Clash of Titans: The challenges of socio-technical transitions in the electrical vehicle technologies – The case study of Thai automotive industry

Abstract

The automotive industry has been focusing on electric vehicles (EVs). This recent change means that there will a transformation in the automotive industry. This situation poses challenges since various actors must engage in this transition. This study combines the strength of Global value chain (GVC) and National systems of innovation (NSI) using multi-level perspective (MLP) to create a framework that could reveal the interconnections between the actors of social settings and evaluate the sources both of innovation and socio-technical transitions by integrating both the national and international analysis together. The global system of innovation (GSI) framework is introduced to point out the key players in the transition and investigate the effects of interactions between actors and to explore their effects on the transition in the Thai automotive industry towards EV. Our research highlights that the EV transition in Thailand is challenging as there seems to be low level of collaborations among stakeholders. The Thai government should carefully analyze the EV situation and collaborate with carmakers and local suppliers before introducing policy support.

Keywords: innovation system; multi-level framework; global value chain; electric vehicle; transition; Thailand

Part 1: Introduction:

The automotive industry has been facing technological challenges and various studies have shown that the automotive industry has been changing, particularly in developing countries (see more in Giuliani et al., 2005; Sturgeon et al., 2009; McDermott and Corredoira, 2010). There is more pressure from the carmakers to produce at low cost and provide integrated system of products. There has also been influx of foreign-owned suppliers, who attains better production and design capabilities, entering developing countries. It is argued that local suppliers in developing countries must have higher technological capabilities to be able to participate in product

development or product engineering to maintain the orders from lead firms (Kohpaiboon and Jongvanich, 2013). There has also been a new challenge for automotive suppliers on innovation. The automotive industry has been focusing on electric vehicles (EVs). Germany is planning to ban combustion engine cars by 2030, while Great Britain and France will also ban the sale of new petrol and diesel cars from 2040 to reduce air pollution (Reuters, 2017). The change from conventional cars to EVs means that suppliers must also change technologies on both new products and production processes as different parts are applied to the cars. As the industry is moving towards EV trend, developing countries must prepare for this radical change. To overcome obstacles faced, it is imperative that there is good coordination within the automotive supply chain (Ivarsson and Alstom, 2005). Moreover, the development of the automotive industry towards EV is not only the responsibility of single actor but requires interactions and collaboration from various sectors.

This study intends to understand the interaction(s) and clash(es) between actors in each level of transition in the automotive industry and map those actors to explore their effects on the transition towards EV. Diverse types of actors located in three distinct positions, supplier firms at the micro-level, organizations within the country, such as universities, research organizations and industry associations, at the meso-level and transnational corporations at the macro-level, affect the system of innovation and socio-technical transitions. The development of the automotive industry towards EV requires collaboration from various sectors. The case of Thai automotive industry offers valuable insights due to the importance of the automotive industry in the country. Moreover, we believe that the study of the Thai country context reflects the situation in other developing countries in the same context, such as Brazil, Mexico and India, as they are facing comparable situation that suppliers are struggling to grow towards EV. In order for the automotive industry of developing countries to move forward, adoption of new technology, particularly EV, could be an answer. Yet, substantial investment is required to produce EV parts which generates debate on the who should take responsibility on the burden of EV investment and whether developing countries, such as Thailand, should take actions towards EV. There are two main research questions in the study. Firstly, who are the main actor(s) that affect the socio-technical transitions of the EV technology in the Thai automotive supplies industry? And secondly, how does the interplay between technology and society affects socio-technical transitions of the EV technology in the Thai automotive?

This paper explores not on the economic aspect of the source of innovation, but also social aspect on how socio-technological transition occurs in developing countries, when taking both national and international sources of knowledge and their dynamic interactions into account. The study begins with the review of the main literatures, consisting of national innovation system (NIS), global value chain (GVC) and multi-level perspective (MLP). These frameworks are the foundation for the newly introduced framework in this study. Afterwards we provide an overview of the automotive industry after which we describe our research methodology. Following this, we present our research findings and conclude with its implications and suggestions for further study.

Part 2: Theoretical Context

2.1 National innovation systems and the importance of local actors

The systems of innovations have been implemented as a device to explain the productive problem of firms or to understand economic growth and the catching-up process of emerging countries (Iizuka, 2013). The approach emphasizes the interdependence between technical and institutional change as the main theoretical area (Freeman, 1988). The focus on the institutional level is important as it creates patterns of interactions which could explain why and how innovations differ across contexts (Giuliani and Marin, 2007). The actors involved, the networks and institutions may vary depending on how we choose the level of analysis. Systems of innovation can be viewed in several dimensions.

According to Nelson (1993, p. 4), NIS "*is a set of institutions whose interactions determine the innovative performance of national firms*" while Lundvall (1992, p. 2) defined NIS as "*constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge*". Smith (1995, p. 72) added that "*the overall innovation performance of an economy depends not so much on how specific formal institutions perform, but on how they interact with each other*". The NIS approach shows that the innovation process is sophisticated and involved dynamic arrangements and links between various actors within the national boundary. Not only the activities of firms, but other functions in the country such as universities, research institutions, government, etc. and the interactions among them enable knowledge sharing and support for firms' innovation activities (Dodgson, 2009). To improve overall performance of the nation, formal institutions such as firms, universities, government, etc. should interact with each other as elements of a collective system of knowledge creation.

However, NIS plays down the impact of international information exchange through inter-firm networks on the generation and diffusion of knowledge and innovation. The assumptions that innovations emerge within a country have become less true (Carlsson, 2006). The key players that generate innovations, particularly in developing countries, are transnational corporations (TNCs), who increasingly operate on a global scale, not only in manufacturing, but also on innovation and R&D activities as well. Thus, participate successfully in the more intense global competition, local institutions on training and education, support for local entrepreneurial activities, and improvement of physical infrastructures must be developed (Dicken, 2011).

