	0	3	1	3	3	4110	5360	550	300	3	1	1	1	4310	2210	450	0	3	1	1	1	4310	2210	450	0
1	1	1	2	2560	2810	50	0	3	2	3	3	6300	6300	650	300	1	1	1	1	3000	2600	0	0	1	1	1	1	3000	2600	0	0
1	1	1	2	2560	2810	50	0	3	2	3	3	6300	6300	650	300	1	1	1	1	3000	2600	0	0	1	1	1	1	3000	2600	0	0
1	1	1	2	2560	2810	50	0	3	2	3	3	6300	6300	650	300	1	1	2	1	3000	3600	400	0	1	1	2	1	3000	3600	400	0
1	1	1	1	2950	2600	0	0	2	3	3	3	7250	7500	650	700	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0
1	1	1	1	2950	2600	0	0	2	3	3	3	7250	7500	650	700	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0
1	1	2	1	2950	3500	350	0	1	1	3	3	3010	6460	700	550	1	1	1	1	3400	2600	0	0	1	1	1	1	3400	2600	0	0

X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
3	2	3	3	6000	6000	550	300
3	2	3	3	6000	6000	550	300
3	2	3	3	6000	6000	550	300
3	2	3	3	7200	7200	950	300
3	2	3	3	7200	7200	950	300
3	2	3	3	7200	7200	950	300
1	1	3	3	3400	6800	700	550
1	1	3	3	3400	6800	700	550
1	1	3	3	3400	6800	700	550

Table 61.sensitivity analysis of case study according to (Cnp, Cnq) = (1200, 800)

Cap \ Caq		900																				1350							
	αa \ α n	15								150								1500								15			
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	1900	2000	0	0	1	1	1	1	2100	2000	0	0	2	1	1	1	3700	2310	650	0	1	1	1	1	2150	2000	0	0
	200	1	1	1	1	1900	2000	0	0	1	1	1	1	1900	2000	0	0	1	1	1	1	2100	2000	0	0	1	1	1	1	2150	2000	0	0
	2000	3	3	1	1	5400	2090	350	500	3	3	1	1	5400	2090	350	500	3	3	1	1	5400	2090	350	500	3	2	1	1	5400	2090	900	350
1200	20	1	1	1	1	2210	2110	0	0	1	1	1	1	2210	2110	0	0	1	2	1	1	3500	2450	0	200	1	1	1	1	2550	2300	0	0
	200	1	1	1	1	2210	2110	0	0	1	1	1	1	2210	2110	0	0	1	2	1	1	3500	2450	0	200	1	1	1	2	2650	3000	50	0
	2000	3	3	1	1	6610	2110	950	500	3	3	1	1	6610	2110	950	500	3	3	1	1	6550	2310	750	450	3	1	1	1	5050	2400	800	0
1600	20	1	1	1	2	2610	3010	0	0	1	2	1	1	3610	2510	0	0	1	3	2	3	4300	4900	850	400	1	1	1	1	2950	2700	0	0
	200	1	1	1	2	2610	3010	0	0	1	1	1	2	2610	3010	0	0	1	3	2	3	4300	4900	850	400	1	1	1	1	2950	2700	0	0
	2000	1	3	1	1	4410	2510	0	250	1	3	1	1	4410	2510	0	250	1	3	1	3	4410	3810	0	350	1	1	1	2	2950	3200	350	0

150								1500								15								150								1500							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2150	2000	0	0	3	1	1	3	3750	4000	50	300	2	1	1	1	3400	2500	0	0	2	1	1	1	3400	2500	0	0	3	1	1	3	4200	4000	200	250
1	1	1	1	2150	2000	0	0	3	1	1	3	3750	4000	50	300	2	1	1	1	3400	2500	0	0	1	1	1	2	2700	3000	100	0	3	1	1	3	4200	4000	200	250
3	2	1	1	5400	2090	900	350	3	3	1	1	6850	2300	850	450	3	1	1	1	4400	2000	850	0	3	1	1	1	4400	2000	850	0	3	1	1	1	4300	2100	700	0
1	1	1	1	2550	2300	0	0	3	1	1	3	4950	4000	500	150	1	1	1	1	3000	2700	0	0	1	1	1	1	3000	2700	0	0	3	2	3	3	7200	7200	950	300
1	1	1	2	2650	3000	50	0	3	1	1	3	4950	4000	500	150	1	1	1	1	3000	2700	0	0	1	1	1	1	3000	2700	0	0	3	2	3	3	7200	7200	950	300
3	1	1	1	5050	2400	800	0	3	3	3	3	7650	6600	750	300	3	1	1	1	5500	2800	600	0	3	1	1	1	5500	2800	600	0	3	2	3	3	7200	7200	950	300
1	1	1	1	2950	2700	0	0	3	2	3	3	7500	7800	850	600	1	1	1	1	3400	2700	0	0	1	1	1	1	3400	2700	0	0	1	1	3	3	3400	7400	1000	550
1	1	1	1	2950	2700	0	0	3	2	3	3	7500	7800	850	600	1	1	1	1	3400	2700	0	0	1	1	1	1	3400	2700	0	0	1	1	3	3	3400	7400	1000	550
1	1	1	2	2950	3200	350	0	3	2	3	3	7500	7800	850	600	1	1	1	1	3400	2700	0	0	1	1	1	1	3400	2700	0	0	1	1	3	3	3400	7400	1000	550

