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Intelligent connected vehicles: the industrial practices and impacts on automotive value-chains in China

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ABSTRACT

The intelligent connected vehicle (ICV) concept represents the commanding heights of prospective automotive product shape and technology, which will pose significant impacts on the value-chain of future automotive industry, especially in China. The development of ICV will also provide the Chinese automotive industry with a strategic opportunity for transformation and upgrading. Currently, the government and enterprises have increased investment in the research and application of ICV. A detailed study in the development of ICV in the PRC can have theoretical implications for exploiting the future automotive value-chain. From the perspective of value-chains, this article analyses ICV's significant impacts on the new industrial value-chain and its essential features, according to the latest practical cases in China. On this basis, suggestions of upgrading paths are proposed for different categories of Chinese enterprises from the dimensions of process, product and functional upgrading.

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KEYWORDS
Automotive industry; China; enterprises; intelligent connected vehicles; upgrading; value-chains

1. Introduction

There are billions of vehicles running on the roads worldwide every day causing the problems of traffic accidents, energy consumption, environmental pollution and urban congestion. To achieve safe and sustainable mobility, automotive industry is moving towards a low-carbon, information-based and intelligent era. The interaction and co-improvement between technical advancement and business innovation will facilitate the transformation and upgrading of the industry. In the wave of new technology represented by Internet and Artificial Intelligence, it is widely expected that traditional automotive industry will in time upgrade to an intelligent connected vehicle (ICV) industry (Li, Cao, et al. 2016).

According to the *'Made in China 2025'* strategy, ICV is defined as a new generation of vehicle equipped with advanced sensors, controllers and actuators, in combination with modern network communication technologies. ICV enables the functions including information sharing, complex environment sensing, intelligent decision-making and automated cooperation, which is able to realize highly-effective, safe, comfortable and energy-efficient driving.

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The core technologies of ICV can be concluded as three categories. First, the automated driving (AD) systems empower vehicles to drive automatically replacing human drivers. The Society of Automotive Engineers (SAE) classifies AD into six levels including No Driving Automation, Driver Assistance (DA), Partial Driving Automation (PA), Conditional Driving Automation (CA), High Driving Automation (HA) and Full Driving Automation (FA) (SAE On-Road Automated Vehicle Standards Committee 2016). Almost all the automakers and several ambitious technology companies have been devoting themselves to conducting AD vehicle research. Today, Tesla's Autopilot feature has already allowed vehicles to adjust speed, keep direction and change lanes automatically in several daily driving scenarios. Many agencies predicted that PA and CA would be available in 2020 and a further application of HA and FA can be expected around 2030 (EPoSS 2015; SIP-adus 2016; ERTRAC 2017).

Second, the Internet of Vehicles (IoV) technologies assist vehicles in intelligent communication with the environment, in the forms of in-vehicle infotainment, telematics, vehicle-to-vehicle communication (V2V) and vehicle-to-infrastructure communication (V2I) (Papadimitratos et al. 2009). IoV services can offer various benefits to users, businesses and the whole society. Vehicle users will have lower operation and insurance costs and time saving, while the societal benefits will be obtained from crash decrease, congestion control and emission reduction (Contreras-Castillo, Zeadally, and Guerrero-Ibanez 2017). Hence, the U.S. government is promoting mandatory equipment of V2V systems for new light vehicles to improve traffic safety by 2023 (NHTSA 2017) and will issue guidance for V2I communications separately.

Third, the in-vehicle artificial intelligence help drivers and passengers with non-driving tasks, such as speech recognition, gesture recognition (Pickering, Bumnham, and Richardson 2007) and intelligent co-pilot. Due to the future liberation of drivers' time and attention, autonomous vehicles are transformed into places of productivity and relaxation or even emotional companions taking advantage of artificial intelligence to cognise human's intentions and respond initiatively (Kelleher 2016). Thus, ICV goes beyond the concept of autonomous vehicles and realizes assistance, liberation and comprehension of human beings.

Along with rapid technical progress in the fields above, ICVs may in due course gradually replace traditional vehicles. This tendency represents the commanding heights of prospective automotive product shapes and technologies, which will fundamentally change the property and creation process of automotive product value, thus influencing the whole automotive industry value-chain. China has become the largest automotive market in the world (OICA 2017), simultaneously Chinese consumers have high passion for intelligent and connected products. Hence Chinese automotive industry expects to grasp the opportunity of ICV to catch up with and even outpace the foreign leaders. The *'Made in China 2025'* strategy has definitely listed automotive industry as one of the ten key areas to be developed, which includes energy saving and new energy vehicles, as well as ICVs (*China Daily* 2015). Considering the typicality and significance of Chinese automotive industry in the world, the development of ICV in China has important implications to be explored.

2. Research questions

This article aims to conduct a *pilot-study* on the new features and connotation of future automotive value-chain by focusing on the impacts of ICV applications. Two research issues are discussed to find out development-paths of automotive industry in the upcoming times of ICV:

> First, how does the introduction of ICV affect each value-added link and the essence of the automotive value-chain?
>
> Second, in what ways can Chinese enterprises cope with the changes above and achieve upgrading along the value-chain?

To explicitly answer these questions, the following study is structured in four parts.

First, we outline our research methodology and then the second part briefly summarizes the industrial practices of ICV in China in the form of *case-study*. A detailed research in the impacts of ICV on the future automotive value-chain is then presented in the third part. Finally, the fourth part proposes implications of upgrading paths for the corresponding enterprises to seize the moment to improve core competencies of Chinese automotive industry.

