# The Technological Innovation and the Development of Parts Production in Electric Vehicle Industry of Taiwan

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## 1. Introduction

The development of electronic and semi-conductor industries in Taiwan has been represented as a success story in state industrialisation policies and attracted scholarly attention in innovation studies. The role of the Industrial Technology Research Institute of Taiwan (ITRI) has been that of institutionally successful cases and has been studied from various aspects.

The automobile industry in Taiwan, however, has been in a minor position behind the large success of the semi-conductor and liquid crystal display (LCD) industries. This study attempts to shed light on the automobile industry in Taiwan and analyse the new possible shift to electric vehicles (EVs). This study takes the development of part production for EVs in Taiwan and discusses the innovation and industrial policies and the role of the ITRI. This paper tries to analyse the development of the EV industry of Taiwan from the theoretical framework of innovation studies, especially the international division of innovative labour.

Taiwan and Japan experienced falling export competitiveness due to a rise in labour costs and the rapid development of China. Rising labour costs have driven the relocation of production from Taiwan to China. After the economic reform of China in 1978, Taiwan has played an important role in the Chinese economy. Taiwan started investing in China in the 1980s and accelerated the pace of this investment between the late 1980s and the 1990s.

The rapid emergence of Taiwanese electronic manufacturing system (EMS) firms in China has shown the different pattern of international division of innovative labour among China, Taiwan, and Japan. One of the leading EMS firms, Foxconn, is an example of the new division of innovative labour of EMS firms.

The automobile industry in Taiwan has been hovering around 300,000 in production volume for many years. In 1994, the sales volume of automobiles in Taiwan reached 570,000 and is expected to increase to 1 million[1]. However, production volume and sales have remained around 300,000 since then. Now, the EV is becoming the new target for development.

The Taiwanese government has announced a framework for its sustainable energy policy which set the goal of reducing $CO_2$ emissions to the level of 2000 by 2025. In order to achieve the goal, the EV industry has been considered a prioritised industry.

This paper tries to analyse the development of EV industries in Taiwan from the theoretical framework of innovation study, especially the international division of innovative labour. After the introductory and theoretical framework, the status of the EV industry in Taiwan is analysed. Lastly, the case of Fukuta as a supplier of EVs is studied and the role of international division of innovative labour between the US, Taiwan, and Japan is investigated to build an analysis of the EV development process and the strategies of Taiwanese firms.

## 2. Theoretical Background of technological Innovation in Automobile Firms

Innovation is not a new phenomenon. It is as old as mankind itself. There seems to be something inherently "human" about the tendency to think about new and better ways of doing things and to try them out in practice. Without innovation, the world in which we live would look very different. Invention and innovation are closely linked. Invention is the first occurrence of an idea for a new product or process. Innovation is the first attempt to carry it out in practice. They are closely linked, but there is a time lag between the two.

In spite of its obvious importance, innovation has not

[1] Fourin 2014

always received scholarly attention. For example, economic change used to focus on factors such as capital accumulation or the workings of markets, rather than innovation. Schumpeter (1937)[2] identified innovation as the critical dimension of economic change. Economic change revolves around innovation, entrepreneurial activities, and market power and seeks to prove that innovation-originated market power can provide better results than the invisible hand and price competition. Technological innovation often creates temporary monopolies, allowing abnormal profits that would soon be competed away by rivals and imitators. These temporary monopolies are needed to provide the necessary incentives for firms to develop new products and processes (Pol & Carroll 2006).

Innovation studies started in the 1960s, mostly outside the existing disciplines and at the most prestigious universities. The Science Policy Research Unit (SPRU) which specialises in cross-disciplinary research, economics, sociology, philosophy, and engineering was founded in 1965 at the University of Sussex in the United Kingdom by Christopher Freeman.

Sustainable development requires stable economic development, which is possible with the continuous upgrading of technology led by innovation. Without innovation, or new and better ways of doing things, the world would look very different, not only in terms of high-tech innovations, but also fundamental innovations and many ways of doing things better.

Organisational innovation is often seen in the Japanese automobile industry. In the development of the automobile industry, American Fordism manufacturing, based on standardised products for mass consumption produced in long series by low-skilled workers controlled by a hierarchy of foremen, engineers, and managers, was innovated into the Japanese production system. Just-in-time and lean production systems were developed by the Japanese auto industry, combining the advantages of mass production with flexibility in adjusting to changes in the composition and level of demand (Aoki 1988). The production items and volume are decided by the market. Orders are placed on a daily or hourly basis at the firm's production department, which has to deliver the requested products just in time. This also involves parts suppliers and their systems, referred to as the zero-inventory system. To increase quality and eliminate defects, organisational practices are required. This new organisational innovation needs more competent, committed, and motivated workers (Womack et al. 1990).

