Evolution of knowledge networks, technological learning and development of SMEs: A multi-level perspective of innovation and environmental trends in the automotive sector in Thailand

by

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Finally, I declare the responsibility of all errors of omission and commission in this thesis to be entirely my own.

Pattarawan Charumilin

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Abstract

Car producers are under pressure in the shift towards automotive technologies that are environmentally sustainable, from the use of internal combustion engine to technologies associated with electric mobility. The question remains how firms along the automotive supply chain react to such challenges posed by environmental trends. The issue raised by this research is crucial to the automotive industry in Thailand which is the main industry with a major contribution to the country's economy. As SMEs constitute the lion's share in the supply chain of the Thai automotive industries, it is crucial to examine their ability to adapt to evolving technologies and the factors influencing their capability development.

This research aims to investigate how existing firms, particularly SMEs, react to the sustainability transition by elucidating their processes of technological learning and participation in knowledge networks. To explore potential shifts in practices, the Multi-Level Perspective (MLP) framework is employed. Specifically, the study centers on SMEs as established entities involved in niche innovations, examining how government interventions can facilitate their technological transition. In this study, the entrance of EV constitutes a concern for all firms, but SMEs tend to feel more of an impact than large firms. Most firms expect some product or process modification due to the advent of EV. To prepare for the shift, most firms show similar interest in joining the EV value chain and a diversification to new markets so as to maintain existing production capacity. Both SMEs and large firms primarily acquire technological knowledge using their own internal effort rather than networking with academia. The results also suggest that large firms seem to network with external partners for knowledge development activities more than SMEs. It is also found that firms required R&D capability improvement to support them in

the transition to EV. This study has identified that SMEs have less absorptive capacity than large firms which is crucial for their adaptability and ability to innovate. Thus, the evidence of this study implies that, despite the responsiveness to change, SMEs may experience difficulties in the transition to EV more than large firms. The results also suggest that firms may increase their ability to learn new knowledge or increase their absorptive capacity through networking deeply with triple helix partners.

It is found that the lack of an overarching EV policy framework at the landscape level and the lack of demand side policy tends to impact the direction of firm's technological development or the regime shift. The role of government interventions is significant in terms of promoting investment policies to attract the establishment of the EV industry. However, the capability for niche technological improvement in local firms wishing to join the EV value chain seems to be mostly limited to large firms, either for incumbents or new entrants. Government policy intervention and strong implementation regarding the development of human resources and R&D support by providing researchers and funding are required, particularly for SMEs which lack both skills and resources. The focus on the establishment of EV industry without parallelly improving local technological capability is identified as a potential risk to the country's future competitiveness.

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List of Abbreviation

ABBREVIATION	DEFINITION
ASEAN	Association of Southeast Asian Nations
AHRDP	Automotive Human Resource Development Program
APC	Absorptive Capacity
BEV	Battery Electric Vehicle
BOI	The Board of Investment
CASE	Connected Autonomous Shared and Electric Vehicle
CBU	Completely Built-Up Unit
CIT	Corporate Income Tax
CKD	Completely Knocked-down Unit
EEC	Eastern Economic Corridor
EU	European Union
EV	Electric Vehicle
EVAT	Electric Vehicle Association of Thailand
FDI	Foreign Direct Investment
FCEV	Fuel Cell Electric Vehicle
FTA	Free Trade Agreement
FVA	Foreign Value-Added
GDP	Gross Domestic Product
GHG	Green House Gas
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
ITAP	Industrial Technology Assistance Program
LCR	Local Content Requirement
MLP	Multi-Level Perspective
METI	Ministry of Economy, Trade, and Industry
MNC	Multi-National Company
NSTDA	National Science and Technology Development
OEM	Original Equipment Market

PACAP	Potential Absorptive Capacity
PHEV	Plug-in Hybrid Electric Vehicle
PPV	Pick Up Passenger Vehicle
RACAP	Realized Absorptive Capacity
REM	Replacement Equipment Market
SKD	Semi-Knocked Down
SME	Small and Medium Enterprise
SNM	Strategic Niche Management
STI	National Science Technology and Innovation Office
TAI	Thailand Automotive Institute
TAPMA	Thai Auto Parts Manufacturers Associations
TPS	Toyota Production System
TSRI	Thailand Science Research and Innovation Office
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organization

CHAPTER 1
INTRODUCTION

1.1 Background of the study

The commitment of the global community to addressing the challenges posed by climate change through multi-lateral agreements – from the Kyoto Protocol in 2007 to the Paris Agreement in 2015 - has put pressure on countries to cut back greenhouse gases (GHGs), including CO_2 emissions. This has had wide ranging implications for policies and activities across the economic and social spectrum that bear on environmental trends across countries, not least Thailand. During the UN climate change conference 2021, Thailand had also announced a target to achieve carbon neutrality within 2065-2070. Responding to the global environmental challenge calls, among other things, for technologies in use to be 'environmentally-adjusted' and for public policies and regulations to promote developments that are capable of reducing CO_2 emissions. The transport sector is one of the main contributors to increasing CO_2 emissions in both the developed and developing countries. This follows on growth in income per capita, growth in population and rapid increase in car ownership and use (Timilsina R. & Shrestha, 2009).

This makes the global automotive industry subject to the pressure of environmental regulations, so that activities across the auto supply chain systems at all levels of operation are environmentally-adjusted enough to ensure that the problem of CO_2 emission is significantly curtailed. Hence the need for a shift towards automotive technologies that are environmentally sustainable. Thus, multi-national companies in the automotive sector are under a strong pressure to shift from the use of the century-old technology of the “internal combustion engine” to technologies involving the use of “alternative fuels and powertrains”.

Car manufacturers are generally known to be responsive to the technological as well as market trends and have in recent years developed technologies, like hybrid electric vehicles, battery-driven electric vehicles and fuel cell vehicles, that are compatible with prevailing environmental trends. However, the question remains how firms along the automotive supply chain react to such challenges posed by environmental trends on both the technology and market frontiers. Where Small and Medium Enterprises (SMEs) constitute the lion’s share in the supply chain of automotive industries. As in Thailand, the ability of SMEs to catch up with changing technology and market trends and the factors that promote and inhibit the development of such capabilities in SMEs have yet to be addressed. This study acknowledges the need for both producer and consumer behavioural patterns to adjust to prevailing trends, and within this context seeks to explore the extent and direction of technological learning and the development of knowledge networks of SMEs in the automotive sector in Thailand.

According to *Table 1.1* , the definition of SME and its basis used in this study is according to the small and medium enterprises promotion act and the Thai ministerial regulations providing detailed definition of SMEs using employees and fixed assets[1] as a basis. Within the context of this study, firms that are included in the survey are manufacturing firms.

[1] In 2020, Thailand applied a new definition of SMEs using employments and revenue instead of employments and fixed assets. This study conducted the survey during July-October 2019 before the new law was enacted.

Table 1.1 Definition of SMEs

Type	Small Enterprise		Medium Enterprise	
	Employees	Fixed Asset (Thai Baht million)	Employees	Fixed Asset (Thai Baht million)
Manufacturing	not more than 50	not more than 50	51-200	51-200
Service	not more than 50	not more than 50	51-200	51-200
Wholesale	not more than 25	not more than 50	26-50	51-100

1.2 The Research problem and research question

Environmental trends are bringing pressure to bear on activities in the automotive sector to shift from technologies based on internal combustion engine to technologies associated with electric vehicles. The issue raised by this research study are particularly crucial to the automotive industry in Thailand since it is the main industry with a major contribution to the country's economy. The automotive industry has been operating in Thailand since 1961. The structure of the industry is hierarchical. It consists of MNCs (assemblers), foreign and local large enterprises (tier 1) and local small and medium enterprises (SMEs) (tier 2 and tier 3 respectively). Local SMEs are tier 2 and tier 3 suppliers and numbered approximately 1,700 firms in 2014. As the automotive industry is experiencing the radical technological change from internal combustion engines (ICE) to electric mobility technology, it will require a new knowledge base and new production processes (Hill and

Rothaermel, 2003). According to Sadovnikova et al., (2016), the changing path in automotive sector technology can be considered radical, moving from internal combustion engine (ICE) to hybrid electric vehicles (HEV) and in due course to battery electric vehicles (BEV), which requires a significant change in the core powertrain technology. The development of radical innovation often affects stakeholders, namely suppliers of automotive firms, as suggested by Hall and Martin (2005). For SMEs operating in the automotive supply chain, this shift involves technological learning that would keep them abreast with the shifts in both the technology and market frontiers relating to the automotive industry. Thus, the main research question arising is "how do SMEs in the automotive sector respond or adjust to the technological requirements of transition from internal combustion engine to electric vehicles?" Do SMEs learn in an open innovation framework in partnership with other automotive companies or other actors; or does the process of technological learning prompt SMEs to evolve in a disruptive innovation framework?

1.3 Aim and objectives

Based on the above research question, the aim of this study is to "explore the extent and direction of technological learning and the development of knowledge networks within which SMEs in the automotive sector in Thailand evolve as niche players through open or disruptive innovation"

Based on the research aim, this study aims to achieve the following objectives :

1) To explore the responsiveness of SMEs to the transition from internal combustion engine vehicles to electric vehicles

2) To determine the extent of learning requirements that would equip SMEs with the knowledge and technology set that is consistent with the policy objective of reducing carbon emissions;

3) To determine technological learning processes of SMEs in the automotive industry;

4) To identify factors contributing to technological learning of SMEs in the Thai automotive industry;

5) To analyse the development of knowledge networks of SMEs engaged in technological learning;

6) To explore the role of government policy interventions in prompting network creation resulting in knowledge exchange, technological learning and technological capability development of network member

1.4 Research Methodology

This study attempts to address the knowledge gap in relation to the research question as to how incumbent firms i.e., automotive companies and suppliers particularly SMEs in the socio-technical regime respond and potentially adjust to a technological transition, analysed using the multi-level perspective framework (MLP). A multi-level perspective framework (MLP) is adopted in this study to address how the socio-technical change occurs, focusing on the technological regime shift from internal combustion engine to electric mobility. This study is based on the MLP approach, which believes that the process of sustainability transition is complex; it involves an interaction between multiple actors and institutions for the transition to occur.