Table 62.sensitivity analysis of case study according to (Cnp, Cnq) = (1200, 1200)

Caq / Cap		900																1350							
	αn / αa	15								150								1500								15							
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	2400	2400	0	0	1	1	1	1	2400	2400	0	0	1	1	1	1	2500	2400	200	550	1	1	1	1	2350	2400	0	0
	200	1	1	1	1	2400	2400	0	0	1	1	1	1	2400	2400	0	0	1	2	1	1	3900	2600	0	550	1	1	1	1	2350	2400	0	0
	2000	3	3	1	1	5600	2400	50	800	3	3	1	1	5600	2400	50	800	3	3	1	1	5600	2400	50	800	3	3	1	1	6750	2400	400	1000
1200	20	1	1	1	1	2400	2400	0	0	1	1	1	1	2400	2400	0	0	1	1	1	1	2500	2400	0	150	1	1	1	1	2550	2400	0	0
	200	1	1	1	1	2400	2400	0	0	1	1	1	1	2400	2400	0	0	1	1	1	1	2500	2400	0	150	1	1	1	1	2650	2600	0	50
	2000	3	3	1	1	6600	2500	600	650	3	3	1	1	6600	2500	600	650	3	3	1	1	6600	2500	600	650	3	3	1	1	7850	2600	850	900
1600	20	1	1	1	1	2600	2600	0	0	1	2	1	1	3700	2710	0	50	1	1	3	1	2700	5100	950	0	1	1	1	1	2950	2700	0	0
	200	1	1	1	1	2600	2600	0	0	1	1	1	1	2600	2600	0	0	1	1	3	1	2700	5100	950	0	1	1	1	1	2950	2700	0	0
	2000	1	3	1	1	4500	2400	0	600	1	3	1	1	4500	2400	0	600	3	3	1	1	7800	2710	950	700	1	3	1	1	5750	3000	0	650

1350								1800							
150								1500							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2350	2400	0	0	1	1	1	1	2550	2400	0	450
1	1	1	1	2350	2400	0	0	1	1	1	1	2550	2400	0	450
3	3	1	1	6750	2400	400	1000	3	3	1	1	6750	2500	400	900
1	1	1	1	2550	2400	0	0	1	1	1	1	2550	2400	0	0
1	1	1	1	2650	2600	0	50	1	1	1	1	2550	2400	0	0
3	3	1	1	7850	2600	850	900	3	3	1	1	7850	2700	800	850
1	1	1	1	2950	2700	0	0	2	3	3	3	7250	7800	950	500
1	1	1	1	2950	2700	0	0	2	3	3	3	7250	7800	950	500
1	3	1	1	5750	3000	0	650	3	3	3	3	8850	7800	750	700

15								150							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2600	2500	0	50	1	1	1	1	2700	2500	0	50
1	1	1	1	2700	2700	0	100	1	1	1	1	2600	2500	0	50
3	1	1	1	4400	2400	650	0	3	1	1	1	4400	2400	650	0
1	1	1	1	3000	2800	0	0	1	1	1	1	3000	2800	0	0
1	1	1	1	3000	2800	0	0	1	1	1	1	3000	2800	0	0
3	1	1	1	5500	2800	800	0	3	1	1	1	5500	2800	800	0
1	1	1	1	3400	2900	0	0	1	1	1	1	3400	2900	0	0
1	1	1	1	3400	2900	0	0	1	1	1	1	3400	2900	0	0
1	1	1	1	3400	2900	0	0	1	1	1	1	3400	2900	0	0