3. Methodology

3.1. Value-chain theory

A method of *value-chain analysis* is employed in this study. Value-chain theory is proposed to analyse an enterprise's business operations and competitive advantages (Porter 1985), and then is extended to the research of inter-enterprise relationships. The automotive value-chain refers to all value creation activities including research and development, production, procurement and logistics, marketing, aftersales services and recycling. Current studies of automotive value-chains focus on three aspects: to discuss how to integrate into the global value-chains for Original Equipment Manufacturers (OEMs) and suppliers (Barnes 2000; Wad 2008; Castelli, Florio, and Giunta 2011), to study the existing problems and upgrading paths of automotive value-chains (Humphrey and Memedovic 2003; Holweg, Luo, and Oliver 2008; Li, Kong, and Zhang 2016), and to design a development strategy for the boom of electric vehicles industry (Kley, Lerch, and Dallinger 2011; Huth, Wittek, and Spengler 2013). However, these studies are mainly based on the analysis of traditional automotive value-chains, which are supposed to be dramatically changed by ICV. Therefore, this article discusses the influences of ICV and the essential changes of future automotive value-chain according to a wide range of literature and Chinese enterprises' cases.

3.2. Data preparation

Two types of data resources provided the presented cases and data for analysis. First, semi-structured interviews were conducted to obtain expert knowledge about ICV technology and business development. *The interviewees were department heads or above from two automakers A, B, three automotive suppliers D, E, F, one Internet company G and two local governments H, I, in Shanghai and Beijing*, respectively, whom we have anonymized in this research.

In total, 37 informants were interviewed face-to-face, in the Chinese language over the last two years and each session lasted more than half an hour. The interviews were kept anonymous in order to avoid conflict of interests and ensure unbiased opinions. Interview questions were specifically designed for different types of interviewees, while the informants from enterprises were asked more about their products and business strategies, the ones from governments were inquired how they formulated policies for the development of ICV and what roles they regarded ICV as in economic construction.

Another method of data collection was archival research. Information about ICV's progress was collected from open-access resources, such as journals, magazines, newspapers, reports, official websites and other Internet media. Some internal materials provided by the interviewees, such as product brochures and project documents were also considered. Moreover, the authors attended several seminars and forums on the topic of ICV to acquire the newest industrial information and knowledge.

4. Data analysis

In order to generate an understanding of the future automotive value-chain, we needed to look through the current industrial practices of ICV in China to figure out their effects. Considering that ICV was closely related to infrastructure such as communication base stations and intelligent transportation systems, as well as relied on political support including traffic rules and financial assistance, governmental involvement also played a crucial part in this industry. Therefore, we summarized the case data mentioned above from two perspectives of both governmental activities and business behaviours to conclude what features Chinese practitioners had in ICV development, enabling further discussion about industrial transformation and upgrading paths for Chinese firms.

4.1. Governmental policies and planning

The Chinese government has already realized the great significance and profound effects of ICV, and is promoting development of ICV technologies and industry. The official *Roadmap for Energy Saving and New Energy Vehicles* takes SAE's definition for reference to chart the course for different stages of ICV as shown in Figure 1 (The Strategic Advisory Committee of Technology Roadmap for Energy Saving and New Energy Vehicles, and SAE-China 2016).

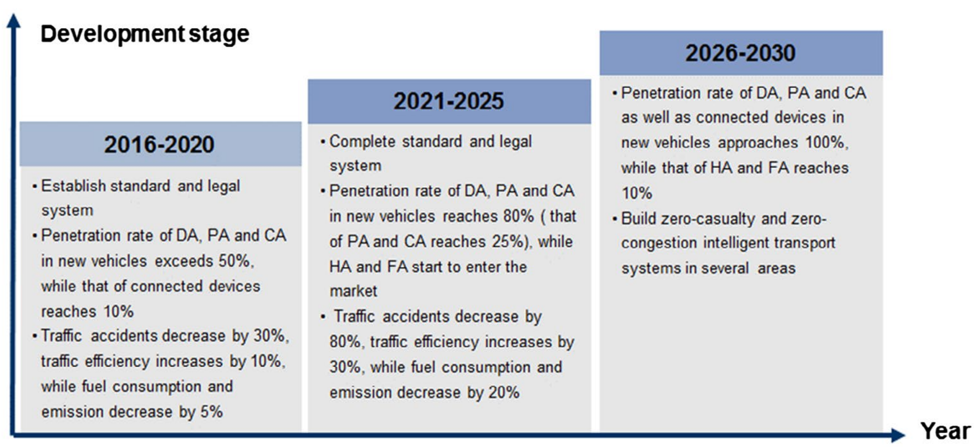

Figure 1. Key targets of ICV in the *Technology Roadmap for Energy Saving and New Energy Vehicles* of China. Source: Drawn by authors based on *Technology Roadmap for Energy Saving and New Energy Vehicles* 2016.