According to Geels (2018), technological transitions derive from interactions between players at these three socio-technical levels. Geels gives a definition to socio-technical regime as "established practices and associated rules that stabilize existing systems" or a lock-in system which resist change. On the other hand, niches are defined as "practices or technologies that deviate substantially from the existing regime"; and socio-technical landscape is defined as "the external environment that influences interaction between niche and regime actors" and also put pressure on regime actors to be supportive of innovations at the niche level (Geels, 2011 pp.26-27).

Thus, the transition theory is applied to explore how the long-term socio-technical transition of SMEs and firms in the automotive industry from producing the traditional fossil fuel-based vehicle technology to alternative powertrains i.e., Hybrid-electric vehicles (HEV), Battery-electric vehicles (BEV) technology could occur. In the case of Thailand, SMEs constitute a majority of the suppliers, and it is they who are facing the challenge of this technological transition through the processes of network development, knowledge exchange, and technological learning. This study examines the technological regime shift placing attention on the regimes by exploring incumbent firms particularly SMEs on how they would reorient towards niche innovations. The governance and policy intervention to shape transitions is also reviewed in an aspect that it can encourage, facilitate, expedite the transition or even destabilize the regimes

The mixed methodology, both quantitative and qualitative, is used to investigate the research question and objectives. This study used a questionnaire survey to provide empirical evidence focuses on incumbent regime actors (automotives and parts firms) of their responsiveness and technological learning readiness whether firms are willing and can potentially transform into the new EV industry. Simultaneously, the qualitative method using semi-structured interviews provides a view of governance issues and policy intervention at each socio-technical level. The data collected covers the data from actors at each level of the MLP framework, i.e., regime, landscape, and niche. The collected data include responsiveness of firms, the present status of SME suppliers' technological learning processes, the current linkage and knowledge networks of suppliers and partners, or the current regime. Furthermore, institutional data relating to plans and policy support for EVs of different agencies were explored.

The data collected was retrieved through document reviews, use of a questionnaire, and in-depth interview. First, published documents of government agencies and consultant reports relating to electric vehicles' current development in Thailand were reviewed to develop questionnaires and interview questions. Second, the list of firms to survey and interview was identified by choosing firms based on the auto parts category impacted by EV technology production. The government agencies, universities and industrial associations were selected by their responsibility for the development of the automotive and parts industry and EV industry. Third, self-administered surveys were sent out, and the interview process was conducted simultaneously. The surveyed data was analysed using both descriptive and inferential statistic. The interview data were analysed using the thematic analysis method. The research design and methodology are discussed in full in CHAPTER 4.

1.5 Context of the study

The focus of this study is on SMEs; in particular, on technological learning of SMEs in the Thai automotive sector and the development of knowledge networks to support technological learning for the transition from ICE to EV technology. The study explored learning processes of SMEs and identify how SMEs learn in the context of environmentally motivated changes in policy, technology and market regimes. It also explored the dynamic interactions of these firms with different partners on networks that correspond to vertical relationships (i.e. supplier-client based relationships) and horizontal relationships (i.e. industry-university-government or triple helix-based relationships); and how these relationships influence technological learning processes in SMEs. The study also takes interest in the effect of government policies on network formation to facilitate triple helix interactions and expedite the processes of knowledge exchange and technological learning.

The study explored if there are technological learning and innovation opportunities deriving from inter-firm relationships or triple helix network and the extent of knowledge-sharing among players in the knowledge network. To explore the status and level of their learning can imply a firm's ability to learn and exploit new knowledge. The study also seeks to determine the factors that contribute to technological learning among SMEs, which in this study is represented by the absorptive capacity. The identification of absorptive capacity is used to identify firm's learning capability and ability to adapt because absorptive capacity is a crucial ability in collecting and exploit new knowledge. Absorptive capacity is an integral part of learning process that support firms in developing new knowledge (Lane, Koka, & Pathak, 2006). Moreover, the study explored government policy support mechanisms that would be an enabler of change by accelerating the processes of knowledge transfer, knowledge exchange and technological learning of firms.

1.6 Significance of the study

For all its limitations, this study has contributions to the body of knowledge of sustainability transition in general, and the transition to EV of the Thai automotive and parts industry. The findings of the study are expected to shed light on the sustainability transition focusing on (1) the challenges of incumbent firms and the firm's strategy in response to the sustainability transition (2) the importance of technological learning processes, particularly sources of learning and the development of knowledge network for the adjustment of incumbent firms to sustainability transition (3) The role of government policy interventions through the provision of policies for each socio-technical level to support the overall socio-technical transition.

There are several studies on the sustainability transition, particularly in the automotive sector relating to the transition to EV. However, most of the transition studies focus on the role of niche actors in developing radical technology to support the sustainability transition. In contrast, incumbent firms are viewed as a hindrance to niche development and try to maintain their status quo in socio-technical regime. Little research has been conducted examining the plausible regime shift emerging from the regime actors and the government interventions to enable the transition. Most studies focus on lead firms in the regime such as car manufacturers while this study also includes non-lead firms i.e., suppliers. And little research has been conducted on sustainability transitions using Thailand as a case study. This calls for more research on the regime shift focusing on the incumbent firms' responses to transition or existing industry and how to govern the transition to promote the regime reconfiguration.

The importance of this study is also to show how SMEs can deepen and broaden their technological learning processes within a fast-changing environment through participation in knowledge networks. This could have implications for policy aimed at supporting SMEs' efforts at technological learning.

The empirical insights derived from this study have the potential to shape policy recommendations designed to provide guidance to policymakers and public authorities. The study's results illuminate the eagerness of companies to explore new industries. Nevertheless, achieving this aspiration will demand the implementation of focused policies aimed at addressing the existing technological constraints that hinder this transition.

The findings obtained from the survey and interviews conducted with diverse firms yield valuable insights that can steer both governmental and non-governmental organizations in devising effective policies and governance frameworks. These strategies can facilitate the smooth advancement of technological learning among established companies and other relevant stakeholders. Furthermore, the findings carry significance for countries that serve as suppliers to multinational automotive firms, presenting them with valuable lessons and considerations to ponder.

1.7 Structure of the thesis

This thesis is organized into seven chapters. The following chapter (CHAPTER 2) begins with the reviewing of literatures relating to main theoretical concepts, namely multi-level perspective, technological learning of firm, knowledge network and firm's ability to learn or absorptive capacity. CHAPTER 3 reviews the research context of the Thai automotive and parts industry and its firm's technological learning including the challenges from the advent of electric mobility and the context of EV promotion in Thailand. CHAPTER 4 presents the study's research design and methodology. The chapter also covers target population and sampling, data collection method and data analysis. CHAPTER 5 presents the findings of the study relating to the firm's responsiveness to the transition and the firm's status on technological learning and network. CHAPTER 6 shows the results from interviews with government agencies, universities, research institutions, and firm representatives. Finally, the last chapter (CHAPTER 7) discusses the main findings relating to the firm's possible transition by analysing the firm's responsiveness to the transition, the firm's technological learning processes, knowledge network of firms, roles of government policy intervention, study limitation, future study and policy recommendations.

CHAPTER 2
Socio-Technical Transition and Technological Learning

The deterioration in natural resources and human consumption creates sustainability challenges, particularly in the environmental areas. One of the global environmental concerns is related to greenhouse gas emissions resulting in global climate change and other environmental problems such as air pollution. These challenges require a multitude of changes or a transition from current practices toward more sustainable manners (Frank W. Geels, Sovacool, Schwanen, & Sorrell, 2017). The system transition involves a deep structural change from one system to another. The transition not only consists of the change in specific technologies and artefacts, but also societal elements that co-evolve with such technologies (Frank W. Geels, 2002). Thus, the technological transition from internal combustion technology of an automobile to electric mobility, which is the focus of this study, will require considering several aspects that could constitute a transition, such as technological development, policy, and legislation, markets, complementary infrastructure, user's practices.

A multi-level perspective framework (MLP) is adopted in this study to address how socio-technical change occurs, focusing on the technological regime shift from internal combustion engine to electric mobility. In this chapter, transitions literatures and MLP are reviewed and discussed. The understanding of why the socio-technical systems is challenging to change will be identified by addressing the socio-technical regime concept and its stability.

MLP incorporates the view of the transition from both the production side where innovation takes place and also embeds the user side where the innovation is diffused. This study examines the technological regime shift placing attention on the regimes by exploring incumbent firms and how they would reorient towards niche innovations.

The reorientation to niche innovations would require new knowledge and capabilities based on the assumption that firms have existing knowledge based on existing technological trajectories. Thus, this study investigates the firm's technological learning processes that would allow firms to access future knowledge and technology.

The examination of the technological learning process within and among firms is fundamental to the niche dynamic process which could lead to the transition to the new regime and to determine appropriate government policy interventions. The governance and policy intervention to shape transitions are also reviewed as an aspect that it can encourage, facilitate, expedite the transition or even destabilize the regimes. Although the study focuses on the creation of knowledge or firm's technological learning, the MLP analytical framework used in this study helps broaden and allow this study to address other elements such as markets, users, policies, or institutions that would support the overall technological regime transition.

2.1 Technological transitions and theories

Technological transitions refer to the complex changes from existing technologies to new ones in specific industries, societies, or global contexts. It's important to understand that these transitions involve many factors. To study them, various theories and frameworks are used. In this study, we discuss four frameworks that help analyze technological transitions.

2.1.1 Technological Innovation System (TIS): The TIS framework highlights interactions and dynamics among diverse entities, institutions, and processes integral to technological change. These entities encompass private enterprises, governmental and non-governmental bodies, academic and research establishments. The framework underscores the significance of comprehending systemic factors that influence innovation, such as networks, knowledge exchange, user demands, and policy frameworks. However, the TIS framework is primarily focused on the development and diffusion of new technologies, but it does not take into account the broader socio-technical context in which innovation takes place (Markard & Truffer, 2008). The TIS framework has been used to study a wide range of technological innovations, including information and communication technologies, renewable energy technologies, and medical technologies.The TIS framework has been criticized for not being able to explain technological transitions. In response to this criticism, the framework has been combined with other frameworks, such as the multi-level perspective (MLP), to better understand technological transitions (Geels, 2004).