The technological innovation of automobile firms shows an evolutionary process. From manufacturing simple customer request, moving to a strict policy of quality and later to become a key player of industries, the automotive industry upgraded to fulfil innovation and technology development cycle. This long-term process has allowed firms to consolidate innovation and technology development efforts. In automobile production, innovation management systems have brought benefits of going from assembling to being a company that provides added value propositions to the customer.

The division of innovative labour pointed out by Arora (1994)[3] is from four perspectives: limiting factors, between large and small firms, between users and produces, and patent protection. Mazzucato (2013) added the issues of public and private sectors[4].

International division of labour has been an important issue for the study of the development of the global market economy. The changes in the investment, production, and distribution decisions made by firms have affected the international division of labour. Globalisation increases demand for international markets and is expected to increase the international competition concerning location factors. In the global economy, the rapid economic growth in China has accelerated the production shift to China and effected and transformed international division of labour in the region. The international division of labour is production operation system by firms geographically separating and different production stages across world. It is to exploit differences of the production cost. Dunning (1988, 1997) describes three essential factors for international expansion, ownership, location, and internalisation.

International division of innovative labour is becoming an important issue when we look at the Japan–Taiwan

[2] Joseph Schumpeter (1937) The Theory of Economic Development

[3] Ashish Arora and Alfonso Gambardella (1994) The changing technology of technological change: general and abstract knowledge and the division of innovative labor, Research Policy Vol. 23, 523-532

[4] Mazzucato, M. (2013), "The Entrepreneurial State – Debunking Public vs. Private Sector Myths", Anthem Press, ISBN 978-0-857282-52-1.

alliance. The automobile industry shows strong cases of international division of labour among China, Taiwan, and Japan. In 2008, Li and Sadoi surveyed the technical division of labour among Taiwan, China, and Japan in the case of automobile parts suppliers. The findings show that Taiwanese suppliers have been accumulating advanced technologies from Japan through technology collaborations and capital involvement. Such technology accumulation was upgraded through competition and cooperation over years in the case of the automobile parts industry. Li and Sadoi (2008) also pointed out that one characteristic of Taiwanese activities in China is that no Taiwanese parts suppliers have set up research and development (R&D) centres in their Chinese subsidiaries. This might because the technology Taiwan has accumulated over the years is more concentrated in intermediate levels of technology. From a strategic point of view, Taiwanese suppliers preferred to maintain their competitive advantage in R&D. This study implies that the importance of the international division of innovative labour is between Taiwan and Japan.

Innovation and human resource development are associated with a variety of outcomes of interest to the political economist. The investment in human capital is seen by many economists as an engine of growth (Acemoglu and Pischke 1998). Several studies point to a strong link between human resources and productivity (Acemoglu 1996). Country’s knowledge base is an important resource for innovation and which has linked cross-national differences in education and in per capita income (Romer 1990).

Both Japan and Taiwan have developed relatively stable systems for human resource development, but based on very different principles and sustained by quite different institutional arrangements. Both systems have been successful in achieving high skill-based industries. Japan is best known for its extensive firm-based system of training strongly associated with complementary personnel policies such as seniority wages and internal career ladders (Thelen 2004). Taiwan’s system of vocational training approaches the ideal typical collective solution.

In Taiwan, the government has been successful in upgrading the educational and technological levels of the labour force through the use of vocational schools. During the 1960s, when the period of compulsory education was extended to nine years, the proportion of children in vocational schools increased from 40% in 1960 to 57% in 1970 and by 1990 the proportion in vocational schools had increased to 72% (Ashton et al. 2002). Skill formation and technological upgrading programmes with state intervention played an important role in setting up research institutes and developing high-level engineers and entrepreneurs (Ashton 2002, Sato 2008).

As a result, Taiwan achieved a high technological level in the manufacturing industry by the 1990s, using the competitive advantage of its flexible and strong supplier networks. Having integrated capital and intensive technology and tie-ups in global value chains, Taiwan developed original equipment manufacturing and original design manufacturing production and exports.

Literature on innovation intermediaries has been appearing in recent years, with the majority of the literature seeking to understand the role of intermediaries in innovation systems (Hoppe and Ozdenoren 2005; Howells 2006; Stewart and Hyysalo 2008). The functions and activities of innovation intermediaries have also been studied. Sutthijakra and Intarakumnerd (2015) investigated the capability-building processes of intermediaries[5]. In the case of Taiwan, ITRI played an important role for intermediaries of innovation.