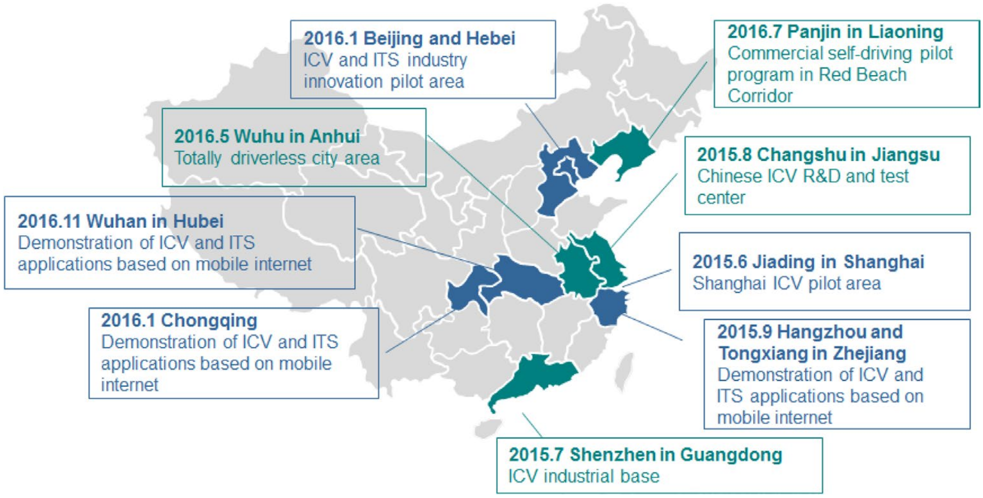

Figure 2. Major districts of ICV development in China. Source: Authors.
Note: The districts highlighted in blue have signed cooperation agreements with MIIT.

Meanwhile, the roadmap sets targets for major products, key components, common technologies, demonstration projects and strategic supports.

On this basis, the Chinese government accelerates the formulation of ICV laws, regulations and standards. In the 2016 China's *National People's Congress* and *Chinese People's Political Consultative Conference*, both of the representatives of Geely and Baidu submitted proposals to push through legislation of AD (*China Daily*, March 4, 2016). The Ministry of Industry and Information Technology (MIIT), the Ministry of Public Security and the Ministry of Transport are all intensifying the formulation of road test regulations for AD vehicles, which contain the amendment of current traffic laws, the establishment of electronic identity management systems and the construction of comprehensive test fields. The National Technical Committee of Auto Standardization is also working on ICV standards which are expected to be completed in about eight years.

The local governments have been also promoting industrialization of ICV by launching various ICV pilot demonstration projects since 2015, as shown in Figure 2. Among these places, Shanghai Jiading District is the first one to be authorized by MIIT and has been open to public since June 2016 (*China Daily*, June 13, 2016). The demonstration area regards 'Mcity' project in the US as a benchmarking, and it will construct the test and validation environment for ICV by revamping the infrastructure which consists of intersections, sidewalks, traffic lights and streetlamps. 1,000 units of ICVs are expected to go into operation here in 2020. The area will also contribute to formulation of relevant standards and formation of industrial clusters.

4.2. Chinese enterprises' practice

Chinese enterprises wish to narrow the gap to foreign brands by developing ICV. The existing OEMs have made initial planning of ICV through cooperation with scientific institutions and IT enterprises. Table 1 shows their development plans and it is expected that vehicles with HA functions can be introduced after 2025.

Table 1. ICV planning of Chinese OEMs.

OEM	Partners	IoV brand	AD			
			DA	PA	CA	HA-FA
FAW	National University of Defense Technology, Baidu, etc.	D-Partner	2013	2018	2020	2025+
DFM	Huawei, KOTEI, LeEco, etc.	WindLink	2016	2018	2020	–
SAIC	Alibaba, Huawei, etc.	inkaNet	–	2017	2020	2025
Changan	Tsinghua University, Huawei, Qihoo 360, AutoNavi, etc.	InCall	2015	2018	2020	2025
GAC	Chinese Academy of Sciences, LeEco, Uber, etc.	T-BOX	2016	2018	2020	2025
BAIC	LeEco, Didi, Jingdong, etc.	i-Link	2016	2018	2020	2025
BYD	A*STAR, Baidu, ZTE, LeEco, etc.	BYD Cloud	–	–	–	–
Chery	Wuhan University, Yidao Yongche, PATEO, etc.	Cloudrive	2015	2017	2020	2025
Geely	Ericsson, Uber, iFLYTEK, AutoNavi, etc.	G-netlink	2015	2017	2020	2025

Notes: A*STAR, Agency for Science, Technology and Research; BAIC, Beijing Automotive Industry Corporation; DFM, Dongfeng Motor; FAW, First Automotive Works; GAC, Guangzhou Automobile Group Co., Ltd; SAIC, Shanghai Automotive Industry Corporation.
Source: Compiled by authors.

At the same time, due to the boom of electric vehicles and ICVs, a large number of experienced entrepreneurs from Internet and automotive industries have founded new automotive brands with the support of enormous capital investment. Table 2 lists the typical start-ups. These Chinese companies may pose great impacts on the traditional industrial structure by adopting differentiated strategies, inspired by the foreign innovations such as Tesla and Google.

Furthermore, some Chinese enterprises have operated automotive telematics business since 2009 in various business models (Song et al. 2012). The major models are summarized as shown in Table 3. The dominant firms utilize their own key resources to establish telematics business systems for target markets, and design appropriate profit models. Currently, there is no company that has attracted enough customers to be capable of dominating the whole market, which provides an opportunity for the development of Chinese domestic industry.

4.3. *Features of ICV development in China*

It can be inferred from the cases above that there are some advantages to develop ICV in China. First, China has become the largest market of automobiles and Internet, whose consumers have higher demands for ICV than other countries that could direct the development of ICV (Accenture 2014). The environment, traffic and energy problems in China require the industry to provide ICV products meeting the special demands (Zhao, Hao, and Liu 2016), thus creating opportunities for homegrown enterprises which are familiar with Chinese market. Second, Chinese powerful IT industry is able to cooperate with homegrown OEMs to narrow the gap of core capabilities in strategic links of ICV industry and move up the value-chain. The representative IT firms such as Baidu, Tencent, Alibaba and Huawei possess massive information resources and key processing technologies, making the industrial upgrading possible (Zhao and Liu 2016). Third, ICV is highly coincident with the national strategies including *'Made in China 2025'*, *'Internet Plus'* and *'Internet of Things (IoT)'*. The central government has adopted active measures to facilitate the research, testing, demonstration and industrialization of ICV, meanwhile the local governments are supporting relevant enterprises to comply with the national policies.