2.1.2 Transition Management Theory: Rooted in sustainability and governance studies, Transition Management Theory centers on steering, facilitating, and intervening in transitions toward more sustainable technologies and practices. It underscores collaboration, learning, experimentation, and adaptable governance as pivotal in navigating technological transitions. The framework points in on the roles of actors within innovation systems, institutions, and networks in propelling technological evolution. Transition management theory encompasses the broader socio-technical context in which innovation takes place, but focusing on facilitating transition by governance interventions that create a favorable environment for innovation and change (Grin, Jan, & Schot, 2010)

2.1.3 Strategic Niche Management (SNM): SNM emphasizes the role of experimental niche innovations in driving transformative change toward sustainability. It underscores the creation and nurturing of niche innovations that challenge the existing status quo and provide sustainable alternatives. Learning and experimentation within these niches are highlighted (Caniëls & Romijn, 2008; Kemp, Schot, & Hoogma, 1998). SNM, while complementary to other theories like the Multi-Level Perspective, distinctively focuses on the niche level and strategies for its development and diffusion.

Each framework can be harnessed to analyze technological change by spotlighting distinct facets that drive change. Notably, TIS narrows its focus to actor relationships within innovation systems, Transition Management Theory emphasizes governance and actor roles in facilitating transitions, and SNM centers on niche innovations. In contrast, MLP, chosen for this study, offers a comprehensive framework accounting for the intricate dynamics and interdependencies integral to transformative change. We chose the Multi-

Level Perspective because of the capacity to embrace a holistic view of sustainability transitions, encompassing landscape-level and regime-level factors alongside niche innovations.

According to Figure 1.1 this research study is centered around the concept of sustainability transition, with a specific focus on examining the shift from conventional internal combustion engine (ICE) vehicles to electric vehicles (EVs) within the automotive industry. The study adopts a Multi-Level Perspective (MLP), which offers a comprehensive and systemic approach by considering various levels within the socio-technical system and a broader context that shapes this transition.

At the landscape level, the analysis encompasses global environmental concerns, climate change, the worldwide agenda for phasing out ICE vehicles, and political objectives. Moving to the regime level, the study takes into account the established automotive ecosystem dominated by well-known companies, intricate supply chains, existing knowledge reservoirs, governmental policies, regulations, and consumer behaviors, all of which might impede rapid change. At the niche level, the MLP aids in exploring the emergence of the EV niche within the automotive sector, as well as the rise of new innovative firms in this context.

This research employs the MLP as a framework for dissecting the transition from conventional mobility to electric mobility, with a particular emphasis on comprehending how established players, especially companies within the conventional automotive industry, might navigate this transition. In the socio-technical regime level (or meso level), this involves an examination of key stakeholders like car manufacturers, suppliers, users, as well as the knowledge enablers such as universities, research institutions, and government agencies. Meanwhile, the landscape level encapsulates external influences that exert pressure on firms to adopt technological changes, such as the urgency of addressing climate change and the global consensus on phasing out ICE vehicles. At the niche level, the framework outlines potential knowledge networks that can bridge from the existing regime players to influence the configuration of the new regime.

By applying the MLP as an analytical lens to the automotive industry's journey towards EVs, this approach facilitates a comprehensive grasp of how different socio-technical levels interact. Furthermore, it offers an analytical framework to explore policy interventions and governance strategies that can effectively facilitate the transition to electric vehicles within the automotive sector. In the following section, we delve deeper into the intricacies of MLP and its role in understanding technological transitions.

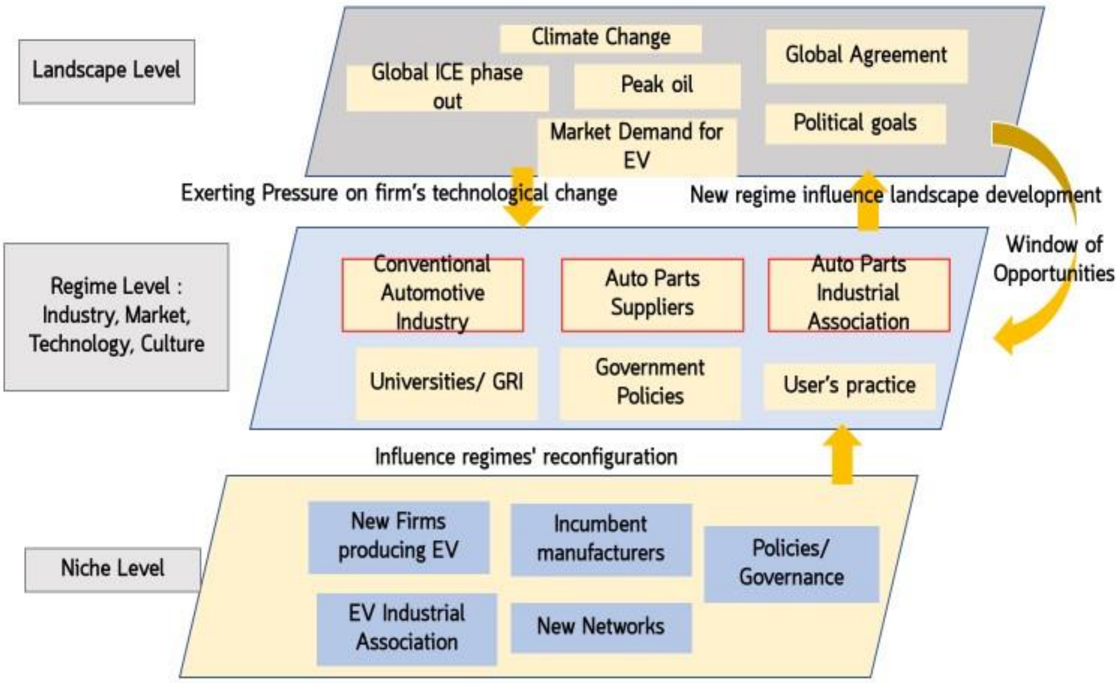

Figure 2.1Analysis Framework of the automotive industry transition to EV using MLP

2.2 Technological transition and the multi-level perspective (MLP) framework

The multi-level perspective or MLP, is developed from quasi-evolutionary theory, sociology of innovation, and institutional theory (Frank W. Geels, 2004). MLP is adopted mainly in transition literature, notably sustainability transition, to explain how the transition process occurs. MLP provides an understanding of the complex transition process involving interrelated actors, variables, and processes. MLP is the framework used by others in sustainability transitions literature, such as transition management, strategic niche management, or technological innovation systems (Markard, Raven, & Truffer, 2012).

Before moving further to MLP, first, we will review the meaning of sustainability transition and technological transition. We discuss sustainability transition because it is central to this study that the substitution of old technologies is required to shift to more sustainable technologies, particularly in the transport area, to tackle current environmental problems.

Markard et al. (2012 : 957) defined sustainability transition as “long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production or consumption”. Technological transition is a major transformation of technology that not only involves the change in the technology itself but also changes to serve societal functions (Geels, 2002). Thus, technological change occurs as part of the sustainability transition. The notion of heterogenous elements combined as parts of technological transitions has been highlighted in the MLP theory; the other elements to be considered other than technology, are those such as user practices, regulations, infrastructures, and cultural meaning.

In the case of automobility, it can be seen that the transition of automobility is a piece of a jigsaw of a wider sustainability transition. And the element to be considered is not only a technological change by car manufacturers but also the entire related elements in the automobility regime.

The term socio-technical system is proposed by Geels (2004) to broaden the existing innovation system, which primarily focuses on the creation of knowledge and production of technology, to include production, diffusion, and the use of technology which place more attention on the user of technology. Socio-technical systems are made of actors, rules and regulations, and artefacts and the body of knowledge relating to artefacts. The activities of actors that can be categorized into various social groups help to form the socio-technical systems. Mainly social groups can be categorized into production side and functional or user side, while each side consists of sub-social groups that operate autonomously but at the same time interact and coordinate between groups. The production side of social groups may consist of manufacturing firms, suppliers of components, financial institutions, universities, research institutes, schools, labours etc. In contrast, user side consists of distribution networks, users, maintenance networks, media, etc. For example, socio-technical configuration of personal transportation may consist of the artefact (vehicle), road infrastructure, industry structure (car manufacturers, suppliers), maintenance networks (repair shops, car dealers), regulations and policies (traffic rules, standards, taxes), markets and users' practices (driver preferences, culture and symbolic meanings (freedom of driving) (Frank W. Geels, 2002). These heterogeneous elements form a socio-technical system. Regarding this notion, the technological transition thus involves reconfiguring technology and other intertwined elements in socio-technical systems. Thus, the socio-technical transitions do not involve only the shift in technology but also include many elements such as user practices, institutional structures (rules and regulations), socio-cultural change.

MLP is an analytical framework used in several studies to examine transition dynamics, particularly in the area of sustainability as also in the case of the transition to electric vehicles in response to environmental problems (Berkeley, Bailey, Jones, & Jarvis, 2017; Mazur, Contestabile, Offer, & Brandon, 2015; Nilsson, Hillman, & Magnusson, 2012; Wells & Nieuwenhuis, 2012). MLP provides an understanding of the transition process which is complex, involving interrelated actors, variables, and processes.

The MLP framework consists of three nested hierarchical socio-technical levels; socio-technical regime, socio-technical niches, and socio-technical landscape. (See Figure 2.1)

(1) The socio-technical regimes represent the prevailing system at the meso-level; this represents the established technological practices and other factors that help maintain and stabilize the existing system, such as incumbent actors, shared belief, institutional setting, and user practices (Frank W. Geels, 2011).

(2) The socio-technical niches are at the micro-level and cover the area where radical innovations that can disrupt the existing regime may arise. Niches form a protected space for radical innovation to develop and shield from the mainstream selection environment.