2.2 Global value chain and the sources of global innovations

Coe et al. (2004, p. 471) declared that the world has become *"globally organized nexus of interconnected functions and operations by firms and non-firm institutions through which goods and services are produced and distributed"*. Global value chain takes the entire chain of productive activities into account. The chain analysis maps the vertical sequence of events leading to the delivery, consumption, and maintenance of goods and services; at every stage and every location of value chain. It is sustained by a variety of inputs such as human resources, services, infrastructure, and capital equipment (Sturgeon, 2001). The focal point of the GVC literature is on the importance of a firm's upgrading to face global competition and the role of governance structure by the TNCs that impact improvement of firms in developing countries that are linked to the global productions (Gereffi, 1999). The value chain perspective is effective in conceptualizing the forms of global integration of business as it shifts focus to the entire range of activities, from design to material sourcing, production and marketing (Humphrey and Schmitz, 2002).

Inclusion in global value chain benefits developing countries as it enhances the corporate capital, technology investment, and access to international markets (Dicken, 2011). Participations in global production networks cause industrial upgrading in developing countries as firms that enter the global production network tend to be larger than firms which only focuses on the domestic market, earn higher profits, have higher R&D rates as they will receive better knowledge and technology from TNCs (Cattaneo et al., 2013). Insertion in global value chain provides one of a few opportunities to gain access to and obtain information about the product demand in global market (Gereffi et al., 2005; Sturgeon et al., 2009).

2.3 Multi-level perspective and the sources of local innovations

The MLP is an analytical and a heuristic framework to understand how system innovations come about through the interplay between technology and society and how transitions from one socio-technical system to another occurs (Geels, 2005). Innovation triggers transitions; however, the effect of change is not limited to technological transitions but to the entire socio-technical system. Geels (2005, p. 1) defines socio-technical system as a cluster of elements that are "linked together to achieve functionality, for example, technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and production systems" at the level of societal functions.

The relationship between the three levels can be understood as a nested hierarchy or multi-level perspective. The first level is the meso-level formed by socio-technical regimes. Regime level refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems. The regimes not only refer to the social group of engineers and firms, but socio-technical systems are also actively created and maintained by several social groups such as public authorities, research institutions, financial institutions, etc. The second level is the micro-level, which is formed by technological niches. Niches are the major source of radical innovations. Niches also provide locations for learning processes on many dimensions, and provide space to build the social networks which support innovations. The macro-level is the third level and is formed by the socio-technical landscape; it is an exogenous environment which affects the socio-technical development and is beyond the direct influences of internal actors. The three levels provide diverse kinds of coordination and structuration of activities in local practices. Regimes are embedded within the landscape and niches within regimes. Radical innovations from niches create changes in the existing regime.

Geels and Schot (2007) believes that transition does not only involve technological changes, but also social changes. Socio-technical system widens the idea that some large social groups influence technological trajectories. The stability of established socio-technical configurations results from the linkages between heterogeneous elements. The elements and the linkages are the result of activities of social groups which produce them. The activities of these separate groups are aligned to each other and coordinated. Socio-technical transition does not occur due to a shift from one regime to another; however, new regimes gradually grow out of the old ones. Changes in one elements of the regime trigger changes in other elements which, in turn,

trigger further changes. Such reconfiguration processes take place on all dimensions of the socio-technical regime (See more in Geels and Schot, 2007; Geels, 2011).

2.4 Towards global systems of innovation

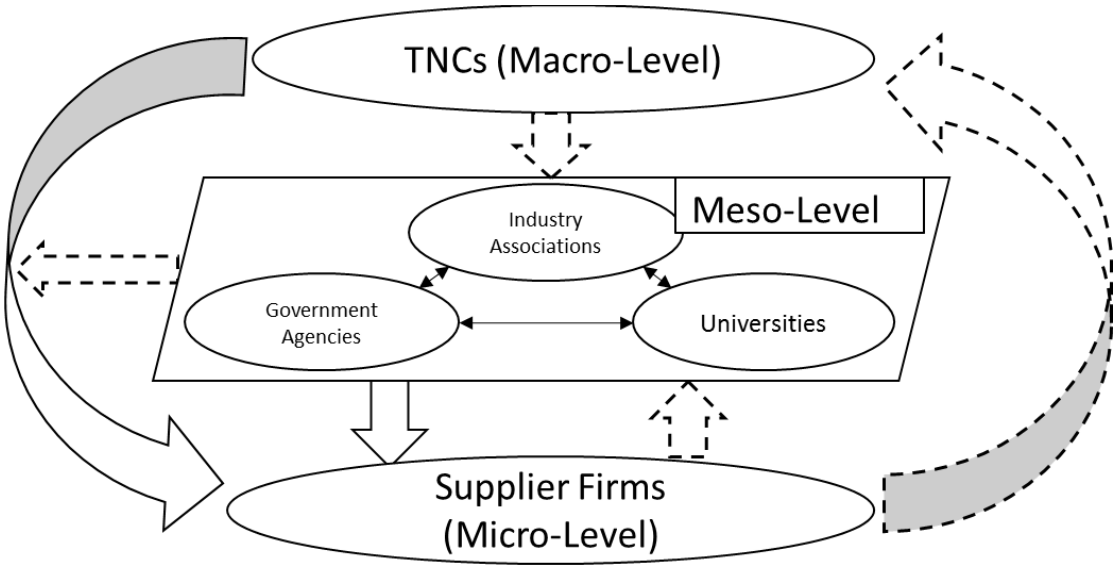
This paper analyses research on how innovation as an interactive process between different socio-economic level and systems of innovation in a development context can be combined with how insertions in the global value chains could contribute to socio-technical development. One alternative approach, Triple Helix, has provided update on the relationships between government, industry and universities, emphasizing that the more active roles of universities are important for innovation; however, interactions between industry, universities and government are not sufficient enough to generate transitions toward newly advanced technology in developing countries. The GSI framework has expanded the meso-level from national innovation system and Triple Helix as there are more important actor(s) that could provide knowledge and technological support which generates socio-technical transition in the national level, particularly in developing country, as will be shown in this case study below.