## 3. The Current Status of the Electric Vehicle (EV) Industry in Taiwan

### (1) EV Development Background

On 5 June 2008, Taiwan Executive Yuan passed the ‘Framework of Taiwan’s Sustainable Energy Policy’[6], which announced the goal of reducing $CO_2$ emissions to the level of 2008 between 2016 and 2020, and the goal of reducing $CO_2$ emission to the level of 2000 by 2025. In the meantime, the EV industry has been considered a prioritised technical item of development by advanced countries in Europe, the US, and Japan, and even developing countries such as China. To respond to the upsurge of EV development and the goal of reducing $CO_2$ emissions, in April 2010 Taiwan Executive Yuan passed

[5] S. Sutthijakra and P. Intarakumnerd, Role and Capabilities of Intermediaries in University–Industry Linkages: A Case of Hard Disk Drive Industry in Thailand, Science, Technology & Society 20:2 (2015): 182–203

[6] See official ministry website:http://web3.moeaboe.gov.tw/ECW/english/content/Content.aspx?menu_id=1524

**Table 1 Development Strategy and Programme of Action for Smart Electric Vehicles (EVs)—**
**A Comparison between the First and Second Stage**

| Period | First Stage (2010–2013) | Second Stage (2014–2016) |
|---|---|---|
| Development strategies | 1. Formulate standards for environmental energy conservation | 1. Intersectional promotion of the electric bus |
| Measures and Methods | (1) EPA set $CO_2$ emission standards<br>(2) Energy Board investigates and tightens up standards of fuel consumption | (1) MOTC and EPA jointly support electrical bus replacement<br>(2) MEA promotes EV surveillance<br>(3) CA promotes transportation connection of forest recreation or scenic areas<br>(4) Assist manufacturers in international marketing |
| Development Strategy | 2. Promote EV Surveillance | 2. Provide Purchasing Incentives |
| Measures and Methods | (1) MOEA promotes EV surveillance of seven programmes, totalling 287 EVs | (1) Waiving of licence tax or merchandise tax for three years |
| | (2) Passing safety tests of 11 units, totalling 25 models | (2) MOTC, EPA, and MOEA provide subsidies |
| Development Strategy | 3. Raise purchasing incentives | 3. Innovative operation models |
| Measures and Methods | (1) MOF waives goods and licence tax for three years<br>(2) MOI relaxes regulations on public recharge stations | (1) Separate car and battery for lower cost<br>(2) Promote the battery recycling mechanism and the reutilisation operational model<br>(3) Promote the fruit/vegetable wholesale operational model |
| Strategies | 4. Strengthen utilising environment | 4. Encourage business investment |
| Measures and Methods | (1) Establish 500 recharge stations<br>(2) Formulate 50 national standards<br>(3) MOTC revises and enlarges signs at recharge stations | (1) Government agencies and state-owned enterprises get priority to purchase or lease EVs<br>(2) Assist in developing commercial types of EV such as electric vans or trucks<br>(3) Government agencies and state-owned enterprises get priority to purchase or lease EVs |
| Policy objectives | 5. Assist in the development of the EV industry | 5. Construct industrial value chains. |
| Measures and Methods | (1) Improve product policies of 73 manufacturers<br>(2) Promote whole-vehicle development<br>(3) Promote exports of components by joining the Tesla supply chain | (1) Promote autonomous technical development of electric energy and power systems<br>(2) Continuously formulate laws/standards and boost up industrial energy<br>(3) Promote cooperation of the upstream as well as downstream enterprises of the industrial chain and localisation<br>(4) Adopt artificial intelligence and safe electric circuits systems |

Source : 財團法人中技社編著『我國電動車產業發展』, 2014 年 4 月, pp63–65 the 'Intelligent Electric Vehicle Development Strategy and Action Plan' with the creation of concrete measures such as formulating strategies and goals, establishing plans and tactics for counselling, and organising a promotional task force, all showing the firm resolution of the government to develop the EV industry.

(2) Development Policy and Measures

The aforementioned policy underwent revision again in May 2014. As shown in Table 1, the five development measures of the first stage after four years of promotion, with an investment of 2.2 billion NT$, have successfully built EV Surveillance Platform, Technology Platform, EV Industry Clusters Website, and Verification Platform, together creating to a solid foundation for the development of the domestic EV industry. The policy development of the second stage is to head towards a strategic development of 'the intersectional promotion of the electric bus', 'stimulating purchasing incentives', 'an innovative operational model', 'encouraging business investment', and 'establishing industrial value chains'. For the development goal[7] up to 2016, the EV industry in Taiwan is to push the entrance of more than five key component manufacturers into the international EV supply chain. The electric bus goal is to reach 12.2 billion dollars in output value, with a prediction of more than a total of 2,234 people in employment.