(3) The macro-level contains socio-technical landscapes referring to exogenous environments that slowly change over time, such as environmental and demographic change, political or social movements, and rapid landscape shock events such as wars and financial crises. The structural change in the landscape could exert pressure on the regimes and niches while

providing windows of opportunity for niche innovation to break out (Smith, Voß, & Grin, 2010).

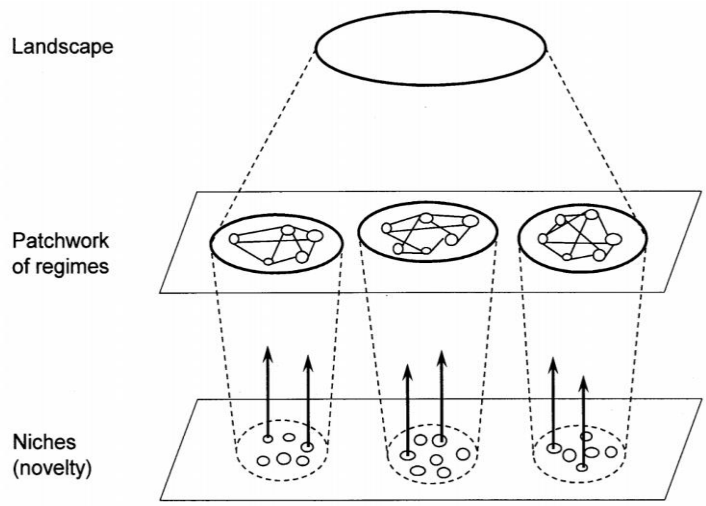

Figure 2.2 Multi-level perspective framework as nested hierachy, Source : Geels (2002 : 1261)

Each socio-technical level contains a different degree of stability that impacts the actor's behaviour. At the macro-level, the landscape represents a certain degree of hardness and stability of the exogenous environment, for both material factors (e.g., high ways, electricity infrastructure) (Frank W. Geels, 2002) and for non-material factors such as macroeconomic factors (e.g., economic growth), natural environments, wars, demographic change. This broader context suggests that actors in regime and niche cannot directly or suddenly influence the development of the landscape. The change in landscape is slow and difficult to change. However, the change in the landscape can also occur in a sudden shock manner, such as in wars. However, the main idea is that actors cannot directly influence that landscape.

At the meso-level, the socio-technical regime represents the existing context of established technologies, rules, and practices that serve a societal function. The socio-technical regime contains an engineering practices concept initially based on the technical regime concept by Nelson and Winter (1982).

It also includes other complementary elements of technologies and engineering practices in terms of usage and functionality, such as production networks markets, policy and regulations, cultures (Geels,2004). Geels (2004) proposed the classification of heterogeneous elements into systems, actors, and rules to show how each element is interrelated. Systems refer to material aspects or artefacts; actors can be classified into different social groups responsible for supporting and changing the system. Rules or institutions guide or regulate actors' activities. All three dimensions are linked and aligned, creating stability in the socio-technical regime. Despite the regime stability, regimes do not remain stagnant, but the development is relatively incremental rather than radical.

At the micro-level, are situated the niches defined as a protective space where new technologies emerge or the locus of radical innovations (Geels, 2005; Smith & Raven, 2012) Radical innovation requires protection from mainstream market selection in the existing regime for the development and learning processes for both technology producer and user (Kemp, Schot and Hoogma,1998).

For example, the trial of electric vehicles in a specific area is considered a niche experiment in the protected space. The stability of niches is low due to the uncertainty relating to technical design, market acceptance, and public policies. Thus, nurturing niches to become dominant and replace the existing regime requires a special kind of management or so-called strategic niche management (Kemp et al., 1998). Generally, actors who play an essential role in developing new technology and the transition process are often associated with entrepreneurs or newcomers in the socio-technical system. However, the latest strand of literature often explores the role of incumbent actors involved in niche activities who becomes drivers of socio-technical change (Trencher, Truong, Temocin, & Duygan, 2021).

The structure of regime and niche is similar in terms of social groups and shared rules. However, the difference is the size of social groups which is smaller in the niche, and the stability of shared rules is unstable compared to the regime. Systemic transitions occur due to the interactions between the three nested hierarchies of socio-technical level (Frank W. Geels & Schot, 2007). Generally, the change can happen when there is destabilization at the regime level due to pressures from the landscape level and the push from the niche accumulation at the micro-level. The landscape pressure causes destabilization at the regime level and would open a window of opportunity for niche innovation to be developed (Schot & Geels, 2008). The transition would be complete when niche innovation that solves existing regime problems evolves as acceptable practice at the regime level. Thus, MLP views transitions as the co-evolution of the three socio-technical levels, successful niche development process based upon the changes in the landscape, and the destabilization in regimes, ultimately resulting in a regime shift. The transition is the result of structural change from the interaction between agencies across three levels. The socio-technical transition is a long-term process that could take approximately fifty years for the new technology to replace the regime (Hoogma, Kemp, Schot, & Truffer, 2005). Although terms such as radical innovation are used in transition study, the process of transition is mostly a gradual process rather than sudden.

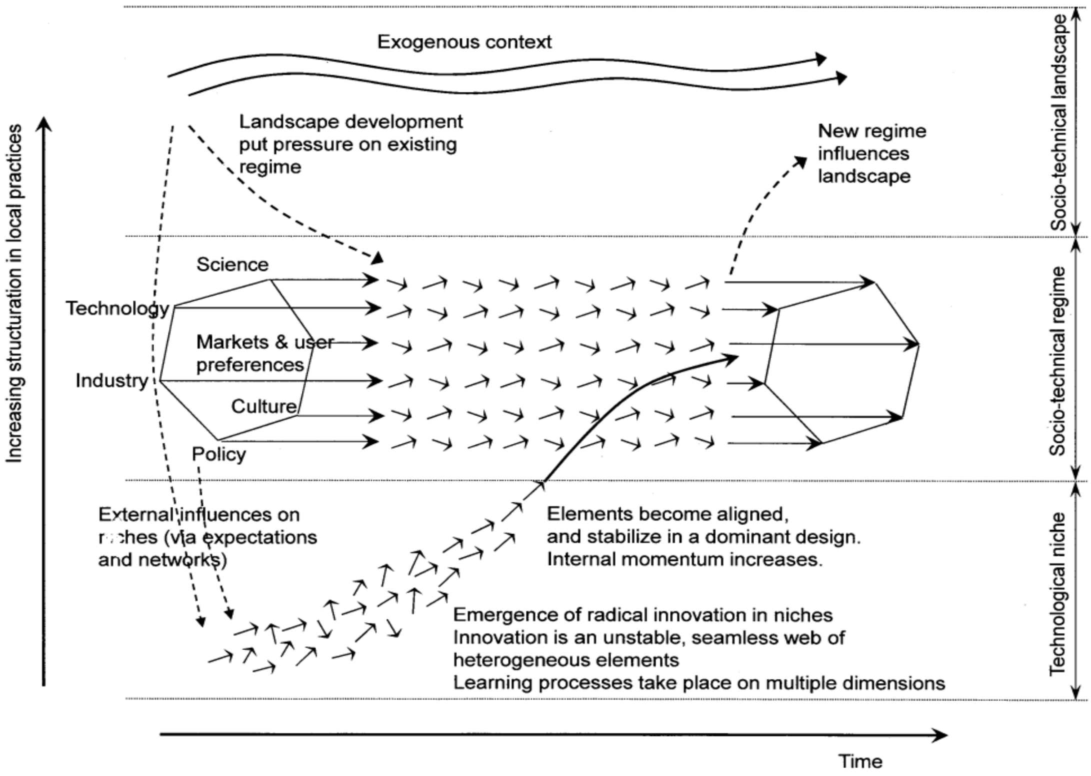

Figure 2.3 Socio-technical transition : Source (Geels, 2011:30)

A transition pathways typology has been developed to clarify the interaction between socio-technical levels in the transition processes (Frank W. Geels & Schot, 2007; Smith, Stirling, & Berkhout, 2005).

The study by Smith et al. (2005) developed transition typologies based on how regime members respond to the selection pressure (firm-level economic pressure, landscape development, or pressure from niches development) and the availability of resources required for the regime transition. The concept of selection pressure is similar to landscape pressure and niches development push from the MLP theory. The response is either coordinated or uncoordinated and the resources required (knowledge and capabilities) to achieve regime transformation either come from within or outside the regime. The source of change in regime transformation may occur by the incumbent regime members trying to adjust to the selection pressures or from members of external niches. The four transition pathways are developed as follows,

1) Endogenous renewal refers to the transition resulting from regime actor response to the selection pressure with coordinated efforts by exploiting internal resources within the regime. The transition in this scenario tends to be incremental because the innovative activity is driven by the regime actor's vested interest.

(2) Re-orientation of trajectories occurs from the sudden shock from an exogenous environment that stimulates a radical change, and regime actors already have resources for the change process. However, the direction towards the end is uncoordinated.

(3) Emergent transformation results from the development of selection pressures outside the regime and the response of actors outside the regime to this selection pressure.

(4) Purposive transitions refer to the intended transition with a coordinated response and external resources.

The first dimension that distinguishes the transition is the response to the selection pressure of regime members, whether it is coordinated or uncoordinated. The coordinated response implies that regime members share the same vision and interest towards the selection pressure, or the regime transformation is intended and purposively governed. The internal adaptation that exploits resources within the regimes tends to create incremental change, while external adaptation is likely to be more significant in structural change. This terminology is similar to the MLP concept; however, Geels and Schot (2007) argued that the transition could not be planned and coordinated from the beginning. However, later during the transition process, activities and visions of social groups can ultimately be aligned. (Geels and Schot (2007) categorized transition pathway into four types that articulate the regime transition focusing on the timing of landscape pressure, regime stability, and readiness of niche development. The transition occurs due to landscape pressure and niche development that are either reinforcing or disruptive to the regime. The four types of transition pathways help articulate and support the analysis of interaction among three socio-technical levels to be more succinct. The four transition pathways can be classified into :

(1) Transformation: This scenario explains the adjustment in the socio-technical regime from within that regime actors gradually reorient their technological trajectories due to moderate landscape pressure and insufficient niche development.