There have been attempts to study the knowledge and technology transfer aspect from both NIS and GVC proponents. Carlsson (2006) believed that national innovation systems are becoming internationalized. Lundvall (2007) believes that the relationships between globalization and national systems need to be further integrated into NIS study to explore more about how globalization processes affect the possibility to build innovation systems Pietrobelli and Rabellotti (2011) showed that innovation system approach interact with GVC and concluded that the combined frameworks explained the trajectory of learning and innovation of firms in developing countries. Binz and Truffer (2017) provided the most up-to-date innovation system concepts by combining national (Lundvall, 1988), regional (Cooke et al., 1997), sectoral (Malerba, 2002) and technological (Bergek et al., 2008) together to analyse the impact of globalization of innovation. Jurowetzki, Lema and Lundvall (2018) believed that the combination between national innovation system and global value chain is helpful to explain socioeconomic processes and build a more useful knowledge base for action.

This framework expands the key idea from MLP literature that innovations are not generated solely from micro-level actors. The sources of innovation could come from anywhere in the industry. This is particularly important for developing countries in which the technology

level of the firms is low, and they usually rely on technology from meso- and macro-level actors. The outcome of innovation from the integrated framework will be determined by the effort made inside the firm, the national and international context. The strong emphasis upon dynamic interactions from MLP literature can be used to specify how innovation process is generated in a unique way since there has not been a study that systematically reflects how the interactions between firms (micro-level), their domestic environment (meso-level), and external forces (macro-level) affect innovation and the socio-technical transitions in developing countries as illustrated in Figure 1.

Figure 1: Theoretical Framework: The Global System of Innovation



Source: Author

In the proposed framework, there are three layers of analysis, at the micro-level (firms), various actors at the meso-level (including government agencies, universities, industry associations, etc.), and at the macro-level (TNCs). The interactions among each level are dynamic and can be explained as follows. Firstly, as seen from NIS and GVC, there are direct interactions from TNCs and the meso-level to supplier firms to support the innovation of firms. Then, there is an indirect interaction between the regime level to the TNCs. First, each actor at the regimes level can indirectly influence the knowledge sent from the landscape level to the niches via different mechanisms, for example, government could provide subsidy on TNCs who support innovation

generations at the niche level. Second, the demand from TNCs could also indirectly influence the meso-level to provide knowledge that the TNCs demand to the supplier firms. Finally, suppliers' capabilities could indirectly affect the knowledge/technology transferred from TNCs to local firms and suppliers' demand could impact the knowledge transferred from meso-level to their firms. The researchers propose that all the interactions mentioned collectively then create the shifts in socio-technical transitions.

Part 3: Innovation Systems in the automotive industry

3.1 Structure of the automotive industry

The automobile industry is a strong producer-driven industry, which means that the value chain is mostly coordinated by the automakers by bringing together many components produced by various suppliers to assemble vehicles (Dicken, 2011). At present, the automotive value chain has evolved into a complex, multi-tiered supplier structure with a high degree of outsourcing. Automakers own car brands and maintain their power by investing in key R&D, design, marketing, after-sale services and quality assurance (Abe, 2013). First-tier suppliers are component specialists' manufacturers that supply major systems, such as transmission, engine, brake, etc. directly to the automakers and have significant R&D and design expertise. Second-tier and third-tier suppliers provide raw materials and labor-intensive parts that would later be incorporated by automakers and higher-tier suppliers. There has been a geographic shift in automotive industry from developed countries to developing countries since the 1990s (Sturgeon et al., 2008). Local production has been a strategy for expansion for TNCs as the industry experience the enforcement of high tariff and local content requirements and TNCs need to reduce production costs and to gain access to new emerging markets (Hess and Yeung, 2006;).

The automotive industry in developing countries has been facing technological challenges and is evidenced by research conducted, such as in Latin American countries (Giuliani et al., 2005; Ivarsson and Alvstam, 2005; McDermott and Corredoira, 2010), Czech Republic (Pavlinek and Zenka, 2010), Poland (Gentile-Ludecke and Giroud, 2012) and previous studies on the automotive industry in Southeast Asia (Wad, 2008; Sadoi, 2010). These studies have shown that the automotive industry has been changing. Firstly, there is more pressure from the carmakers to produce at low cost and provide integrated system of products. Secondly, there has also been more intense competition and significant changes in automotive parts business. To overcome the

obstacles, it is imperative that there is good coordination within the automotive supply chain (Ivarsson and Alvstam, 2005). To critically analyze the situation, the researchers review three distinct levels, micro-, meso- and macro-levels, and interrogate relationships among those actors.

3.2 Global transition towards EV and change of actors

EVs consists of normal hybrid (HEV), plug-in hybrid (PHEV) and battery electric vehicles (BEVs). They are emerging automotive products that have the capability to reduce the environmental impacts and increase the efficiency of vehicle fuel. The first HEVs were introduced in 1997. PHEVs were introduced to limited production in 2004 and to mass production in 2011 (Bradley and Frank, 2009), and BEVs were introduced for sale to the public in 2011 (Al-Alawi and Bradley, 2013). The global cumulative PHEV and BEV sales have surpassed 2 million in 2016 (IEA, 2017).

The growing number of EV sales has resulted in two significant changes in the automotive industry. Firstly, there is a shift in the creation of value-added in the supply chain. Although EVs and conventional vehicles share some of the same component parts, there are various new systems used for EVs that are not compatible with conventional vehicles, including new gear boxes, electric power steering, and water pumps to cool the electric engine (IDEC, 2013). Moreover, 60% of the total EV cost are due to the battery compared to 30% vehicle cost of power train system in normal cars. Furthermore, the production of electric drivetrains requires new know-how, which has not yet developed from either parts suppliers or carmakers. The new components and systems deployed in EVs will create opportunities for battery makers, cell component makers, and their suppliers, while reducing the role of traditional component suppliers (Bierau et al., 2016).