(3) Related Promotion Agencies

Under this program, the Executive Yuan founded a 'Promotional Group of Smart Electric Vehicles' across different sectors and a 'Promotional Office of Smart Electric Vehicles' under the Industrial Development Bureau of the Ministry of Economic Affairs (MOEA) as the main leading and executing divisions of this project. To create a better environment for the EV industry, the Executive Yuan further invited the collaboration and assistance of the Ministry of the Interior, the Agricultural Council, the Ministry of Transportation, the MOEA (Bureau of Energy, Bureau of Standards), and various sectors of the Environmental Protection Administration, as well as municipal governments and state-owned businesses (e.g. Taiwan Power Company and CPC).

Meanwhile, the Industrial Development Bureau of the MOEA activated 'Plan for EV System Modules and Pivotal Technology', and set up the 'Taiwan Automotive Research Consortium' (TARC) as an industry alliance, with members including ITRI, VSCC, the Metal Industries Research & Development Centre, the Chung-Shan Institute of Science & Technology, and Haitec to integrate the domestic research capability and establish technology platforms, at the same time developing key EV modules collaboratively and eventually achieving an autonomous pivotal technology for domestic enterprises[8]. Until December 2013, 24 companies including TARC, Delta Elec., and TECO have started up an autonomous electric and commercial technology platform, jointly developing key EV modules such as the chassis, energy system, dynamoelectric, and electric add-ons for EVs[9], with an added value of over 63.5 billion NT$ by December 2014[10].

(4)ITRI's Role

Starting from 2010, ITRI has invested a huge amount of resources in green energy research[11]. In particular, it focuses on researching EV motorised systems (the development of key EV technology and modules) by assigning two of its subsidiary units—the Materials and Chemical Research Laboratories and the Mechanical and Systems Research Laboratories. Of these two units, the former develops high-safety STOBA lithium battery material technologies, high-energy/high-capability battery plates, and production technology. The latter is in charge of the development of smart vehicle systems and related application technologies, key module technologies for energy-saving EVs, and their industrialisation.

Under the promotion of the 'Program for the Development of Key Module Technology for Energy-saving EVs and Industrialisation', the ITRI has further developed relevant pivotal technologies through cooperation with leading industrial manufacturers, so as to strengthen the modelling technology of vehicles with enhanced industrial values, implement the product applications of mod-

[7] 財團法人中技社編著『我國電動車產業發展』, 2014 年 4 月, pp63-71

[8] 經濟部能源局『能源』, 台灣經濟研究院編印, 2012 年 8 月, pp7-8

[9] 財團法人中技社編著『我國電動車產業發展』, 2014 年 4 月, p72

[10] 工研院「電動車多元典範運行 共探車輛產業未來」, 工研院編印, 『工業技術與貿易月刊』, 第 278 期, 2014 年 12 月 30 日, p2

[11] 工研院「綠能物流創新商機 可望帶動電動車產業發展」, 工研院編印, 『工業技術與貿易月刊』, 第 266 期, 2013 年 12 月 30 日, pp1-2

ule technology in key components, and thereby reach the goal of mass production and popularisation of EVs in a long-term perspective. For example, in May 2013 the ITRI and TECO signed 'Complete Solutions for Electric Vehicle Power', which transfers the motor driven technology and expands their cooperation in EVs with a view to penetrating the market of special cars abroad in the future[12].

At the same time, ITRI promotes sustainable commercial EVs with autonomous key technology modules and integrated platforms of laboratory vehicles. Through the advantages of EVs' low noise and zero emissions, the logistics industry is enhancing their competitiveness in the market. During the first stage it has attracted the participation of enterprises such as Uni-President Enterprises Corporation, HCT, and China Airlines.

(5) Effectiveness of Promotion

According to Executive Yuan[13], the following effects have been achieved since the programme was put into execution in 2010.

1. Certification of EV and Recharging Stations: 11 EV enterprises were assisted, among them 25 models that have passed the safety tests of the MOTC, and 35 electric recharging systems of five units that have completed verification by the Bureau of Standards, Metrology and Inspection (BSMI) of the MOEA.
2. Tutorship of Smart EV enterprises: The MOEA has tutored 102 enterprises to improve their product function; the scope of the enterprises ranges from material and system integration to OEMS in a complete EV supply chain.
3. Development of domestic commercial EVs: The industry has developed pivotal EV technologies and successfully applied them to commercial types of EV.
4. International Cooperation Promotion: Car dealers of the Philippines, La Poste, Bollore group, Venturi, and PSA have come to Taiwan to investigate the supply of EVs and its key components, thereby leading to the technical cooperation between the Li Kai Company and Sony Energy, and between RAC[14] and Japan.