(2) De-alignment and re-alignment: A major shock in the landscape creates enormous pressure on the regime, causing many problems in the regime's stability. Niche development is not fully developed, which creates a "vacuum" that leads to various alternative technology developments. Moreover, the transition occurs when one innovation becomes dominant.

(3) Technical Substitution: A specific landscape shock puts pressure on the regime. At the same time, niche innovation is fully developed, and if radical innovation gains enough internal momentum, it eventually replaces the existing regime. During the transition process, there is competition between the regime and niche since regime actors try to defend their vested interests by improving their technology.

(4) Reconfiguration: Multiple innovations are developed, and transition occurs due to various components- innovation. The landscape pressure is also coming from multiple sources. Regime actors compete with multiple innovations, and new regimes eventually grow out of the existing regime, but the basic architecture in the regime is changed dramatically.

Table 2.1 Typology of transition pathways based on Geels and Schot (2007) adapted by author

Typology of Transition Pathways	**Landscape development**	**Niche development**	**Regime actors Reaction**	**Regime transition**
Transformation	Landscape development provide moderate pressure to regime (disruptive)	Niche-innovation is not yet sufficiently developed	Not enough pressure on regime actors so only uses adaptive capacity in response to external pressure	New regime grew out of old regime
De-alignment and re-alignment	Sudden change in many landscape developments provide utmost pressure on regime level	Niche innovation is not fully developed. However, there are multiple “niche” developments	No substitution for regime changes but unstable rules in regime constitute the co-existence of multiple niche co-evolution.	Co-existence of multiple innovations until one niche innovation from multiple-niches become dominant
Technical substitution	A specific shock in a stable landscape development	Niche innovation have sufficiently developed	Regime is very stable and still well-established and regime	When there is a specific shock that exert pressure on the regime,

Typology of Transition Pathways	Landscape development	Niche development	Regime actors Reaction	Regime transition
			actors only produce incremental change	then technology substitution occurs
Reconfiguration	Landscape development provide moderate pressure to regime	Several niche innovations or components were developed to solve particular problem	Regime change co-exist with multiple add-on innovations	Multiple niche innovations eventually merge in and change overall regime's basic architecture

These typologies can help analyse the current context of this study in the transition from internal combustion engines to electric mobility. Although the four pathways are distinct in this table, multiple pathway aspects may appear in one scenario when applied to an empirical scenario. This study also tries to respond to the criticism of niche-driven bias by providing examples showing that transitions occur due to multiple developments among three socio-technical levels. However, the example provided is still focused on the bottom-up niche innovation development, which means that technological transition starts in niches with little emphasis on regimes and incumbent actors as the agent of change, which will be later discussed in section 2.2.3 The role of incumbent firms in developing niche-innovation.

Understanding transition typologies also connects to the suggestion for governance and government policy intervention (Kanger, Sovacool, & Noorkõiv, 2020; Smith et al., 2005). Different pathways or transformation contexts indicate the status of niches, selection pressures intensity, and direction of regime change, thus suggesting types of policy intervention or governance that best support the transition. The governance intervention can manage the selection pressures or the resources required to support regime members in response to the transformation and drive the transition towards the desired pace and direction (Smith et al., 2005).

The governance of transitions can be provided through government policies and regulations in several forms, such as through industrial policy or innovation policy. Industrial policy can be imposed to support new “niches” by providing tax incentives or tax subsidies or destabilizing the current regimes by providing tax burden or withdrawing subsidies. Innovation policies can be provided to support the emerging of niches, for example, R&D funding support, government procurement, or setting the long-term vision. Government policies play an essential role in supporting the emergence of new technological regimes by providing essential public infrastructure and incentive mechanisms, including rewards for innovation and public procurement policy (Kemp, 1994) However, governance not only include conventional government policy but also a coordination activities with non-state actors (Nilsson & Nykvist, 2016), for example, facilitation of stakeholders' involvement in the niche development learning process.

The following section reviews the conceptual level of the socio-technical regime. The process of regime shift is reviewed by exploring how the change and innovation process occurs. The difficulty of regime shift due to its stability and barriers are also reviewed in detail.

2.2.1 Socio-technical regimes and regimes stability

The concept of socio-technical regime represents the established practices which are derived from the coordination of elements and the linkages of activities reproduce by social groups in socio-technical regimes. The term socio-technical regimes is developed by Geels (2002) building upon the concept of a technological regime developed by (Nelson & Winter, 1982; Nelson & Winter, 1977) which was used to specify an engineer's or technician's belief of how the specific technology could solve particular problem. The engineer's notion of potential technology indicates the research and development activities or research agenda that stem out of such particular technology or the "technological regime". The fundamental concept of technological regime is a "core technological framework" or "prevailing technologies and designs" that are shared by the entire engineer or technician community (Kemp, 1994). Technological regimes indicate stability due to the activities shared in the engineering community moving in the same direction.

When a specific technological regime is established, a technological trajectory follows such a regime. The search heuristics of engineers and a firm's organizational routine define technological trajectories. Furthermore, when the growth of manufacturing and a technological regime is established this broadly constitutes "dynamic scale and learning effects" (Kemp, 1994). The higher learning curve in manufacturing resulted in lower unit costs. The lower price means the increase in technology adoption and the domination of technology in the market, which implies stability of the regime.

Kemp et al (1998) and Rip and Kemp (1998) advanced the concept of the technological regime by extending the boundary from engineering activities and embedding it into a larger technical and socio-technical concept. The definition of a technological regime includes "the whole complex specific knowledge involved engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of technology" (Kemp et al., 1998). While Rip and Kemp (1998) defined the term technological regime as "a set of rule or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems- all of them embedded in institutions and infrastructures" (p. 338).

The advancement of the technological regime concept goes beyond the engineering practices of Nelson and Winter (1977) ; Nelson and Winter (1982) which tend to neglect other groups of actors that could also influence technological trajectories. The new concept also refers to rules of practices executed by related actors other than an engineer in the regimes, such as market rules, user requirements, and government rules.

Actors involved in a sociotechnical regime beside engineers are those such as manufacturing firms, suppliers, users, policy makers, researchers, bankers etc. The term socio-technical regimes implies a set of rules followed by these groups of actors (Frank W. Geels, 2002). Rules, in this case, comprise regulative, normative, and cognitive rules. The regulative rules refer to formal rules such as laws and regulations, standards, or incentives that guide regime actors' behaviour or regulate interactions. Normative rules concern values, norms, duties, and responsibilities.

Moreover, cognitive rules relate to social perception. These rules are created and followed by multiple actor groups such as technology producers, suppliers, users, researchers, and public agencies, and each group may follow its own set of rules. Thus, rules are not easily altered because one rule tends to align with other rules that are followed by different social groups or members within a socio-technical regime.

This definition also implies that there are several elements that make up a technological regime. For example, the regime of an automobile includes auto technologies and designs, car manufacturers and suppliers, regulators, road infrastructures, car users and markets, cultural aspects associated with car use, etc. These heterogeneous elements and related actors are all considered an automobile technical regime, not only the technological knowledge relating to automobiles. Thus, the advanced concept of a technological regime is broader and includes other actors such as users, policymakers, and infrastructure development actors. These actors' activities also influence technological trajectories, and the activities of these different groups of actors are guided by a set of rules for which Geels (2002) introduces the term "socio-technical regime."

This concept of technological regime has been broadened to cover not only supply-side aspects of technology but also demand aspects and societal aspects or the selection environment. The focus that shifts from only engineers to include related factors indicates that not only the unilateral action of a firm can deliver change (Smith et al., 2005).

The complex element of the technological regime also shows its natural structure that inhibits changes or so-called "regime stability." The key feature of the regime is the regime structure instigated to a high degree from the interrelationship between heterogeneous elements, i.e., existing technology, infrastructure, user practice, user perception, rules, and regulations are linked to existing technology which constitutes regime stability.

Various elements previously developed that are linked and aligned constitute regime stability in the socio-technical system. Actors within a regime from different social groups such as firms, users, and policy-makers reproduce and maintain these elements according to a shared set of rules (F.W. Geels, 2019).

One of the barriers to the socio-technical transition is that regime resistance occurs due to the regime's stability. There are several contributing factors to regime resistance. Kemp et al. (1998) and Hoogma et al. (2005) identified barriers to the regime shift into technological factors, government policy, cultural, demand factors, production factors, infrastructure, and undesirable impact of new technologies. The technological factors concerning incompatible of new technology with the existing system, such as electric mobility, would require charging infrastructure to be developed extensively. Government policy and regulations are essential in setting the direction for a sustainability transition. A clear vision of government can encourage technology producers to invest in alternative technology, while the existing regulations might be a barrier to developing new technology. Cultural aspects, particularly regarding the user's perception of technology can constitute a barrier due to unfamiliarity, which could lead to skepticism of new technology. This also leads to the demand barrier, which is considered the main barrier for manufacturers. The demand factors that inhibit the adoption of new technology, include the performance of new technology, not meeting users' specific requirements or the high price during the initial stage of market launch. On the supply side, developing new technology means new investment in new knowledge and production infrastructure, while existing production facilities may be committed sunk investments.

Technological development in a socio-technical regime is path-dependent and locked into the old technological regime. The socio-technical regime is a reflection of a lock-in effect, i.e. technological, organizational, and consumer lock-ins. The technological regime lock-in effect refers to the state in which there is an increasing adoption rate and to the extent that certain technologies or practices become too entrenched to dislodge (Cecere, Corrocher, Gossart, & Ozman, 2014).

At the firm level, organizational lock-ins occur when firms develop their capabilities over a period of time set on specific technological trajectories so that activities become routinized, limiting the adaptive abilities of organizations to learn and adopt new ideas (Cecere et al., 2014). Incumbent firms' competitive asset is organizational knowledge and constantly working on reproducing routine actions such as production processes responding to established user needs.