Secondly, national government has become a more important player in steering the direction of the national automotive industry. Policy support is crucial tool for lowering barriers to electric car adoption (IEA, 2017). Key support mechanisms adopted in leading electric car markets, such as Norway, China and the US, use both the financial incentives of electric cars purchase and increasing the number of charging infrastructure. In Norway, electric cars are exempt from acquisition tax of NOK 100,000 (OECD, 2015). BEVs are exempt from the 25% value-added tax (VAT) on car purchases. EVs are also exempted on road tolls and ferry fees. These policies provide a highly favorable environment for EV sales and generate 29% market share of total vehicles in Norway (IEA, 2017). The adoption of EVs would have been very limited without

support from external factors such as stringent emissions regulations or financial incentives (Eppstein et al., 2011; IEA,2013). Thus, it is important to reveal how interactions of actors would change after the EV becomes important in the automotive industry.

Part 4: Research Methodology

4.1 Research design

To analyze the phenomenon of the global system of innovation, the study needs to fully understand the interactions between numerous actors within the social context of study. This will require rich data sources from individuals within diverse groups. As a result, qualitative approach has been selected to explore this issue. Qualitative research looks through the in-depth analysis for the phenomena (Bryman, 2012). This method emphasizes the importance of contextual and situational issues underlying complex social phenomena and attempts to give a concise account for the research problems (Silverman, 2010). Case study research is selected as a method of study as this technique explores a complex issue and can extend experience or add strength to what is already known through previous research. Case studies emphasize detailed contextual analysis of a limited number of events or conditions and their relationships (Yin, 2017). Furthermore, case study method is effective in approaching phenomena that are dynamic and includes relationships which are complex and difficult to overview and predict (Thorpe and Holt, 2008). The case study of Thailand automotive industry reveals the complex interactions among various actors in the automotive industry in developing countries regarding knowledge and technology transfer in order to achieve socio-technical transitions, particularly on the topic of electric vehicle which has not yet been deeply explored in developing countries.

4.2 Data collection

This research uses purposive sample to select the samples with high possibility to provide technological support for the suppliers. Semi-structured interviews were utilized to obtain primary data. The interviews lasted about 90 min and were performed between May 2017 and December 2017. The interviewees from selected organizations are also the head of the programs related to the research topic to ensure that the interview data would be beneficial to the Thai automotive industry. For the supplier category, the researchers selected variety of suppliers including, foreign suppliers, Thai suppliers, joint ventures, and second-tier suppliers to gather wide variety of

automotive parts supplier businesses. The number of participants selected from automotive suppliers is higher to ensure that the interview will cover different type of suppliers. Research institutions, industry associations, universities, carmakers and independent organization were chosen to provide information on how each actor in the framework collaborates with and how each actor provides support to automotive suppliers. In summary, there were 17 semi-structured interviews comprised of five stakeholders, two carmakers (C), ten supplier firms (S) inclusive of both seven local and three foreign-owned firms, two public organizations related to the automotive industry (P), one industry association (I), and two universities (U) (as illustrated in Table 1) to explore the innovation and sociotechnical transitions in the Thai automotive industry.

Table 1: Participants Sampling Table

Sample	Position of Interviewee	Description	Justification
C1	Senior management	Japanese Carmaker	Market leader of automobile sales in Thailand
C2	Senior manager in marketing department	Japanese Carmaker	Large Japanese automobile TNC
S1	President	Tier 2 100% Thai owned	Medium-sized local second tier suppliers with potential to become first-tier suppliers
S2	Senior engineer (Thai)	Tier 1 100% Japan owned	One of the biggest Japanese TNC first-tier suppliers with various branches around the world
S3	Managing director	Tier 1 and 2 100% Thai owned	Medium-sized local suppliers which is subcontracted by both Japanese, European and the US carmakers
S4	Senior management	Tier 1 100% Thai owned	One of the largest local firms in Thailand with its own R&D units and capabilities to challenge foreign-owned suppliers

S5	Senior engineer (Thai)	Tier 1 and 2 Majority Japan owned (83%)	Large-sized majority Japan-owned suppliers with HQ from Japan and provide products to two Japanese firms
S6	President	Tier 1 and 2 100% Thai owned	Medium-sized suppliers that just invested money on new machinery
S7	Senior management	Tier 2 100% Thai owned	Medium-sized second-tier suppliers
S8	Senior management (under supervision of company vice president)	Tier 1 and 2 100% Thai owned	Medium-sized suppliers that not only produce parts for Japanese firm but also assemble parts for German firm
S9	Engineer (Thai)	Tier 1 100% Japan owned	Japanese suppliers that entered Thailand since 1990s. Produce solely for Thailand's market leader
S10	Senior engineer	Tier 1 100% Thai owned	One of the largest local firms in Thailand with its own R&D units and capabilities to challenge foreign-owned suppliers
U1	Head of engineer department (automotive technology)	Private University	Highly ranked private university with its own automotive engineering program
U2	University professor of automotive engineer programme (International programme)	Public University	One of the high-ranked public universities in Thailand with automotive engineering program. Engineering professors from the university have been doing various researches to support automotive industry

I1	Vice president	Auto parts Association	One of the largest industry associations with its aim to provide technological supports to local suppliers
P1	Senior researcher	Research Institution Metal Research Unit (Automotive)	Research institution which mainly focuses on the technological aspect of the suppliers in the automotive industry
P2	Senior researcher	Research Institution Design and Engineering Research Unit (Electric Vehicles)	Research institution which mainly focuses on the technological aspect of the new trend of vehicles in the Thai automotive industry

4.3 Case study description

To survive in a world where technological developments continue to take place at a fast pace rate, firms must introduce innovations. The automotive assembly and components production have moved to emerging economies (Ivarsson and Alvstam, 2005; Pavlinek and Zenka, 2010). Suppliers in developing countries must take on more enhanced roles such as, design, R&D and developing component modules and systems (Dicken, 2011). Moreover, the automotive industry has been focusing on electric vehicles (Reuters, 2017). This situation has posted a new challenge to the socio-technical transitions in the automotive industry, particularly on the development choice of automotive industry in developing countries.