Under the promotion of government policies since 2010, the EV industry in Taiwan has gradually laid a solid groundwork of development with a complete supply chain and taken a lead in cutting into the supply system of international EVs. According to the statistics of ITRI[15], the numbers of supply parts for EVs and HEVs[16] have increased from 107 items (EVs accounted for 11 and HEVs for 96 in 2011) to 4,260 items (49 EVs and 4,211 HEVs) in 2014, indicating that Taiwan is equipped with the strength to produce EVs, which paves the way for its future development in the EV industry.

## 4. The Case Study of Fukuta Electric (Fukuta)

This chapter examines the case of the Taiwanese EV parts suppliers from the viewpoint of industrial policy, technological capability building, and the international division of labour. The case of Fukuta provides a strong case of major EV parts with the international division of innovative labour.

Mr Gordon Chang, President of Fukuta, was originally in charge of the motor design of the development department of Taiwan's leading integrated electronics manufacturer, TECO. In 1988 he established Fukuta and devoted it to the development of the servo motor to provide a tailor-made product targeted at small- and medium-sized enterprises (SMEs), in order to differentiate itself from major manufacturers such as TECO and Datong Electric. From the beginning, he focused on R&D to ensure its technology. In addition to self-development, Fukuta actively applied projects with the government's affiliated organisation and joint research with universities. Therefore, Fukuta received good reputation in technology. At its peak in 2009, about 60% of employees (50 out of 85) were in R&D. Of its current 215 employees, about half of them are in R&D under the mass production of motors for Tesla Motors (Tesla).

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[12] 工研院「產研合作開創台灣電動車新紀元」, 工研院編印, 『工業技術與貿易月刊』, 第 259 期, 2013 年 5 月 10 日, pp3-4

[13] 行政院網頁「四大智慧產業 - 智慧電動車」: http://www.ey.gov.tw/policy8/cp.aspx?n=243D7E993A404388

[14] RAC Electric Vehicles Inc. is a Taiwan-licenced car manufacturer, and the first company in Taiwan to have successfully developed an all-electric low-floor city bus. The RAC e-bus is the first electric commercial vehicle in Taiwan to be officially road-licensed by the Ministry of Transportation and Communications, and it is a zero-emission green vehicle that brings enormous cost-saving potential to the public transport system.

[15] 財團法人中技社編著『我國電動車產業發展』, 2014 年 4 月, pp15-17

[16] Hybrid Electric Vehicles

Because of the technology and innovative based management, in 1998, Fukuta developed the first alternating current sensitive servo motor unit in Taiwan with the financial support of Taiwan's MOEA. At the end of 2008, Fukuta developed a 5 kw vertical type small generator as part of industry–university cooperation with the Taiwan Kaohsiung Applied University of Science and Technology (the alma mater of Mr Gordon Chang) and started to export successfully. Since then, R&D has been active and has led to the production of motors for Tesla and the development of driving systems for EVs with the Automotive Research & Testing Center (ARTC).

The relationship with Japan started around 2000, when Fukuta started OEM and ODM export of industrial motors to Japan through the Japanese trading company Yamazen. The R&D relationship with Japan started in 2006 as a joint development project with Waseda University Japan. Fukuta responded quickly to the rough draft order of wind turbines from the Waseda University development team. Fukuta manufactured and delivered 30 generator motors within 60 days and installed them in Tsukuba City. After that, Tachibana, a Japanese technology trading company, came for business. Fukuta delivered ten wind power generators to the central airport in Nagoya.

The R&D relationship with the US started in 2005. In July 2005, Mr J B Straubel, CTO of Tesla, visited Fukuta. Tesla had had difficulty finding a motor alliance partner, having been declined by several major motor manufacturers in Germany, Japan, South Korea, and Taiwan, the last in the case of TECO. At that time, Tesla was an unknown new company, founded less than two years earlier. The order was only 4,800 motors in three years. Therefore, no leading manufacturer showed an interest in the alliance with Tesla at that time.

Eventaully, Tesla visited Fukuta when Taiwan's MOEA picked out Fukuta from the industry directory. Fukuta's CEO, Mr Gordon Chang, who has technical capabilities for tailor-made small scale production and an innovative attitude, showed an interest immediately and started negotiation with Tesla.

Mr Gordon Chang proposed a size reduction and power increase for the servo motor. He said that high thermal efficiency and divergence are the key points for electric motors. Fukuta, in collaboration with Tesla, developed and mass produced the 'Roadster' in two and a half years by achieving a 40% rise in the electrical conductivity in the motor rotor core, an 80% weight reduction, 0–100 km acceleration in 4 seconds with 200 horsepower, and an output 11 times that of a conventional motor of the same weight.