1500							
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
3	1	1	3	4200	5200	50	700
3	1	1	3	4200	5200	50	700
3	1	1	1	4300	2500	500	0
1	2	1	3	4800	5600	150	800
1	2	1	3	4800	5600	150	800
3	1	1	1	5500	2800	800	0
2	3	3	3	8600	9000	850	1000
2	3	3	3	8600	9000	850	1000
2	3	3	3	8600	9000	850	1000

Table 63.sensitivity analysis of case study according to (Cnp, Cnq) = (1200, 1600)

Caq / Cap		900																1350							
	αn / αa	15								150								1500							
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	2600	2800	0	0	1	1	1	1	2600	2800	0	0	1	1	1	1	2600	2800	0	0
	200	1	1	1	1	2600	2800	0	0	1	1	1	1	2600	2800	0	0	1	1	1	1	2600	2800	0	0
	2000	3	3	1	1	6100	2800	0	900	3	3	1	1	6100	2800	0	900	3	3	1	1	6100	2800	0	900
1200	20	1	1	1	1	2600	2800	0	0	1	1	1	1	2600	2800	0	0	1	1	1	1	2900	2800	0	50
	200	1	1	1	1	2600	2800	0	0	1	1	1	1	2600	2800	0	0	1	1	1	1	2900	2800	0	50
	2000	3	3	1	1	6800	2800	450	800	3	3	1	1	6800	2800	450	800	3	3	1	1	6800	2800	450	800
1600	20	1	1	1	1	2600	2800	0	0	1	1	1	1	3020	2850	0	0	1	1	1	1	3020	2850	0	0
	200	1	1	1	1	2600	2800	0	0	1	1	1	1	2600	2800	0	0	1	1	1	1	3020	2850	0	0
	2000	3	3	1	1	7830	2830	950	750	3	3	1	1	7830	2830	950	750	3	3	1	1	7810	2920	950	650

Caq / Cap		1350							
	αn / αa	15							
Factors		X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
800	20	1	1	1	1	2550	2800	0	0
	200	1	1	1	1	2550	2800	0	0
	2000	3	3	1	1	6950	2800	300	1000
1200	20	1	1	1	1	2640	2800	0	0
	200	1	1	1	1	2640	2800	0	0
	2000	3	3	1	1	7870	2800	350	900
1600	20	1	1	1	1	2960	2830	0	0
	200	1	1	1	1	2960	2830	0	0
	2000	1	3	1	1	6310	3500	0	950

1350								1800																			
150								1500								15				150				1500			
X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq	X_{ap}	X_{aq}	X_{np}	X_{nq}	Pa	Pn	Sp	Sq
1	1	1	1	2550	2800	0	0	2	1	1	1	3950	2900	500	0	1	1	1	1	2700	2800	0	0	2	1	1	1	3700	2900	0	0	2	1	1	1	3800	2900	100	50
1	1	1	1	2550	2800	0	0	2	1	1	1	3950	2900	500	0	1	1	1	1	2700	2800	0	0	1	1	1	1	2700	2800	0	0	2	1	1	1	3800	2900	100	50
3	3	1	1	6950	2800	300	1000	3	3	1	1	6950	2800	300	1000	3	1	1	1	4400	2800	450	0	3	1	1	1	4400	2800	450	0	3	1	1	1	4400	2800	450	0
1	1	1	1	3020	2850	0	0	1	1	1	1	3020	2850	0	0	1	1	1	1	3010	2850	0	0	1	1	1	1	3060	2870	0	0	1	1	1	1	3050	2800	0	450
1	1	1	1	2640	2800	0	0	1	1	1	1	3020	2850	0	0	1	1	1	1	3010	2850	0	0	1	1	1	1	3010	2850	0	0	1	1	1	1	3050	2800	0	450
3	3	1	1	7870	2800	350	900	3	3	1	1	7870	2800	350	900	3	3	1	1	9070	2800	700	950	3	3	1	1	9070	2800	700	950	3	3	1	1	9070	2800	700	950
1	1	1	1	3040	2860	0	0	1	1	3	1	3250	5670	1000	0	1	1	1	1	3400	3100	0	0	1	1	1	1	3400	3100	0	0	2	3	3	3	8600	9000	850	1000
1	1	1	1	2960	2830	0	0	1	1	3	1	3250	5670	1000	0	1	1	1	1	3400	3100	0	0	1	1	1	1	3400	3100	0	0	2	3	3	3	8600	9000	850	1000
1	3	1	1	6310	3500	0	950	1	3	1	1	6310	3500	0	950	1	3	1	1	7100	3500	250	1000	1	3	1	1	7100	3500	250	1000	2	3	3	3	8600	9000	850	1000