Table 2. The newly established OEMs in China.

Brands	Founders	Start date	Planning	Features in strategy
Xpeng Motors	Xia Heng, former section chief of GAC	Jun, 2014	• Sep 2016: launched Xpeng Beta • 2017: small-batch production	Develops internet vehicles which keep upgrading
NextEV	Li Bin, founder of Bitauto	Nov, 2014	• Nov 2016: launched NIO EP9 • 2017: produces 50,000 ES8 SUV annually	Emphasizes user experience and services
ZhicheAuto	Shen Haiyin, former vice president of Qihoo 360	Dec, 2014	• Mar, 2016: launched Singulato • 2017: small-batch production	Profits mainly from services
LeEco	Jia Yueting, founder of LeEco	Jan, 2015	• Apr, 2016: launched LeSEE • 2019: produces 200,000 vehicles annually	Establishes an internet ecosystem of automobiles
Qiantu Motor	Lu Qun, president of CH-Auto Technology	Feb, 2015	• Apr, 2016: launched K50 • 2017: produces 50,000 vehicles annually	Satisfies different demands with various products
Yiqitaixing	Zhou Hang, Yin Tongyue, Yingyilun (Yidao Yongche, Chery, PATEO)	Feb, 2015	• 2018: produces 150,000 vehicles annually	Designs vehicles for car sharing
Hexiefuteng	Feng Changge, Guo Taiming, Ma Huateng (Harmony Auto, Foxconn, Tencent)	Mar, 2015	• 2016: split up into two companies (Future Mobility Corporation and AICEV) • 2020: produces 150,000 to 300,000 vehicles annually	Designs luxury cars and cheap cars separately
Chehejia	Li Xiang, founder of Autohome	Apr, 2015	• 2017: produces 200,000 vehicles annually	Satisfies the demand of short trip for one or two persons
WM Motor	Shen Hui, former vice president of Geely	Dec, 2015	• 2018: produces 100,000 vehicles annually	Develops popular intelligent electric vehicles with limited customization
Yodu Auto	Liu Xinwen, former general manager of Chery New Energy	Dec, 2015	• 2017: produces 80,000 vehicles annually	Satisfies both B2B and B2C demands

Source: Compiled by authors, updated to May, 2017.

Table 3. Major business models of telematics in China.

	Commercial fleets administrator	Telecom operator	OEM	Telematics service provider
Key sources	Platform management	Experience with individual clients	Vehicle core data	Platform integration and operation
	Big data operation	Telecom infrastructures	Integration of vehicles and IT devices	Aftersales devices development
Target markets	Commercial fleets	Aftersales market	Factory-installed products	Aftersales market
Profit models	Vehicle sales and service charge	Device sales and service charge	Vehicle sales and service charge	Device sales and service charge
Advantages	Stable profit	Technologies and experience of communication services	Strong willingness	Open and easy entry into industry
	Public policies support	Compatibility	Automotive technologies	Variety of services
Disadvantages	Limited market size	Lack of market channels and experience in automotive industry	Platform lock-in	Product homogeneity
	Incompatibility of platforms	Lack of applications development	Lack of thoughts and capabilities of service	Limited resources and technologies
				Lack of standards
				Influences of public policies
Cases	Higer G-BOS	China Mobile Xingcheweishi	SAIC inkaNet	Ecar telematics
	Yutong TSM	China Telecom InteCare	Changan InCall	PATEO iVoka
			Geely G-Netlink	Vcyber

Source: Compiled by authors.

However, there also exist some constraints. First, ICV still has close relevance with drive-train, chassis, body and other traditional automotive technologies. Chinese OEMs and suppliers have been locked in the low end of the value-chain for decades (Li, Kong, and Zhang 2016; Brandt and Thun 2016), therefore they strongly depend on the technical support of transnational enterprises. Second, the innovation investment and efficiency of Chinese automotive industry are lower than that of major competing countries (Li and Li 2016). According to a patent statistical report of ICV innovation including technologies of telematics, autonomous driving, driver assistance and head-up displays, Chinese enterprises are falling behind (Thomson Reuters 2015) and have to continue developing similar low-end products. Third, China has a sophisticated industrial structure involved with too many participants but in lack of leading automotive enterprises (Li, Kong, and Zhang 2016), resulting in ambiguous functional specialization and low level of collaboration. These factors hinder the standardized scale development of ICV. Fourth, the automotive administrative functions and supervisory authorities are dispersed in various government departments in China. The poor coordination of information and policies might give rise to redundant construction and resources waste of ICV-related infrastructure, which have similarly occurred in Chinese new energy vehicle industry (Zhao, Zhao, and Liu 2017).

5. Discussion

ICV has changed the product forms and service patterns of traditional automotive industry, leading to profound transformation of value creation in each link of the value-chain.

5.1. Design and development

The product forms will change as ICV is widely introduced. AD technology will transform the structure, components and appearance of vehicles. Traditional actuators are replaced with mechatronic systems, and structural redundancy is required for safety considerations (Luettel, Himmelsbach, and Wuensche 2012). Moreover, the safety constraints for vehicle design will decrease along with the improvement of active safety. For instance, Chery's 2015 @Ant 3.0 concept car cancelled the conventional steering wheel, accelerator pedal and brake pedal. This transformation of product forms can be a new challenge for traditional OEMs' design and development capabilities, as well as an opportunity for new entrants to achieve innovation and evolution.