The regime stability came from the acceptance of users leading to the adoption of technology, and the adaption of lifestyle resulted in the regime's stability. The amount and the extent of the network of users could lead to technological lock-ins and economies of scale that would make investments incapable of switching to other technologies. Switching costs are high under "lock-in" conditions. As for consumer lock-in, consumers can be reluctant to adopt new technologies due to factors like incompatibility of innovation, the cost-effectiveness of new technology, or network effects. This irreversibility of an adoption cannot be easily altered (Rip & Kemp, 1998). For example, the case of an adoption of automobile, once the society adopts and adapts to the use of an automobile, it is embedded in the society. The technical and social aspects of an automobile are intertwined and become a structural means of transport that is difficult to change. The difficulty of socio-technical regime transition thus primarily depends on the extent of regime stability.

The existing rules, regulations, and standards that support the existing technology and incumbent actors also create an institutional and political lock-in that could obstruct alternative technology (F.W. Geels, 2019). Thus, regimes' locked-in and path-dependence character explain why the transformation is a long-term process. However, the regime's stability does not mean that there is no development in the regime or stagnation; the development of innovation still occurs but in an incremental manner.

The power and politics of regime players may also cause regime resistance. Regime players in the sustainability transition context generally play an important role as a backbone for economic growth, job providers, or provide affordable goods or services such as car manufacturers or fossil fuels energy providers (coal, gas). The government relies on the industry to maintain economic growth and a reasonable cost of living for the people. While industry also depends on government incentives or subsidies that support such economic sector. In turn, the alliance between policymakers and industry can lead to the internalization of idea that tends to favour the position of incumbent actors that maintain the “status quo” of the regime.

For example, in the German automobile industry, policymakers and car producers’ relationship shows their mutual dependence on each other. Policymakers as part of the government rely on the automotive industry as country’s source of economic growth and job provider and conversely downplay the role of public policy in guiding sustainability transition (Späth, Rohracher, & Radecki, 2016). Moreover, in the case of energy producers and the low carbon transition, the government tends to ally with incumbent actors such as coal and nuclear powers due to the changing economic circumstances.

Thereafter, government deviates from the sustainability goal and provides support for incumbent technologies for economic reasons which in turn creates a strong regime resistance (Frank W. Geels, 2014). At the same time, industry relies on relationship with the government to internalise its idea and requirement in favour of the industry. The dependence between industry and government constitutes an essential limit on the possibility of regime destabilization.

The factors that constitute regime stability suggest that several elements need to be transformed. The automobility regime can be considered a large-scale socio-technical system comprising heterogeneous elements from technology, markets, culture, or policy. The socio-technical transition of the automobility regime requires actors in the socio-technical system such as manufacturing firms, consumers, policymakers, and researchers to perform changes. Thus, for a transition from internal combustion engines to electric vehicles to happen, it will require a systemic change in production technology based on new skills and knowledge categories. It also calls for changes in the behaviour of auto users and changes in government rules and regulations.

This section helps understand why socio-technical transition is difficult. Technological regime shift is a long-term process involving structural changes at different levels (Hoogma et al., 2005). Furthermore, technological change is relatively incremental rather than radical. The following sections explain how radical innovation may occur at the level of the niches or regimes.

2.2.2 Bottom-up transition: niches development

In the process of socio-technological transition, where established practices in socio-technical regimes are dominant, radical innovations are generally generated in niches at the micro-level. While incremental innovations occur in regimes, niches are considered as the locus of innovation or seed of change. Examples of many innovations suggested that innovation often emerges in niches such as the development of the steam engine which was first developed to pump water from mines, or the clock that was first used in monasteries (Hoogma et al., 2005). The example shows that niches often start in a particular application domain and are later adopted in a new and broader area. Niches can be specified into experimental, technological, and market niches. Technological niches refer to a protected space which shielded from a regime environment that might not be ready for niche creation (Kemp et al., 1998). A protected space is a non-commercial experiment of technologies or a testbed for radical technologies to investigate the feasibility of technologies and other aspects by a relevant small network such as by price, related regulations etc. Market niches provide a special selection environment or a certain degree of protection for new commercial products to safeguard innovation development. Because early developed technology is often crude and unrefined, different selection criteria should be imposed. Market niche creation could solve the problem of “chicken-and-egg” that manufacturers lack the incentive to invest in new infrastructure and produce new technology because of insufficient market demand (Birky, 2008). Thus, the process of market niche could stimulate a market demand.

The emergence of innovation could occur against the background of the regimes; it could be in the form of an experiment in a particular space with a different selection criterion. A historical example of niche emergence that occurs as an experiment before being widely adopted is the case of gas lighting. Gas lighting was tested early in the textile factories in England in the early nineteenth century; textile manufacturers could accept the disadvantage of gaslight because of its specific qualities (fireproof and cheap) and be willing to experiment with it in their factories. Later, gas lights continued to be used in the broader application domain by using in street lights, starting in London and other cities that later imitated the developments. Gaslight eventually replaced other traditional forms of lighting such as oil or candle in the nineteenth century. This example shows that the emergence of a niche generally starts in a specific area to experiment with new technologies, which could later produce a bandwagon effect or a wider diffusion of a niche by replicating the niche to other places. Niches development aims to be applied to the existing regime or eventually to replace the old regime.

The emergence of a niche or the transition route could depend on regime stability. In a stable regime, a niche is accumulated and developed at the niche level without competing with existing technology and tries to emerge when it gains sufficient internal momentum coupled with exerting pressure from landscape developments. While in an unstable regime, coevolution between niche and regime could occur, where regime problems and pressure from landscape development provide an opportunity for niche to arise and present innovative solutions, which leads to a transformation (Geels, 2005).

The idea of how niche could emerge into a regime and eventually replace the old socio-technical regime involves three internal processes: articulation of expectations, the building of a social network, and multi-dimensional learning processes (Schot & Geels, 2008). Articulation of expectation allows actors to put effort into alternative technology, such as energy companies' expectations of green energy despite the absence of a current market value (Raven, 2006). Building social networks brings in multiple stakeholders, either regime outsiders or regime actors, to share commitment and resources in operating an experiment. Moreover, learning processes allow relevant actors, i.e., producers, users, and policymakers, to learn in multiple dimensions, such as technical, market, and cultural dimensions, as well as regulations and government policies, and eventually lead to the adaptation of niches.

The critical process of niche development is a learning process that includes not only the learning of technical aspects of new technologies but also the learning of users about the technology, either technical or social aspects of the technology. And also, other relevant actors, such as policymakers, to learn about required regulations. Niches are crucial in shaping new technology by providing the space or "incubation rooms" for interactive learning processes and coordination between actors from the supply and demand side to nurture novelties.

It is understood that during the introduction of new technologies, it is difficult for new technologies to compete with the existing ones because of the readiness of technology or the acceptance from users. Early technologies need to be improved technically and also required adaption to suit the users. Thus, to nurture niche innovations and induce a transition to new technology regimes, strategic niche management (SNM) is introduced (Hoogma et al., 2005; Kemp, 1994; Kemp et al., 1998; Schot, Hoogma, & Elzen, 1994).

SNM is a policy tool aiming to support the introduction and development of niches by providing an experimental platform for new technologies to grow. The experimental platform or a so-called protected space will allow the interaction between actors to learn about new technology in several aspects from technological, demand, and related regulatory aspects. Actors involved in the learning process of strategic niche management include technology actors, government actors, and users or societal groups. SNM focuses on the technology side and the demand side or technology users. The central idea of strategic niche management is to manage and control selection pressures to articulate expectations and nurture learning and networking processes for niche innovation to survive the selection environment (Schot & Geels, 2008). This is when a public policy comes into action, particularly in the context of sustainability transition. Policy initiatives can support or discourage technology options, although not directly. The management of the selection environment could be in the form of government policies or incentives such as R&D subsidies or tax incentives for early market niches. Public policy to support new technologies could remove the barriers to innovation to compete with existing technologies.

In the early work of SNM, it is believed that the process of SNM that supports the development of technological niches into market niches can eventually replace the existing regime, consequently inducing the transition. At the same time, strategic niche management emphasizes bottom-up processes by nurturing activities at the niche level through the provision of protective space and a selective environment. Schot and Geels (2008) argued that the role of niche management alone could not cause the transition.

The process of co-evolution of multiple level activities, landscape pressure, niche internal momentum, and ongoing processes at regime levels altogether trigger the change at the regime level.

The early work of SNM also suggested that radical innovation or technological transition emerge in niches. The niche actor who can bring about radical change or innovation are believed to be small or new entrant firms rather than large incumbent firms. This is because new technology may require different knowledge and skill sets that are not available from actors in the existing industries (Hörisch, 2015; Schot et al., 1994). However, the latter study suggested that niche development can occur as a bottom-up process or from co-evolution within an existing regime. Raven (2006) proposed the concept of niche and dominant regime co-evolution. Niche development could branch off the socio-technical regime and gradually evolve from incremental into radical change. The actors in the process of niche co-evolution could include existing incumbent regime actors and also regime outsiders.

In the case of an automobile, the emergence of niche technology is co-existing with the existing dominant regime, such as biofuel, hydrogen, etc. The industry and users perceive other potential technologies instead of the internal combustion engine as an alternative that could mitigate mobility-related environmental problems. In the case of the development of electric vehicles, the automotive industry has its activities featured by MNCs and their subsidiaries worldwide. Existing car producers or incumbent firms at the regime level are the actors who develop niche innovations in the form of electric vehicles. As such, actors at the regime level can also be niche actors at the same time (Kinn, 2016). The following section discusses incumbent firms' roles and their involvement in the transition process

2.2.3 The role of incumbent firms in developing niche-innovation

Incumbent firms play an essential role in developing and defining technological trajectories within socio-technical regimes. However, the change in selection pressures may affect the established technological trajectories of incumbents, which in turn could also reveal a window of opportunity for new technologies, actors, and markets. The technological transition process explains that the breakout of radical innovations often occurs from the niche to the regime level (Frank W. Geels, 2002; Kemp et al., 1998). The transition occurs from protected spaces or niches that actors beyond the regime level generally develop. Incumbent firms generally commit to the established technological trajectories and their vested interest, thus often generate incremental innovation and are opposed to a sustainability transition. This section reviews another role of incumbent firms in actively joining the niche's activities towards sustainability transitions.