This case study describes the situation in the Thai automotive industry. Thailand has become a final assembly hub for South-East and East Asia, providing opportunities for local suppliers producing automobile parts (Sturgeon and Van Biesebroeck, 2010). In 2013, the automotive sector accounted for 12% of Thailand's GDP. The car production from Thailand was ranked 9th in the world with 2.85 million cars productions (BOI, 2015). Jongwanich and Kohpaiboon (2013) believed that Thai suppliers must improve their capabilities to maintain the orders from TNCs. To improve capabilities, Scott-Kemmis and Chitravas (2007) and Intarakumnerd and Techakanont (2016) mentioned that supports from meso-level actors were

important drivers of innovations of local suppliers in the Thai automotive industry, while Kohpaiboon (2008) believes that international source of knowledge is crucial for the Thai automotive industry.

The support from the government, public organization and the industry association has been vital, particularly to local suppliers. After the local content requirement abolishment in 2000, the Thai government, with collaboration of public organizations and industry association, announced a new industrial plan for the automobile industry in 2001. The plan included several new initiatives, including the shift from import substitution to export, the establishment of the Thai Automotive Institute (TAI) and an increased emphasis on public–private collaboration and consultation. The Thai government also used industrial policy of picking a national product champion and linking this with effective fiscal policy and some local production incentives in 2002. The aim was to attract foreign investments and to develop Thailand into a regional center for the automotive industry in Southeast Asia. The Thai government also promoted particular segments to attract foreign investments, such as pick-up trucks and Eco-car, small, fuel-efficient, lightweight vehicle. These projects have been successful; however, the Thai suppliers lack technological know-how and capabilities to move into more sophisticated, higher value-added activities and compete with more industrialized countries (Intarakumnerd and Techakanont, 2016). Thailand's inferior performance compared with other economies at a similar level of development is due to relative weakness in innovation system and required external supports from international suppliers and carmakers (Kohpaiboon, 2008).

The Thai government have been actively pushed the industry towards EV as a third national product champion during this period (TAI, 2013; 2017). The Ministry of Science and Technology has published a roadmap for EV and charging infrastructure. The Thai government had shown an attention on the EV technology and launched policies to promote EV in 2015. The NSTDA and the Electricity Generating Authority of Thailand (EGAT) are conducting research and development of EV and EV related issues, such as technical support and supporting infrastructure. Yet, EV is different from the other product champions as it requires a change from the use of combustion engines to batteries, which is a radical change in the automotive industry.

Part 5: Research Findings

5.1 Socio-technical view of the Thai automotive industry

The stakeholders that support innovations and create socio-technical transitions in the Thai automotive industry can be categorized into three major groups according to the framework, the firms at the micro-level, domestic actors at meso-level and the foreign actors at the macro-level (See Figure 2).

INSERT FIGURE 2

The main actor from the macro-level are carmakers who possess high technology, however, they outsource their production processes to both local suppliers and foreign-owned first-tier suppliers, so that they could be able to focus on higher value activities, such as R&D, branding and marketing (Humphrey and Memedovic, 2003; Sturgeon et al., 2008). The main factor used in their selection process is the technological capabilities of suppliers. The major carmakers in Thailand are Toyota and Honda which accounts for 80% of total car sales in Thailand (TAI, 2013). Despite there are arguments showing that TNCs support innovation, it has been argued that the presence Japanese carmakers in the Thai market have discouraged local first-tier suppliers from developing new products or designs and have forced suppliers to use designs from them (Busser, 2008). Since the chance to gain contract with Japanese carmakers only arises when there is no first-tier Japanese supplier available and the cost of importing parts is high either due to transportation cost or high tariffs.

At the micro-level, there are suppliers consisting of two groups: local suppliers and foreign-owned suppliers. Within the foreign-owned suppliers group are first-tier suppliers who follow the carmakers to Thailand, as they possess higher technological capabilities required by carmakers relative to the local suppliers. These foreign first-tier suppliers usually outsource to local second-tier suppliers, yet the situation still discourages local second-tier from enhancing innovation capabilities. Even though there are some spill overs of technology from foreign-owned first-tier suppliers to second-tier local suppliers, only small number of incremental innovations takes place (Natsuda and Thoburn, 2013).

Within the meso-level there are three groups that interact with each other and provide knowledge and technological support for innovations in the Thai automotive industry, that is,

public organizations, industry associations and universities. Firstly, there are three key public organizations that support innovations in the Thai automotive industry: the Thai Automotive Institute (TAI), Thailand Development Research Institute (TDRI), and the National Science and Technology Development Agency (NSTDA). TAI was established on July 1998 with the aim of strengthening cooperation between the government and private enterprises to enhance the overall competitiveness of the Thai automotive industry. This role also included the TAI monitoring the status of the automotive industry and the provision of support on human resource development. TAI also provides consultancy services to improve production processes and organization management for local suppliers. Importantly, TAI prepared the master plan for the Thai automotive industry which provided recommendations and direction to strengthen the private sector; it publishes the Master Plan for Automotive Industry every four years. The aim of TAI is to improve the potential of Thailand automotive industry to compete with other ASEAN members and China (TAI, 2012).

TDRI was established as a public policy research institute in 1984 to provide technical analysis to various agencies and help formulate policies to support long-term economic and social development in Thailand. NSTDA as a research organization was established in 1991 and has more than 2,600 employees, 68% of them are researchers with 400 Ph.Ds. NSTDA provide support on R&D, technology transfer, human resources development and infrastructure development for every major industry in Thailand including the automotive industry.

Secondly, there are two main industry associations supporting the Thai automotive industry in Thailand, namely, the Thai Automotive Industry Association (TAIA) and The Thai Auto-Parts Manufacturers Association (TAPMA). TAIA is a private association formed in 1981 and consists of carmakers, suppliers and distributors. The vision of TAIA is to "encourage and support the development of Thailand automotive and auto-parts industry for prosperity, strength, and competitive advantage of the industry, to be recognized in both domestic and international level with transparency, clarity, and equality in its operations." (TAIA, 2014). TAPMA is a union of auto parts manufacturing companies from the private sector to serve as the central voice for auto parts industrialists in the country to protect, support and develop Thai industries. TAPMA focuses solely on local suppliers, specifically, enhancing their capabilities to compete with foreign-owned firms, while the focus of TAIA is on the development of the whole automotive industry which includes assemblers, distributors and parts manufacturers.