Another change is about the design methods. Electronics, especially software has contributed 80 percent of functional innovation in today's automotive industry (Mossinger 2010), such as electronic control units, in-vehicle infotainment and IoV systems. Meanwhile the new technologies of AD and IoV require numerous safety and robust tests in various environments, which may be too costly and time-consuming with traditional field testing methods (Kalra and Paddock 2016). Thus the utilization of computer simulation will become more and more significant to test and improve driving control strategies, human machine interfaces, networking and other functions (Verburg, Van der Knaap, and Ploeg 2002). Therefore OEMs like FAW and Changan have all involved the construction of simulation and test platforms in future ICV strategic plans.

The design principles of ICV are also different from the original ones. Similar to the smart phones or smart televisions, the design system of ICV will turn to an open and multi-participant system with expandability from the closed and unitary one with inflexibility in the past. Methods for collaborative innovation such as outsourcing and crowdsourcing will be adopted more frequently (Bartl, Jawecki, and Wiegandt 2010). And the product definition will also be user-driven rather than producer-driven. Currently a few OEMs are making attempts on innovative design patterns, including the new technology research institute of BAIC, the Internet-connected vehicle fund of SAIC and Alibaba, and the 'Let's Car' crowdsourcing platform of Cowin Auto.

5.2. Production

First, the industrial organization is supposed to undergo a dramatic transformation. ICV covers a wide range of technologies and services, and the product value will transfer from automobiles themselves to the relevant data and services, which diminishes the OEM's dominance. The automotive industrial organization in the past was governed by stringent management hierarchy, and the OEMs led the development and production process by establishing an extremely concentrated structure (Sturgeon, Van Biesebroeck, and Gereffi 2008), in which suppliers and dealers could only follow the OEM's instructions. However, the organization will convert into a multi-cooperation eco-network in the ICV era, where the

OEM is not only an integrator of automotive products but also a ‘supplier’ with integrating skills participating in this network. For example, in the cooperation for smart electric vehicles among Tencent, Harmony Auto and Foxconn, there is even no traditional automotive manufacturer involved.

Second, a clearer trend of modularization and platformization in automotive production will emerge in the future. ICV functions are usually added to the vehicles through data and electrical interfaces, and their mass adoption is based on the premise of unified technical standards and interchangeability among different brands. As a consequence, the modularity and platform concepts will become more significant in automotive industry (Pandremenos et al. 2009). With the rapid popularization of *Industry 4.0*, OEMs could reduce the process complexity and improve the production efficiency by flexible assembling of AD systems, infotainment systems and other ICV modules. At the same time the production of personalized and customized vehicles could be possible (Kagermann et al. 2013). For instance, Changan and Autohome website are cooperating to promote customization of ICV by building an open platform to attract users to participate in the decision-making of development and production.

Third, the product upgrading will become more convenient and flexible. For the ordinary vehicles, the functional or configurable upgrades could only be accomplished by software and hardware tuning in the workshops of dealers or factories. The latest functions are hardly compatible for existed vehicles, forcing consumers to purchase new ones. As for ICV, software methods such as over the air (OTA) technology could be used for real-time online functional upgrades (Shavit, Gryc, and Miucic 2007), and hardware accessories could be added through standard interfaces. Several OEMs have carried out such services for mass-produced vehicles. In China, BYD cloud services have realized remote upgrades of in-vehicle systems and control programs.

5.3. Marketing and sales

ICV is able to collect the user’s information and vehicle operating data, which can be used for precise marketing with big data analysis tools (Sun, Gao, and Xi 2014). The dealers are capable of drawing customer portraits and delivering advertisements individually, based on data covering the owners’ information, consumption habits, driving patterns, vehicle conditions, etc. In this way the marketing costs are supposed to decrease and the brands may engender greater loyalty among the customers. Therefore Chinese e-commerce leader Alibaba is cooperating with SAIC in ICV-related services, and has established its automotive business division to concentrate on automotive precise marketing.

Moreover, ICV could solve the problems like safety risks and inconvenience of vehicle usage in the future car sharing mode with technologies such as identification system, dispatching and reservation systems, intelligent navigation and AD (Barth and Todd 2000). Although car-sharing may decrease the total number of vehicles, the use intensity and frequency of shared vehicles will increase. Meanwhile the non-owners could have more opportunities to use vehicles. Thus the total sales of automotive industry in the car-sharing era might increase in contrast to the OEMs’ anxiety. In this trend, Chery collaborates with Yidao Yongche and PATEO to develop an electric ICV model especially designed for car sharing, called ‘Yiqi Auto by iVokaOS’.

5.4. Aftersales services

There will be many innovations in the following stages of the aftersales market:

5.4.1. Maintenance

Based on the real-time user information and vehicle data of ICV, the maintenance enterprises could realize remote diagnosis for vehicles (Taie et al. 2016) and provide regular reminder messages or emergent services. Due to the standardization of automotive components, the user data of different brands could be gathered to expand business and improve service quality. Therefore the chain-store mode for all vehicle owners may supersede the current franchise-store mode. For example, the Launch Technology Company produces a Golo toolbox to collect data through the standard On-Board Diagnostic (OBD) interface, and establishes a platform to attract various enterprises and technicians to provide maintenance services.

5.4.2. Insurance

On the one hand, the insurance companies are creating billing models which encourages safe and energy-saving driving habits using the important parameters such as mileage, driving behaviour and types of roads (Husnjak et al. 2015). ICV helps to collect these data for the companies to provide individual premium rates and insurance products, allowing the insurers to enhance their risk management and reduce operating costs. On the other hand, the ICV applications such as AD, IoV and car sharing are relevant to personal and property security, which makes insurance products innovation and sales growth possible. Considering the market-oriented reform of Chinese motor insurance industry since 2015, usage based insurance products would become more popular and several high-tech start-ups are pursuing relevant cooperation with the insurers.