The role of incumbent actors is still currently under research, particularly the role in supporting niche development. Most of the studies in the MLP literature explored firm-level roles as the agent of change by focusing on new entrants or niche actors. Scholars in the transition study mostly suggested that radical innovation occurs from the "bottom-up" process resulting from development at niche level. Conversely, incumbent actors are left out as they are locked-in and path-dependent and are trying to stabilize the established practices or typically prevent the changes. The role of regime actors is restricted to only being the defender of old regimes and only adapting by developing incremental innovation (Berggren, Magnusson, & Sushandoyo, 2015). However, regime actors may also be involved in the transition processes, particularly as a participator in niche development, or may engage in diversification activities beyond their primary sector (Steen & Weaver, 2017).

There is increasing study on incumbent firms regarding their response to the transition. One strand of literature explores the parallel role of incumbent firms in exploring potential niche radical technologies, which are found in the automobile industry, where car manufacturers parallelly produce ICE vehicles and develop electric mobility. Another strand of literature explores the diversification activities of incumbent firms into other sectors (Nilsson & Nykvist, 2016; Steen & Weaver, 2017).

As part of the regime, incumbent firms, which are dominant actors, benefit from the regime's existence. It is assumed that incumbent firms would preserve their interest by maintaining the regime's stability. Späth, Rohracher and Radecki (2016), argue that the current transition literature primarily emphasizes the emergence of niche as the change agent in the transition study. Using example of the automobile industry in the Stuggart region of Germany, this study portrayed the role of incumbents in conducting niche activities to respond to the changes in the mobility regime and the government support for incumbents' adaptation. Incumbent actors that are major car producers and major suppliers cooperate in a joint venture or collaborative R&D supported by government funding. Although incumbent actors will try to prolong current business, the activity of incumbent actors in this study suggests that in the transition in the mobility regime from ICE to EV, incumbent firms may also parallelly invest in a potential niche activity as part of the firm's strategy.

Incumbent firms are generally tied to the sunk cost investment in the existing infrastructure of the established technological regime. The study of incumbent firms producing oil and gas and hydropower in the energy sector in Norway suggested that firms diversify to alternative activities, i.e. invest in other renewable energy, to "recycle" the existing resources and capabilities (Steen & Weaver, 2017).

Therefore, according to the latest studies on the role of incumbent firms and niche innovations, it can be seen that in particular industries such as electric vehicles or the energy sector are keen to reorient their strategy toward green innovations. The motivation could come from the change in socio-technical regimes, such as the change in legislation that forces production activities, such as the zero-emission vehicle mandate in California. The business opportunities and economic gain also incentivize incumbent firms to participate in developing niche innovations.

In the sustainability transition literatures, the concept of niche development are believed to bring about the transition (Smith et al., 2010) Research on governing transitions such as transition management or strategic niche management traditionally mostly focuses on government policies or governance to empower niche development emerging in a bottom-up approach from new entrants at a niche level (Hoogma et al., 2005; Kemp, 1994; Kwon, 2012; Smith et al., 2005). In contrast, incumbent regime actors play a small role in how they could be a part of niches to alter the current regime. However, lately, in transition theory, the role of incumbent actors has become increasingly investigated. The traditional role of incumbent regime actors that seems to obstruct the transitions has been explored from a new perspective in which incumbents are part of the niche development actors. There are also several cases where government provides policy support for regime actors to stimulate the transformation of the existing industry to align with the country's vision on sustainability transition.

Government policy intervention in supporting the incumbent regime actors is highlighted in the study by Trencher et al. (2021) using examples from China, Japan, and California in the production and diffusion of electric mobility. The study also emphasizes the role of government and industry as an incumbent actor-network in driving the sustainability transition.

This study suggested the significant role of the national government and local government in providing "top-down" policies and in managing strategies to support incumbent industries to pursue niche activities to maintain their competitive advantage. This scenario is different from the general transition theory, whereby the government usually supports niche actors such as newcomer firms or a new industry to develop radical innovation. Several studies have investigated the government promotion of niche activities by niche actors, while this study focused on incumbent actors compete in niche innovation. The driver for electric vehicles is led by incumbent actor networks, i.e., car manufacturers, electronic firms, industry alliances, universities, and research institutions with support from national and local government and newcomers such as battery firms. The incumbent actor's motivation to join niche activity is mostly from environmental, energy security, industry competitiveness, and economic reasons. In the sample countries, the automotive sector is considered a significant contributor to the country's economy in terms of GDP and employment. Thus, both government and industry try to preserve the existence of the automotive industry and transition to electric vehicles.

Strategies used in three examples, China, Japan, and California, show that some strategies are common but also different due to the incumbent industry position and importance to each country. For example, the difference in propriety technology also leads to a different choice of strategy, mainly to accelerate the decline of the incumbent industry. China's technology on ICE has been inferior compared to other automaker countries, namely Japan and the US; therefore, China sees the entrance of electric mobility as a window of opportunity to leapfrog and phase-out ICE technology.

California does not have a local automotive industry; thus, the phase-out policy is also chosen to achieve an environmental goal. In comparison, Japan's phase-out policy is absent to maintain the local automotive industry during the transition phase. The top-down approach is quite different from the strategy used in the general transition study because this approach focuses more on supporting industry and technology production.

There are deviations from the general perception of the incumbent role in defending the regime to protect its sunk investment. This section shows that besides new entrants, incumbent actors may be involved in the transition process by engaging in niche activities motivated by anticipated interest, particularly in the energy and mobility sector. Government policy intervention is also an essential mechanism for developing new technologies concerning knowledge creation and subsidies to support niche competitiveness.

2.3 Technological learning and knowledge networks

This section will focus on a firm's behaviour and technological regime shifts. Firms are central to the transition in terms of shaping technological trajectories. However, it can be assumed that firms have a limited knowledge base and specific technological capabilities relating to the existing regime (Kemp, 1994). Firms' knowledge involves technical knowledge, marketing knowledge, management skills, etc. This knowledge defines a firm's technological capabilities and technological trajectories. Thus, one crucial question is how firms can participate in developing new technologies that require new knowledge and different skillsets? This is also a central question to this study by focusing on how firms' respond to the transition exploring the extent and direction of a firm's technological learning. Based on the concept of transition in innovation study which, knowledge, capabilities, and coordinating a response to the transition pressure are deemed as the adaptive capacity required for the regime transition (Smith et al., 2005).

Knowledge networks are also believed to be the supporting mechanism for firm to acquire external knowledge in developing innovation. Thus, this section explores innovation literature in addition to MLP by reviewing technological learning of firms and knowledge network theory which is an essential part of the innovation process and niche innovation development.

2.3.1 Firm's technological learning

Technological learning is often used in the innovation study strand of research involving the development of firms and industries, particularly technology-driven industry. Dodgson (1991) suggested that technological learning includes activities that would expand a firm's knowledge and skill; it is essential for its technology strategy and competitiveness. Kim (1997:6) provided that technological learning "is used to portray the dynamic process of acquiring technological capability.

Some studies suggest that learning processes result from acquiring knowledge externally. According to Mowery et al. (1996), the learning process is part of knowledge creation through which firms learn by retrieving resources or skills from external partners. Learning processes happen subsequent to knowledge transfer (Phelps, Heidl, Wadhwa, & Paris, 2012). Knowledge transfer involves two main activities - sharing and learning. Knowledge sharing occurs when the knowledge source transfers information or knowledge to the recipient party, and learning takes place when the recipient parties acquire, absorb, and adopt such knowledge (Phelps, Heidl, Wadhwa, et al., 2012).

In contrast, (Bell & Figueiredo, 2012) argued that learning can either be generated within an organization or from the acquisition of external knowledge (Bell & Figueiredo, 2012). Learning can be understood as deliberate and cumulative processes that individuals create within firms or the organization to increase the organization’s capabilities and thereafter allow firms to progress on innovation activities. And As defined by Bierly and Chakrabarti (1996 : 369) technological learning is “the acquisition and generation of explicit and tacit knowledge, which is used in improving either the development of new products or the production of current products”. For Linton and Walsh (2013), learning is a process of acquiring knowledge to improve specific technological capabilities. Thus, learning, particularly technological learning, can be defined as a process of accumulating knowledge either from internal or external sources and building the basis for the development of the technological capability of firms. Technological learning also implies a firm’s ability to maintain its competitive advantage and is critical in addressing changing technological circumstances (Bierly & Chakrabarti, 1996; Dodgson, 1991).

Technological capability development evolves in phases with advancements in technological learning (L. Kim & Nelson, 2000; Moeini & Zawdie, 1998). The initial phase is production capability, which relates to the efficient use of resources for a given technology and is subject to institutional constraints. Upon achieving production capability, firms would progress to the achievement of investment capability, which involves acquiring knowledge about projects and technology choices from the ‘world technology shelf’. Firms with competency in project and technology choice would be expected to progress to progressing research and development and innovation capabilities (Cohen & Levinthal, 1990). Thus, technological learning is a necessary condition for achieving innovation capability (Edquist, 1997). Whether learning translates into innovation depends on the effectiveness of the learning process at every phase of capability development.

As mentioned, sources of learning can either occur internally within firms or externally to firms. Study by Bierly and Chakrabarti (1996) explored technological learning and strategic flexibility and their influence on firm's technological performance. In this study, technological learning can be divided into two dimensions (1) internal and (2) external learning. Internal learning addressed learning activities aiming for new knowledge creation to occur within the organization, whether as a result of individual or organizational learning. External learning refers to the acquisition of knowledge from external sources outside the organization and integration with internal knowledge through the process of networking. Indicators of "technological learning" include (1) internal learning (R&D expenditure and a number of patents) and (2) external learning (patent citations and strategic alliances). The sources of learning can also be broadly categorized into three groups: international sources, domestic sources, and internal efforts, with each source complementing the other (L. Kim, 1997).

There are various channels for technological learning. Learning can be achieved through formal and informal modes of education and training; or, at a higher level, through R&D activities. Learning can be achieved through experience, as in the case of learning by doing, but it is mostly recognized as an intentional and determined process (Malerba, 1992). This means that policy measures can directly influence the direction and speed of learning.