Finally, the role of universities is to generate new knowledge and transferring knowledge and technology, workforce development, and facilitating competitive initiatives. Two important forms of support from universities are the flow of university graduates to the industry and the flow of new knowledge generated by university-based research through public channels (Intarakumnerd and Schiller, 2009). However, it is observed that the Thai automotive industry does not have a strong interest in university-industry linkages and Thai universities only play a minor role in building the technology/innovation capability of firms (Mongkhonvanit, 2010).

5.2 Situation and the challenges towards EV transition in Thailand

The automotive industry has been moving towards EV and the Thai automotive industry has started to capture this trend. The actors within the meso-level, particularly Thai government, universities and research organizations, have been discussed on the EV opportunity during this phase to property analyze the automobile industry situation and to pass down knowledge to the local suppliers to achieve the EV production nationally. The Thailand's Alternative Energy Development Plan 2012-2021 also includes a renewable energy target of 25% of total energy consumption by 2021 from the current 8%, while EV is viewed as a significant supporter towards the plan's ambitions. The Electric Vehicle Association of Thailand (EVAT) was formed on November 6, 2015 by the collaboration of both public and private organizations.

Various government agencies have been active during this period (TAI, 2013; 2017). The Ministry of Science and Technology has published a roadmap for electric vehicle and charging infrastructure within 2014-2019. This roadmap is approved by the Thai government and includes the promotion of Thailand as a production hub of EV parts and EV production. In 2015, NSTDA and the Electricity Generating Authority of Thailand (EGAT) are jointly conducting research and development of electric vehicles related issues, namely technical, support infrastructure and policy support. NSTDA also introduced the new unit for EV called Next-Generation Automotive Industry Program – Special Activity Session – Electric Vehicle in 2016. EGAT and NSTDA underlined the need of an electric charging infrastructures to accommodate EVs. The interview shows that various meso-level actors believe that Thailand should encourage EV usage, while automakers are already prepared for EV deployment. Yet, the key challenge in the Thai automotive industry to move towards EV is the clash among actors from different levels, particularly the conflict of interest between the promotion of EV from meso-level actors and the halt on EV from micro- and macro-

level actors. Carmakers and suppliers, particularly indigenous suppliers, are unsure about the transformation from producing normal cars to EVs. They also believe that the Thai government has not yet shown enough commitment of EV promotion as shown from various interviews below.

At the macro-level, carmakers believe that that government should put more focus on improving technology of local suppliers on conventional vehicles rather than switching to new uncertain territory of EV. Carmakers EV will be important for the Thai automotive industry in the long run; however, the government must provide support on promoting EV and ensure that the change is gradual rather than rapid. They are ready to invest in EV facilities after the government ensure the EV plan in Thailand.

"…I believe the automotive trend is leaning toward EVs which is a cleaner energy…[W]e need support from the Thai government to ensure the usage of EV. Charging infrastructures and financial support to us [carmakers] and to consumers are important to switch customers from conventional cars to EVs…" (C2)

C1 convinced that Thailand is not ready for full EVs as there are challenges and difficulties such as a lack of charging stations. C1 also sees hybrids as a stepping stone to full electrification in the future, so government should grant investment privileges to hybrids alongside EVs.

"…Thai government will provide more privileges for EVs, but there will be a transition period before the full EV replaces conventional cars. That is the reason why we promote hybrid as there will be a gradual change from hybrid to EV…" (C1)

The result from interviews of the carmakers in Thailand aligned with the EV directions announced by major carmakers. On February 2018, Nissan's regional chief stated that Nissan and other carmakers were seriously considering investing in the modern technology in Thailand, primarily for export to other countries in the Asia-Pacific region, while Nissan is considering on shifting their portfolio to more EV products within the coming three to five years (Financial Times, 2018).

Even though the Thai government and the carmakers have prepared for the EVs, the study shows that Thai suppliers are not ready for EV introduction. As new production systems used for

EVs are not compatible with conventional vehicles, suppliers require investments on new machineries. The interviews show comparable results among different group of suppliers, including foreign suppliers, large local suppliers and small local suppliers. Even though some of foreign suppliers (S2 and S9) can receive knowledge from their parent's company as they already have EV research center in Japan and have produced EV parts in some countries, they (S2, S5, S9) still prefer to produce parts for conventional cars. Some foreign suppliers (S2 and S5) are unsure about the Thai government's direction on EV. Thai political instability could change the direction of Thai automotive industry on EV and they would lose money if they put high investment on EV production facilities. Yet, another supplier (S9) is ready to invest in EV as alternative if there are financial incentives from Thai government.

"…[W]e already have EV technologies, but we are unsure about investing on EV as the investment cost for EV facilities is high and we would need to hire more staff and also need extra training for them…Producing EVs may be too hard for Thai workers and we would need to invest a lot…what if the Thai government change their direction towards EV, we would not want to invest for nothing…" (S9)

Some large Thai suppliers have already started to sought technologies and expand their portfolio on EVs. They believe that EVs will transform the overall automotive industry and could put some conventional parts makers out of business in the long run.

"Due to this new disruptive technology, we have to seek new alliances for a partnership on any new and higher EV technology…[W]e have invested 400 million baht in its R&D center, focusing on support for lightweight materials used in EVs and created more human resources to be ready for the production of EVs if needed…[W]e have been supplying some EV parts for global carmakers such as Tesla Motors since 2017…" (S4)

In contrast to large local suppliers, small-and-medium local suppliers are not ready to produce EV parts. Many suppliers believe that EVs still represent small fraction of the automotive industry. Some suppliers (S3, S6, S8) believe that the investment cost of EV is too high compared

to the benefits they will receive in return, while 2nd-tier suppliers (S1, S7) believe that EVs are not related to their business and there is no need for any investment.