5.4.3. Vehicle rental

Short-term rental of cars would gradually turn to car sharing, whose driving experience could be improved by ICV technologies including AD, identity recognition, electronic payment and intelligent navigation. Didi, the largest transportation platform enterprise of China, has invested in research on AD algorithms in preparation for future car sharing business. Meanwhile, long-term rental trucks or buses could use IoV technologies to connect with monitoring centres in favour of vehicles and drivers management. Hence, some Chinese commercial vehicle manufactures represented by Yutong, Higer and Shaanxi Automobile all regard IoV management services as an important part of product value in their products.

5.4.4. Parking

ICV would apply IoV technologies for locating vacant parking spaces to save time and alleviate congestion, as well as online payment systems for improving the access efficiency of parking facilities. Parking lots could become unmanned by using local autonomous driving and parking technologies, thus optimizing space utilization and decreasing operating costs (Idris et al. 2009).Meanwhile, ICV could take the parking time to purchase services automatically such as charging, refuelling and car washing to create more added value.

5.4.5. Second-hand transactions and recycling

Enterprises can give out reasonable certification results of second-hand vehicles in consideration of the component status, data records of maintenance, insurance and driving behaviours. This certification guarantees the justice and transparency of information for both the buyers and sellers, and also improves the residual value of vehicles. By gathering a large amount of second-hand ICV data, enterprises can set up effective assessing methods and credit systems, and provide OEMs and dealers with big data services.

5.5. Vehicle usage

ICV applications can convert vehicles from physical movement tools into mobile living space and digital terminals. The vehicles could implement more functions and services than traditional ones and extend the industrial value-chain. On the one hand, the freedom of action due to AD technology will reduce the constraints on technical design and regulations of in-vehicle applications such as mobile office, social media and entertainment. These applications could present more diverse contents and forms. On the other hand, the capability of information interaction and intelligent decision-making allows ICV to connect with other industries including catering, tourism, logistics and smart home. The services like online reservation, personal travel advice, intelligent logistics management and smart home control could all be accessible in the car. Currently Chinese OEMs have started to attempt new usage of vehicles. Cowin Auto will launch unmanned delivery services, and LeSee Auto is trying to introduce their video and audio resources into automotive products.

5.6. Essential changes in the industrial value-chain of ICV

The above cases imply that some essential changes in the automotive value-chain will have to be considered for enterprises to build competence and achieve upgrading in the ICV era.

(1) Changes in value distribution. ICV enriches the content of automotive technologies and expands the product functions, creating new profit growth. While the product added value increases in all aspects, the 'smile curve' effect of automotive industry (Ba et al. 2009) will be more obvious and the value content will be extended, as shown in Figure 3. From the perspective of the front end, the R&D of high technologies like AD algorithms design, vehicle data management and intelligent human machine interface will occupy the strategic link of value-chain. Therefore the advantages of low marginal cost in information and software technologies can also be considered in automotive products. And as for the back end, aftersales and new usage market will show 'long tail effect' in various types of services covering maintenance, insurance, finance, rental, advertising and car culture. The value volume of sales and services will increase dramatically as ICV digitalizes and standardizes these activities.

(2) Changes in driving force. According to the differences in authority and power relationships, the governance structures of value-chains are divided into two types: producer-driven and buyer-driven (Gereffi 1994). Traditional automotive industry has a typical producer-driven value-chain. OEMs determine the whole product definition, suppliers develop the components according to the OEMs' design requirements, and dealers' marketing campaigns depend on the OEM's positioning and

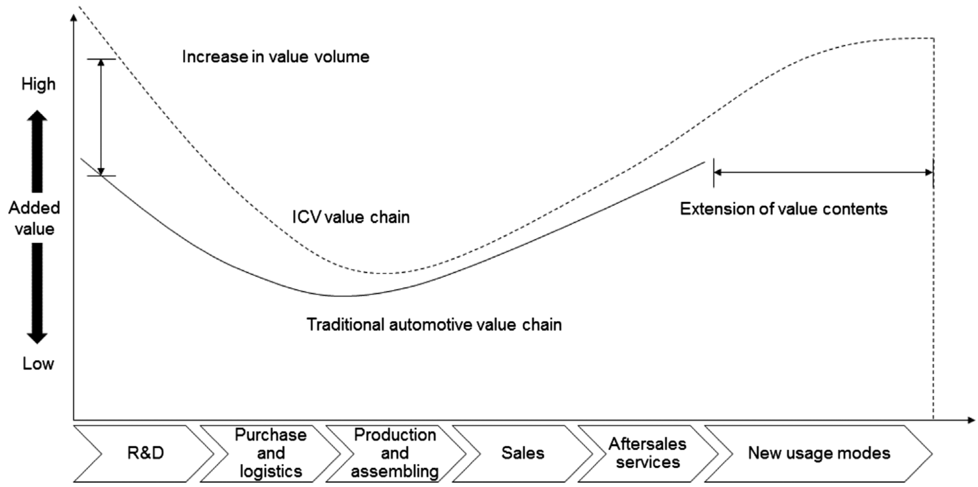

Figure 3. Changes in industrial value distribution of ICV. Source: Authors.

promotion strategies. In the contrary, ICV can satisfy consumers' individual demands, and the product functions are determined by consumers. OEMs only play the role of integration and have no absolute dominance. In this trend, the enterprises who are capable of matching the consumer's need with corresponding resources and have high brand value will take over the market. Therefore, the industrial value-chain will become buyer-driven.