Thus, Tesla launched the world's first fully electric drive sports car, the 'Roadster', in September 2008. Despite its high price at $98,000, reservations from the likes of Hollywood celebrities flooded in. The second generation of the 2011 'Model S', the 'Model X' is expected to be released in September–October 2015. Thus, Fukuta has delivered as the sole motor supplier of Tesla, shipping 35 thousand motors in 2014, and is expected to ship 55 thousand motors in 2015. In response to this, Fukuta completed construction of a new plant at the end of 2014 and reached 300 thousand motors of production capacity. Following their successful supply to Tesla, BMW, Toyota, Nissan, Chinese makers, and many other automobile manufacturers began to visit Fukuta to discuss possible new business alliances.

The case of Fukuta can be analysed from the perspective of the international division of innovative labour with Japan and the US by describing the process of technological capability building. With Japan, there are two technology upgrading opportunities: (1) 15 years of technology exchange with Japan through the trading company Yamazen for its OEM and ODM alliances; (2) through the connection with the development team of Waseda University of wind turbines in 2006. Fukuta, with a joint development team with Waseda University, completed and installed 30 generator motors in Tsukuba. There were occasions for optimising technology through meetings and information and technique exchange during the joint development processes.

In addition, Japanese sales channels and relationships with Japanese trading companies have contributed to technology formation: the sales channels of Yamazen for industrial motors and Tachibana for wind power generators. With Tachibana, personal connections with the general manager contributed to a long and strong relationship with the Japanese trading companies to expand their business and technological development. Moreover, direct technology exchange with Japanese manufacturers as well as the sales channels and trading companies has played an important role in innovation and technology upgrading.

The role of intermediaries in Taiwan, for example technology innovation research centres such as ITRI, played a crucial role in EV technology and innovation platform building. Fukuta is a member of the economics department in ARTC and in charge of building a platform on spin-off technology and EVs. For example, in 2010 Fukuta was in charge of the launch of the EV Advanced Propulsion Driving System (EV-APDS)[17].

In addition, industry–university cooperation contributed greatly to the technology evolution in SMEs. Fukuta is actively promoting several universities and university–industry cooperation. For example, in partnership with Kaohsiung First University of Science and Technology.

Fukuta's business strategy can be summarised into the following three points: customisation-oriented, R&D strength, and quick response. First, as a strategy to target SMEs, Fukuta gave high priority to customised production. In order to differentiate itself from large corporations such as TECO, Fukuta has been devoted to the development of the servo motor. Including mass production for Tesla, Fukuta has a principle of customised production. Second, Fukuta has focused on R&D from the beginning. Currently, the ratio of R&D employees accounts for 50–60% of all employees. The third strength is quick response. As can be seen from the Tesla example, Fukuta completed the joint development project that would normally require four years in just two and a half years. R&D staff hold morning and evening meetings with the American Tesla staff members to perform repeated tests. The flexibility, cooperation, motivation, and passion of Fukuta were indispensable to their success.

As more than 30% of Fukuta's overall sales depend on Tesla, Fukuta started to implement a risk distribution strategy. First, Fukuta aimed at the Japanese EV market. Mr Gordon Chang is expecting to have the opportunity to supply parts to Japan's electric car market. The second strategy is the development with ARTC (i.e. EV-APDS). Fukuta is in charge of the motor development of ATRC. Fukuta is planning to launch a drive system which can be installed in each car model in Taiwan and applicable to export. Third, Fukuta is pursuing the electric bus market. Currently, Fukuta delivers a small volume of motors to the Yulon domestic electric car manufacturer (own brand Luxgen), and to Aleees, RAC, Germany, and Denmark for electric buses. The fourth strategy is to the partner with China's Beijing Automotive Industry Holding (BAIC). In partnership with BAIC, Fukuta provides motors for passenger cars and buses. Another Taiwanese supplier provides chargers and the transmission system. This is promoted as part of the 'Electric Car Development Bill' in the MOEA.

Taiwan was Tesla's most important production base until in 2009. However, Tesla left the Guishan Industrial Park Service Center in 2009 and the situation of Taiwan EV parts suppliers has changed, leading them to seek out other opportunities and several risk distribution strategies. Until Tesla left in 2009, about 25% of their key components had been delivered with the cooperation of R&D in Taiwanese manufacturers[18]. A total of 11 supplier companies were involved in the development and manufacturing of electric motors, motor hard shot processing, transmission gear boxes, and electric control systems, which is regarded as the central nervous system of a car. Thus, in the open division of innovative labour system in IT, Taiwanese manufacturers have been playing an important role as Tesla's laboratory to meet requirement for mass production. Without the support of these Taiwanese suppliers, it would not be possible to complete Tesla's EVs.