"…[S]hifting to EV is not as easy as the government say. Since we have no knowledge on EV, we need to find the source of technology and create new connections. We must invest in new machineries and new human capital…It will take us 5-10 years to be ready...It is already hard enough to improve our performance in conventional vehicles to get more order from carmakers…I don't think we will invest in EV anytime soon..." (S6)

"…Parts of EV is 70% different from conventional cars and EV use less parts compared to conventional cars. If the government shifts focus to EV, many local suppliers, particularly 2nd-tier and 3rd-tier will definitely run out of business…" (S3)

Not only the suppliers themselves are not ready to move towards EV, but the relationships between suppliers and other actors on EV are also challenging. Suppliers do not normally collaborate with local universities for technological support. Moreover, suppliers believe that university do not impact the level of innovation of their firms and in the automotive industry. The interview of universities, both U1 and U2, also show that Thai universities do not impact innovation of the Thai automotive industry.

"Suppliers do not come to us for EV technology. They have their own sources of technology…[W]e mainly associate with researchers from some Japanese carmakers and the government research units on the EV technology." (U2)

The result from the interviews confirms the study of Intarakumnerd and Charoenporn (2015) which stated that firms in Thailand have been slow and passive in technological learning. Government policies and institutions, including research institutes and universities, have not provided enough assistance to firms to enhance their technological capability, especially in terms of absorbing external knowledge from abroad. These results are contrast to the systems of innovation framework, which mentions that universities could perform a substantial share of R&D

and university research can complement research results from international networks (Mowery and Sampat, 2005).

The relationships among meso-level organizations in the Thai automotive industry are manifolds; however, cooperation between organizations is poorly managed, particularly on the EV project. Numerous examples can be drawn from the interviews that the meso-level organizations in the Thai automotive industry are not collaborate with each other. Some researches have been redundant due to poor communication among actors.

"Our university staffs are doing researches on EV. We believe that EV is important for the future and we want to promote EV in Thailand…[Still,] Nobody has contacted us about our EV research even though we believe it would be useful." (U1)

P2 also believes that EV is important to the Thai automotive industry and is conducting EV researches as well. They believe that collaboration between meso-level actors would be useful for innovations in the industry.

"…EV is truly important for our automotive industry to be competitive in the world market…[W]e are conducting many researches on the EV, particularly on batteries and parts for EV…We have never contacted any other party to collaborate on EV research, but collaboration would have been helpful." (P2)

The situation of poor cooperation between the meso-level in the Thai automotive industry is supported by Intarakumnerd et al. (2012) who mentioned that industry association and public institution did not communicate with each other. Despite more efforts from the meso-level organization to enhance the innovation on EVs, the resources have been wasted due to poor collaboration within the meso-level. This situation is not beneficial for the innovations in the Thai automotive industry as local suppliers require support from the meso-level organization on enhancing capabilities and prepare to switch to EV products. In contrast, there is a collaboration between university and the public research organization.

"…[W]e already started EV pilot in Thailand this month (December 2017), called HaMo (Harmonized Mobility) project. It is running in association with…university. There are compact single seat EVs, along with 12 parking stations, 30 parking points and 10 charging stations." (C1)

In summary, there is a clash between three groups of actors in the Thai automotive GSI on the promotion of EVs in the Thai automotive industry due to the demand differences from each party. The macro-level actors and most of the meso-level organizations are ready to introduce EV as Thailand's third product champion; however, their perspectives towards EV differ. Moreover, the micro-level actors, parts suppliers, particularly smaller indigenous suppliers, are not keen to produce EV parts. These conflicts of interest have stalled the move toward EV production in Thailand. Suppliers believe that there has not been enough support and research on EV trend in Thailand. Moreover, the investments required to produce EV is too high to invest alone. Furthermore, local suppliers believe that EV still represent small fraction of the automotive industry and the export of car parts and productions are in Southeast Asia which does not promote EVs as compared to Europe or the US. Suppliers also believe that the government should spend that money to improve performances of local suppliers on conventional vehicles, so they are able to compete with foreign suppliers. The meso-level, carmakers, believe that gradual steps towards PHEV and BEV are important, but HEV should be the focus of Thailand at present. PHEV and BEV require substantial changes both production technology and energy consumption. Finally, the meso-level actors, particularly the government, universities and TAI, believe that Thailand should be prepared for BEV and PHEV or else Thailand will be losing out as an automobile hub of Southeast Asia. The next section summarizes the expansion of systems of innovation by looking at socio-technical transitions of the Thai automotive industry on EVs and provide policy recommendations for the EVs in the Thai automotive industry.

Part 6: Analysis and Discussion

6.1 Expanding the innovation systems - Socio-technical perspective

By using the GSI framework to analyze the actors and interactions in the case study of the Thai automotive industry, we can see that not only technological issues are important for innovation, but social interests of each actor are required to be discussed in order to create new transition in the automotive industry towards EV. The automotive parts and components sector has

been critical to the success of Thailand's automotive industry. There are approximately 2,700 automotive suppliers, including 1st-tier to 3rd-tier, employing over 600,000 labors (TAI, 2014). Local manufacturers supply around 85% of the parts used in pick-up truck assembly and around 70% of the parts used for passenger cars assembled in Thailand. Yet, analyzing only those figures alone to move towards EV without discussion with various actors are not enough to maintain sustainability of the Thai automotive industry. It would neglect the suppliers' opinion in Thai automotive industry which could create chaotic situation and lead to the downfall of local suppliers. The focus of the whole industry analysis should be carefully drawn by utilising GSI framework to determine actions from all levels.

Table 2: Global automobile sales 2011 to 2016

Year	Conventional + HEV	% Growth	PHEV + BEV	% Growth	Total Car Sales	% Growth	% Share of EV (HEV+PHEV+ BEV)
2011	78,109,211	4.2	48,160	634.1	78,157,371	4.3	0.06
2012	81,997,772	5.0	118,690	146.4	82,116,462	5.1	0.14
2013	85,405,297	4.1	192,010	61.8	85,597,307	4.2	0.22
2014	88,000,530	2.5	325,090	69.3	88,325,620	2.7	0.37
2015	89,156,752	1.8	550,570	69.4	89,707,322	2.0	0.61
2016	93,123,825	4.4	781,809	42.0	93,905,634	4.7	0.83

Source: Author's calculation from Organisation Internationale des Constructeurs d'Automobiles (OICA) and International Energy Agency (IEA).