(3) Changes in governance patterns. Three variables are used to identify the governance pattern of value-chains: the complexity of transactions, the ability to codify transactions and the capabilities in the supply-base. These criteria generate five types of governance which are hierarchy, captive, relational, modular and market (Gereffi, Humphrey, and Sturgeon 2005). While the automobile functions become more complicated and elaborate, OEMs can hardly possess all knowledge and know-how alone. This leads to knowledge spillover and transfer to other enterprises, thus suppliers can acquire stronger capabilities. The past hierarchy strategy in vertical integration of OEMs is unsustainable, and the value-chain will turn to relational governance. Meanwhile, the governmental mandatory provisions, corporate modularity strategy and industrial alliance would improve the standardization of ICV modules. As suppliers have the capability to develop systematic products and solutions independently, the value-chain would also show some characteristics of modular governance. Hence suppliers and OEMs will establish collaborative relationships rather than superior-subordinate ones.

(4) Changes in core capabilities. Enterprises compete in both the physical world and the virtual world, and therefore create value in the physical value-chain and the virtual value-chain (Rayport and Sviokla 1995). If the products are regarded as a combination of information and materials, their competitiveness comes from the influences of their information flow on consumers (Clark and Fujimoto 1991). Traditional automotive products' value focuses on the vehicle parameters such as power, fuel consumption and comfort. The consumers pay attention to the material quality

and mechanical performance, and pay high value for high-quality and high-performance products. As a consequence, OEMs regard the development and production of structural components (like power, drivetrain or suspension systems) as strategic links, and the materials design as core capabilities. However, because of the changes in value distribution of ICV, the profit model will become data-driven instead of product-driven. That means the enterprises would collect massive real-time data of vehicles and drivers and analyse these data with processing methods such as big data analysis, cloud computing and artificial intelligence. Then consumer demands are estimated precisely and corresponding products or services are provided. Hence the core capabilities are no longer limited to the capability of hardware design and quality assurance. The ability to gather, organize, select, synthesize and distribute information in the virtual value-chain can be even more important.

6. Implications

As mentioned above, ICV will change the value creation of automotive industry and lead to transformation and upgrading. Industrial upgrading refers to the improvement of the ability to move to more profitable and sophisticated economic niches for a company or an economy (Gereffi 1999). There are four kinds of industrial upgrading including process upgrading, product upgrading, functional upgrading and inter-sectoral upgrading (Humphrey and Schmitz 2002). The upgrading path towards ICV is closely related to the enterprise's characteristics and positions, and different types of enterprises should adopt different strategies. From the dimensions of process, product and functional upgrading, Chinese major companies' upgrading paths are discussed and shown in Figure 4.

(1) Chinese OEMs: overall upgrading of production process, automotive products and corporate functions. First, OEMs must develop technology and product platform strategy of ICV. By cooperating with transnational Tier 1 suppliers and introducing secondary innovation of advanced assembly lines, OEMs could realize process

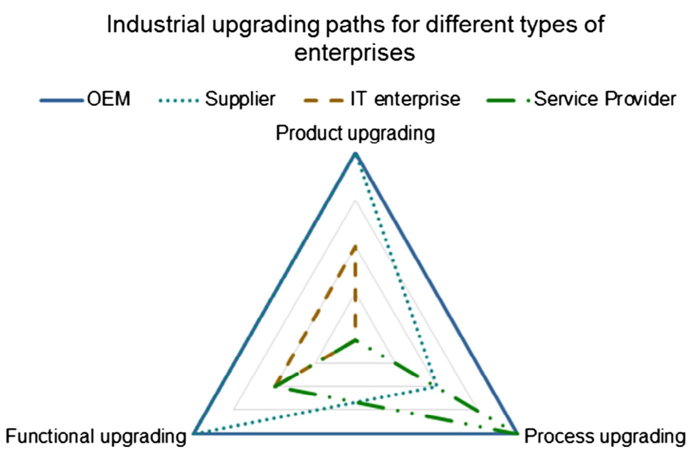

Figure 4. Upgrading paths for different types of enterprises in ICV industry. Source: Authors.

upgrading with improvement of modularity and platformization. Then, OEMs should keep track of the leading firms' ICV product planning and analyse the native consumer demands and preferences as well as the industrial policies. On this basis, OEMs can make product upgrading strategies according to their own technical capabilities and promote the commercialization of ICV technologies to increase added value. Finally, the OEMs with strong technical competence and customer base could focus on the value-chain activities of ICV R&D, sales and services. Indeed, the OEMs with capital strength and integration capability can accelerate functional upgrading by using methods such as merger, joint venture, outsourcing and strategic alliance to absorb external resources.

(2) Chinese suppliers: emphasis on component product upgrading and functional upgrading, and appropriate consideration of process upgrading. Chinese firms often belong to Tier 2 or 3 suppliers and produce low-tech components. Since ICV contains a lot of modules and keeps updating, the leading suppliers can hardly cover all types of products, which offers an opportunity of upgrading for Chinese small and medium enterprises. These suppliers need to promote innovation by acquiring technology patents, employing external experts and collaborating with scientific institutions. Meanwhile they should optimize product portfolios and create system solutions around core products. By highlighting inimitable competitive advantages and providing irreplaceable products, the firms could move up to high-level suppliers or even strategic partners and avoid being trapped in lower value-added segments. Furthermore, considering that ICV will cause wide-range standardization in the industry, the firms have to introduce related technical and quality standards to ensure that their products are safe, reliable and compliant with infrastructure interfaces.