There were several reasons for the closure of Taiwanese production in 2009. The first was Obama's industrial policy to strengthen American industry. It offered Tesla a generous subsidy of $465 million to increase employment by bringing Tesla's EV manufacturing back home. The second reason was the anticipation of future development. Because the EV is a product under development, the proximity of manufacturing and development is considered to be reasonable. Finally, towards the large-scale production of the future, scale merit can be achieved through large companies rather than SMEs in Taiwan. Large companies might be regarded high liability and easy to promote[19].

Under these circumstances, the number of Taiwan suppliers for Tesla decreased from 11 to 4. They are Fukuta, Hartech for the reduction gear, Chroma for the electrical control system, and EEchain for the battery cable.

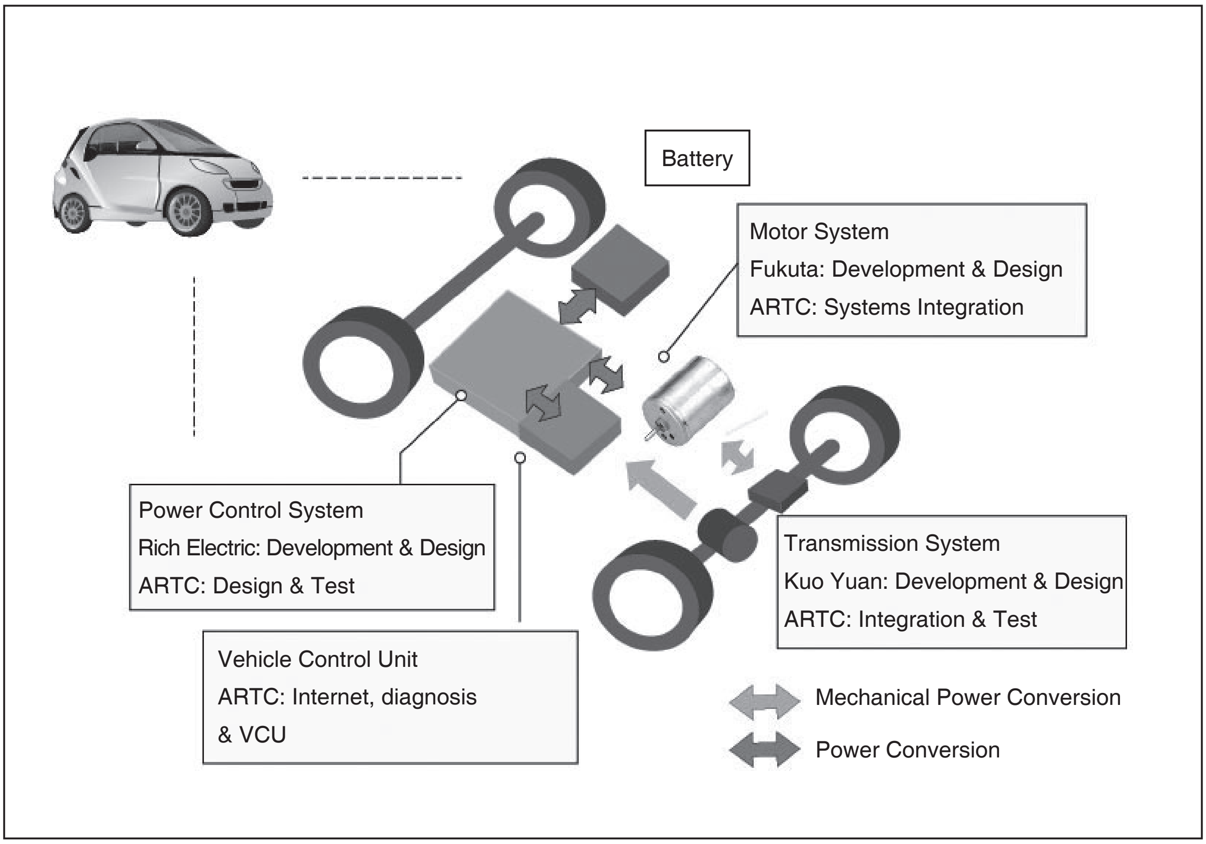
Under the circumstances, the Taiwanese govern-

[17] 財團法人車輛研究測試中心 (ARTC) 網頁：http://http://www.artc.org.tw/chinese/03_service/03_02detail.aspx?pid=1564&nPage=125&syear=&skind1=&skind2=&skeyword