6.2 Policy recommendations on transitions in the automotive industry towards EV

The discussion above has shown many issues required to be explored and answered as switching to EV is a radical change. We believe that every actor in GSI must play key role in this transformation, particularly the national government. Still, the future of EV in Thailand seems to be uncertain. Despite the EV has high growth rate, the sales of EVs that require charging infrastructures represent less than 1% of the world total automobile sales (see Table 2). Furthermore, significant investments and supports must be made by the government to encourage EV adoption. Government will play substantial role in deploying financial incentives from both technology specific policies, such as subsidies to EV consumers, and technology neutral policies,

such as emissions-based vehicle taxes (IEA, 2017). In some cases, lowering taxes for EVs and provide subsidies apart from normal registration and circulation fees could provide financial incentive. Yet, non-financial incentives could also play vital role. According to Sierzchula et al. (2014), the presence of a local EV manufacturing facility and especially the number of charging stations around the country were significant factors of EV adoption rates. Leading EV adoption countries are developed countries. They not only receive supports from their government, but they also have other factors supporting the impressive performance on EV adoption. For example, Norway has the low electricity price due to their hydroelectricity plants (Eurostat, 2017). Korea and Japan possess strong competencies on battery technology (Jussani et al., 2017). China has the largest automobile markets, with high growth rate (OICA, 2017), while the US has Testa Motors which has sparked electric vehicle revolution (Eisler, 2016). It means that government must provide large budget allocations if they want to shift to EV, which would pose a serious challenge on developing countries.

Finally, effective communication and collaborations among actors within different levels are substantial to promote EV. The failure case of India's EV promotion created a waste of resources for their local suppliers (FT, 2018). The situation occurred due to poor communication and change of direction from the Indian government. In March 2016, Piyush Goyal, then the minister of power, had said that by 2030 India could be a 100% EV nation. This target was repeated several times by Goyal and others in the following months. Moreover, Nitin Gadkari, minister of roads transport and highways, announced at the annual convention of the Society of Indian Automobile Manufacturers in September 2017 that India required a shift to EV; however, in February 2018, Gadkari has decided against formulating an EV policy by stating that there is no need for any policy to support EV. It is belief that the EV investment plan was dropped due to that implementing an EV policy package would need huge investments which is not possible for the Indian government.

In our opinion, government in developing countries must balance between conventional vehicles and EVs. EV is still alternative fuel choice as there are other technologies available (fuel-cells, hydrogen). Now, PHEV and BEV account less than 1% of the total automobile market, so the government should put more focus on improving the performance of local suppliers on conventional vehicles rather than EVs. This does not mean that developing countries should neglect the EV. In the case of Thailand, the current research from meso-organizations would

provide a good foundation to the Thai EV market in the future. Furthermore, the government could increase support on EV while less support on traditional cars, following the direction of developed countries, in the future. Collaboration with carmakers are important as the carmakers could already possess technology and experience of introducing EVs in developed countries. The government, collaborating with carmakers, must also provide supports for local suppliers to start EV research. Local suppliers, mainly small-and-medium sized ones, would face challenges to adapt the new EV technology, while foreign suppliers have already established EV departments in their home country. As a result, improving collaborations among meso-level organizations and between local suppliers and macro-level actors would be essential for developing countries to catch up the growing EV trend.

Part 7: Conclusion

Current frameworks to analyze the sources of innovation are exclusive to either within the national boundaries from the NIS research or the support from TNCs to local firms from the GVC framework. This study provides a new perspective of conceptual framework that could systematically analyze the interconnections between the actors of social settings and evaluate the sources both of innovation and socio-technical transitions by integrating both the national and international analysis together. This study responds to Sturgeon and Gereffi (2009)'s recommendation to extend GVC framework by providing new kinds of data that shed light on the position of domestic firms as the study extends GVC framework by combining the national actors to the current GVC analysis. The GSI framework also extend systems of innovation study by integrating the effect from global actor, the TNCs, to the current NSI framework. By integrating both the national and international aspects together, the GSI framework could provide clearer analysis on the supports on innovation to firms. Furthermore, the GSI solves the critique from Smith et al. (2005) and Geels and Schot (2007) who argue that more attention must be given to the how ongoing processes at the regime and landscape level affect the niche level as the GSI analyses interactions among all three levels. Finally, by applying the MLP lens, the GSI framework can analyze not only the technical aspects but also the social aspects.

The case study of Thai automotive industry offers interesting insights for other developing countries. As local suppliers in developing countries usually do not possess high R&D, the sources of innovation and transition are generated from meso- and macro-levels. The top-down approach

from both government (meso-level) orders and global market trend combined with new directions of TNC carmakers (macro-level) force the socio-technological transitions in the Thai automotive industry towards the adoption of EV. By adopting the GSI framework, it is seen that the micro-level actor (suppliers) could be overlooked by the government. Local suppliers also believe government and the meso-level organizations must anticipate suppliers' capabilities before creating transitions as the organization structures, machineries, equipment and products of suppliers must be altered. Thai government should carefully analyze the capabilities of their suppliers before starting the EV transition. Still, the result of this study cannot be generalized as this is a sole case study on analyzing the transition of the Thai automotive industry towards EV.

The GSI framework could be further enhanced by exploring the relationship and interactions between the stakeholders and how to strengthen them. The study how knowledge transfer within the GSI framework, particularly how local suppliers will benefit from each stakeholder is also essential to improve the performance of local suppliers to compete with the TNCs. Further research should also elaborate on the actions required from each actor in the GSI framework to prepare for EV transition. Finally, it would be interesting to analyze whether EV is the right choice for developing countries is also essential as the initial investments for EV are high.