(3) IT enterprises: product upgrading and functional upgrading aimed at automotive industry. IT products are widely applied in daily life with mature technical capabilities and business models. However automotive products have some features like high-speed mobility, closed environment and stringent security requirements. Therefore IT enterprises need innovation in the existed technologies and products to adapt to automotive contexts, leading to product upgrading. Moreover, IT enterprises can dominate the virtual value-chain of ICV with their professional skills of data collecting and processing. But as new entrants of automotive industry, they should adjust positioning strategy and strengthen cooperation with traditional automotive enterprises. Chinese IT enterprises have gained insights into native market demands and acquired large domestic customer bases, and should make use of these advantages to develop ICV products and services with Chinese features. Once a firm defines the dominant design of native market successfully, it could lead the industry in China and try to enter overseas markets.

(4) Aftersales service providers: service process upgrading and corporate functional upgrading. Service providers can always obtain primary data of customers and have advantages of information resources. Currently Chinese aftersales service enterprises usually have small-scale operation and poor management while the whole market is usually in disorder. Considering these problems, the firms should collect and utilize the large amount of standard data produced by ICVs and cooperate with IT enterprises to establish comprehensive management platforms by combining internal

and external data. The data analysis will improve the efficiency and consistency of service process, and also increases the added value of services. In this way a modern service brand with scale effect, unified process and formal management could be built. Furthermore, the firms will be able to cooperate with OEMs, suppliers and other related market participants in data applications, and increase their influence in the value-chain.

7. Conclusions

ICV is undergoing rapid progress in the whole world and especially popular in China, whose revolutionary impacts on the value-chain in automotive industry are emerging gradually, creating potential revenue by billions of dollars (Viereckl et al. 2016; Contreras-Castillo, Zeadally, and Guerrero-Ibanez 2017). However, as followers in automotive industry, Chinese enterprises have to balance the transformation between instant response to market requirements and finite capacities and resources. Thus a distinct understanding of future value-chain is necessary for homegrown firms to generate proper positioning strategies and reconstruct their core competitiveness in new environments.

Through a case study, this study has several practical and theoretical contributions attempting to fill this gap. First, based on an overview of current ICV cases in China, we figure out the conception and behaviour changes in different types of automotive value-added activities, awakening stakeholders to the transforming forces that are reshaping their business and organization. Second, this article provides explanations for essential features of ICV value-chain. In the upgrading process of traditional vehicles towards ICVs, the industry value-chain will become buyer-driven instead of producer-driven, while its governance pattern tends to be relational and modular. The 'smile curve' effect in value distribution will also be more obvious, attracting more participants to upstream and downstream activities with higher additional value. In order to acquire these benefits, enterprises should focus more on information collection and processing to gain sustained competitive advantages. Third, an analytical framework and portfolio strategies of industrial upgrading are proposed for involved enterprises to deal with these changes. Chinese native participants must design different upgrading paths to adapt to the future industrial ecosystem. Chinese OEMs ought to improve production process and product strategy to expand high-tech R&D and value-added services. Suppliers can move up to high end by concentrating on providing systematic products and solutions. IT enterprises are able to make use of information processing capabilities to dominate the virtual value-chain. And aftersales service providers should attempt to build big brands with standard procedures and scale economy.

There are several limitations in this study admittedly. Firstly case data focused on practices and experience in China where ICV industry grew most rapidly, but parallel comparison among different countries was not taken into account in this paper and research results were biased towards a single country. Secondly since ICV had a short history and relevant market data were hardly available, accurate quantitative analysis to describe economic impacts in this new value-chain was difficult at the moment.

Therefore, further research could make an in-depth comparison among different ICV development paths for major countries such as the United States, the European Union and Japan, as well as figure out key political and social factors of future mobility and industry.

The new activity patterns and business models in each value-added link of the automotive value-chain can also be explored in favour of ICV technologies adoption, clarifying the role each participant ought to play in ICV industry and the ways to share extra economic value from this industrial evolution.

In conclusion, ICV is reshaping automotive industry into a strategic emerging industry, with profound social implications and great market potential, which will be an opportunity for Chinese industry to realize upgrading in the global value-chain and achieve the goal of 'corner overtaking'.

Nonetheless, this conversion features collaboration and convergence of both manufacturing industry and Internet business, which may cause new challenges for future managerial and commercial behaviours. Hence there are more questions needed to be discussed insightfully and discreetly such as the following: *What kind of enterprise form and business model will dominate the future automotive industry? How will new entrants cooperate to introduce novel products and services that have never been considered before? And how to distribute the new value appropriately among all the players?*

These related questions remain to be studied in future research by academia and practitioners.

Abbreviations

AD	Automated Driving
A*STAR	Agency for Science, Technology and Research
BAIC	Beijing Automotive Industry Corporation
CA	Conditional Driving Automation
DA	Driver Assistance
DFM	Dongfeng Motor
FA	Full Driving Automation
FAW	First Automotive Works
GAC	Guangzhou Automobile Group Co., Ltd
HA	High Driving Automation
ICV	Intelligent Connected Vehicle
IoV	Internet of Vehicles
MIIT	Ministry of Industry and Information Technology
OBD	On-Board Diagnostic
OEM	Original Equipment Manufacturer
OTA	Over The Air
PA	Partial Driving Automation
SAE	Society of Automotive Engineers
SAIC	Shanghai Automotive Industry Corporation
V2I	Vehicle-to-Infrastructure Communication
V2V	Vehicle-to-Vehicle Communication

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This study conducted research on the development of intelligent connected vehicles across the whole mainland China, especially in Beijing, Shanghai, Chongqing, Hangzhou and Wuhan. Several

government officials and local staffs in Beijing and Shanghai were interviewed to complete case study, while other cities' information were collected by archival research from open data sources such as official websites, journals and magazines.

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