[18] Information obtained by Fukuta

[19]『天下雜誌』，第 532 期，2013 年 10 月 2 日，pp100–103

**Figure 1 The Division of Labour for the R&D of the EV-APDS**




Source: ARTC, 財團法人車輛研究測試中心 (ARTC) 網頁

ment started the 'Industry–government cooperation of Taiwan's industrial policy'. For the further development of the Taiwanese automobile industry, Taiwan's MOEA technology processing established TARC in May 2005. This consisted of the Metal Industrial Research & Development Centre (MIRDC), the Automotive Research & Testing Center (ARTC), the Mechanical and Systems Research Laboratories of ITRI (MSL / ITRI), the Material and Chemical Research Laboratories of ITRI (MCL / ITRI), the Chung-Shan Institute of Science & Technology (CSIST), and the Hua-chuang Automobile Information Technical Center Co., Ltd. (HAITEC)[20].

TARC spin off their development results and establish a platform to integrate five module systems: the electric drive system, battery system, electronic system, chassis system, and charging system.

One of the projects of the ARTC established on 18 March 2010 was EV-APDS. It aims to produce advanced electric drive systems to meet each of the domestic car models in the 'Designed in Taiwan and Made in Taiwan' project and to export overseas as a main supplier in the field. For APDS, Fukuta is in charge of the motor development, Rich Electric the development of the drive control system, and Kuo Yuan the development of the transmission. ARTC is in charge of the system control, smart technology integration know-how, and support for the entire system, as shown Figure 1.

As Taiwan has the appropriate mileage size as a country for EVs and also has a strong ICT industry, the government expects much for the future and potential of the project. Taiwan's MOEA cooperated with ARTC in 2010 and established the EV centre to promote the plan to produce 3,000 EVs in three years. If even Tesla completely withdraws, Taiwanese suppliers are prepared to shift to domestic EVs and electric buses. For this, the support and development of domestic electric car-related companies is indispensable. In fact, 60% of the parts of electric

[20] 台灣電動車產業聚落交流平台網頁 :http://www.ev.org.tw/Home/Page/?n=TARCIntroduction

buses produced by RAC are supplied by Taiwanese manufacturers. Fukuta supplies motors, and Rich Electric supplies drive control systems and charging stations.

## 5. Conclusion

This paper studied the development of the EV industry in Taiwan from the innovation and division of innovative labour viewpoints. The first section of this paper examined the theoretical background of innovative studies from the perspective of the technological development of Taiwan and the role of intermediaries. The second section introduced the status quo of Taiwan's EV development policies and the role of intermediaries, such as ITRI, for EV development. The final section studied the case of EV parts suppliers in Taiwan.

Under the promotion of government policies since 2010, the EV industry in Taiwan has gradually laid a solid groundwork of development with a complete supply chain and taken a lead in cutting into the supply system of international EVs. This paper indicates that Taiwan is equipped with the strength to produce EVs, which paves the way for its future development in the EV industry.

Fukuta's case examined the international division of innovative labour between Japan, Taiwan, and the US. It was originally between Japan and Taiwan, but Tesla from the US had a strong impact on the Taiwanese EV industry due to the R&D and innovative role of Taiwan. At the same time, intermediaries in Taiwan played an important role in facilitating and developing EV part production networks in Taiwan.

After Tesla left, those intermediaries supported the enhancement of EV supplier networks in Taiwan and created new possibilities for domestic and international innovative labour. Fukuta's case illustrates the current situation of EV part networks and the possibilities and issues they are facing.

Nonetheless, the industrial structure of the autonomous EV industry in Taiwan still awaits strengthening in respect to the production of whole cars and the integration and supply of components. Moreover, although some domestically produced parts have been used for domestic EVs at present, the production rate of key components for whole cars is still low. At the same time, Taiwan has entered the supply system of international electric depots, yet there remain issues of subsequent product performances, system capabilities, and economies of scale to be resolved for better performance.

Most of the EV businesses in Taiwan are SMEs. These enterprises have an edge in the techniques of electric engineering, electric control, and electronic and mechanical engineering. In the future, domestic enterprises are expected to strengthen the design of key modules and system integration, shorten the gap between the techniques of other foreign manufactures, and combine government resources and existing development platforms. The aim is to move towards liberalisation, small scale and cost-competitive EVs, the development of related components, and even the leap into the international market to take up a key role in the supply chain of the industry. Meanwhile, the government is advised to continue integrating strengths across different departments and implementing the 'Intelligent Electric Vehicle Development Strategy and Action Plan'. The strategy of the second period is to build up an appropriate environment for the development of the EV industry and to attract investment in domestic and international enterprises. In the long run the domestic automobile industry is expected to be upgraded, thereby achieving the goal of energy saving and carbon dioxide reduction.

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