Many studies explore firms' learning processes in emerging economies (Moeini & Zawdie, 1998; Oyelaran-Oyeyinka & Lal, 2006; Suwannapirom & Lertputtarak, 2008). However, there is no consensus as to the best way for firms in different settings to achieve technological learning.

Looking into the Iranian case, Moeini and Zawdie (1998) classified modes of learning in industrial sector into learning from training, learning by doing, learning by copying, learning by reverse engineering, and suggest learning by doing seems to be a major source for the development of technological capabilities. A study by Oyelaran-Oyeyinka and Lal (2006) covering firms in India, Uganda and Nigeria confirmed that learning by doing is the most preferred mode for all firm sizes. However, they argue that learning by doing becomes less effective where firms adopt more advance technologies. While learning by doing may be a costless way of learning, it might not lead to radical innovative development (Oyelaran-Oyeyinka & Lal, 2006).

Guo and Guo (2011), classified the knowledge acquisition channel or source of learning into 7 categories: 1) interpersonal ties (informal contacts with employees in intra and extra organizational cluster; parts and service suppliers); 2) learning by hiring; 3) imitation/reverse engineering; 4) independent R&D; 5) training (by clients or professional training); 6) collaborative development (with universities, research institutions or firms); 7) codified knowledge (licensing, publications, patents). These channels can be formal and informal, unintentional and intentional, internal or external, vertical or horizontal. This study found that the most successful means of technological learning for firms in emerging economies is through learning by imitation or reverse engineering. However, there can be several sources of learning for firms. Guo and Guo (2011) also found that the technology complexity element also affects the learning behavior of firms by resorting to multiple learning channels. For instance, firms in Korea achieved technological learning largely by exploiting international resources, and on the back of these they developed their own indigenous capabilities (L. Kim & Nelson, 2000).

Learning levels might also be different between firms since the learning process is path-dependent. Learning tends to be path-dependent and a collective social process when the past cumulative experience provides a foundation for firms to cope with new technologies in the future. Numerous factors affect the technological learning level of firms, such as experience, qualification of technical personnel, size of firms, R&D activities or age of firms. The level of knowledge sought and the organizational learning process adopted by firms is mostly industry-specific (Bell & Pavitt, 1993) and can differ in each industry. Moeini and Zawdie (1998) argue that different industry may achieve different levels of technological learning as a result of long operating periods or age of firms, quality of human resources available to firms and the relationships firms forge with foreign companies. The study surveyed Iranian firms in the electronics, chemical, and automobile industries. And found that firms in the electronics industry achieved more significant technological learning than firms in the other industries due to factors such as a long operating period, quality of human resources, and relationship with foreign companies. The study by Kim and Nelson (2000b) found that firms operating under different circumstances may have different levels of learning depending on their former experiences and their learning efforts. Moreover, the basis of industrial sectors – i.e. whether they are supplier- dominated or science-based - also have a bearing on the learning trajectory of firms.

Technological learning occurs at individual and organizational levels. Individual learning is a necessary part of organizational learning (OL), but there is no reason to presume that individual learning would ipso facto translate into organizational learning. It requires an effective organizational strategy and management to translate individual learning into organizational knowledge (D. H. Kim, 1993).

Organizational learning is considered multi-level, Argyris and Schön (1997) distinguished organizational learning into single-loop learning and double-loop learning. Single-loop learning involves a simple reaction to solve an error in organization. While double-loop learning refers to the adjustment of organizational norms, policies and objectives responding to the detected error which implies adaptive ability (Romme, Romme, & Witteloostuijn, n.d.). Each learning level implies the complexity, the higher the learning level, the higher the ability to adapt and manage with problems.

Environmental change, discontinuous events or critical incidents also trigger the learning processes since the firm requires new information and this leads towards higher learning instead of processing on with routine or habitual learning (Cope, 2003; Saunders, Gray, & Goregaokar, 2014). Also networking becomes important when firm facing discontinuous events. Several studies suggested that firms that learn located and interacting within a complex network system are more likely to be resilient and innovative than firms that are poorly networked (Brink & Madsen, 2016; Jeffrey H Dyer & Nobeoka, 2000; W. Powell, Koput, & Smith-Doerr, 1996). The following section reviews how firms that engage in networks may increase their technological learning and thereafter, competitive advantage.

2.4 Knowledge networks and technological learning of SMEs

A firm's source of competitive advantage can be categorized into internal sources and external sources. Internal sources of competitive advantage based on the resource-based view (RBV) suggest that the difference in a firm's performance resulted from the firm's own idiosyncratic resources that are unique or difficult to imitate and reside within the firm (J. H. Dyer & Singh, 1998).

Resource-based theory (RBT), also known as the resource-based view (RBV) of the firm, is a strategic management theory that examines the competitive advantage of a firm through the lens of its internal resources and capabilities. It suggests that a firm's unique resources and capabilities are the primary drivers of its competitive advantage and long-term success. Resource-based theory suggests that firms can achieve sustained competitive advantage and superior performance by leveraging their unique, valuable, rare, inimitable, and non-substitutable resources and developing dynamic capabilities to adapt to changing circumstances (Grant, 1996; Wade and Hulland, 2004). While the resource-based view of the firm has been widely influential and valuable in strategic management, it has also faced some criticisms and limitations by focusing on internal strengths rather than external factors. The RBV argues that the resources and capabilities of a firm are the primary source of its competitive advantage. However, The RBV does not explain how resources and capabilities create competitive advantage particularly through isolating mechanism (Peteraf & Barney, 2003). According to Teece, Pisano and Shuen (1997) suggests that to sustain a firm's competitive advantage, firms may require resources beyond firm boundaries. This paper argues that the resource-based view needs to be supplemented by a capabilities view, which focuses on the ability of firms to integrate, mobilize, and deploy their resources in a way that creates value.

Although RBV is a valuable framework, there is still much debate about its validity in sustaining competitive advantage since its emphasis is on internal resources and capabilities.

In a world where technology is changing rapidly, innovation occurs in an open mode, which involves a firm's interaction with key actors outside its boundaries (Van Hemert et al., 2013). The external network can be a source of knowledge and an input for innovation. This is particularly significant since not all firms can conduct in-house R&D activities - especially small firms, which may need to acquire knowledge from external sources. Bell and Pavitt (1993) suggest that despite the cumulative nature of technological learning, firms' capabilities rarely go beyond the incremental, thus, using networks to acquire new areas of knowledge and complement their existing knowledge is key. Networks play a crucial role in supporting technological learning processes. Technological learning is not a linear process (Bell & Pavitt, 1993; Edquist, 1997) nor an isolated process - it occurs through engagement with external organizations. It involves the interaction of firms with a wide range of actors such as suppliers, customers or consultants (L. Kim & Nelson, 2000).

This relates to an interactive model of innovation involving intra-firm and inter-firm interactions accommodating feedback and cooperation processes (Fischer, 2006). Tsai (2009) suggested that firms exploit inter-firm cooperation to gain access to new knowledge, shorten the time in accessing new technologies or markets, or take advantage of economies of scale from joint R&D projects to respond to the increasing market demand and the rapid change of technology. However, not all firms may have the same approach to achieving technological learning.

Previous research suggests that the network of firms may provide external resources such as human capital and knowledge transfer and that an inter-firm network can enhance the learning of firms that are crucial for the development of competitive advantage.

Dyer and Singh (1998) suggested how inter-firm relationships can create more benefits than depending solely on the resources of an individual firm by creating a knowledge-sharing routine and investing in complementary resources between firms. Dyer and Nobeoka (2000) studied the automotive industry using the Toyota Production Network (TPS) case in Japan and the U.S., a knowledge-sharing platform between Toyota and its suppliers to support customer-supplier network learning. The development of a knowledge-sharing platform aims to facilitate the exchange of tacit knowledge among Toyota's suppliers. Toyota firstly creates weak ties among suppliers through supplier associations to create an informal atmosphere. Later it developed strong ties between Toyota and its suppliers through bilateral relationships by sending consultants to visit the supplier's plant. And finally, in created strong multilateral ties among suppliers by creating sub-networks under supplier associations to encourage knowledge sharing among network members. It is found that suppliers joining the knowledge network realized the benefit of knowledge sharing rather than isolated learning. However, it is worth mentioning that the case of Toyota that creates a strong tie among members enables the flow of existing tacit knowledge that is Toyota's know-how rather than new knowledge. Powell et al. (1996) used the case of U.S based Biotech firms to explore the effect of network on a firm's learning. The study suggested that for firms to stay competitive and relevant, they should collaborate with external partners such as research institutions or competitors rather than work individually. This has the effect of enhancing their absorptive capacity or "capability to learn". Powell et al.

(1996) also point out that networks provide a complementary resource, which may be unavailable internally, and play a crucial role in providing space for innovative activities to thrive.

Chesbrough (2003) emphasis the importance of an open innovation paradigm that besides developing its own internal knowledge, a firm should explore the external knowledge outside firms that can create economic value for firms. Instead of conducting every process of R&D internally to create valuable knowledge, a survey of the external knowledge landscape could provide complementary to internal knowledge and develop the integrated knowledge into discoveries.

Open innovation is vital for SMEs with fewer resources and lower R&D capabilities. Several studies have suggested that networks are important for expediting knowledge exchange and building the innovative capabilities of SMEs (Brink, 2017; Clifton, Keast, Pickernell, & Senior, 2010; Hewitt-Dundas, 2006; Nieto & Santamaría, 2010; Potinecke & Rogowski, 2009; Zeng, Xie, & Tam, 2010). Hewitt-Dundas (2006) studied the constraints to innovation performance using longitudinal data of large and small plants in Ireland. The results show that the lack of innovation partners significantly influences SMEs' innovation development. However, in the same study, the lack of partners did not impact large firms' ability to innovate, implying the greater importance of external resources to smaller firms. The importance of inter-firm collaboration for SMEs is also confirmed in the study of manufacturing firms by Nieto and Santamaría (2010) by suggesting that technological collaboration increases firms' ability to innovate, particularly in developing new products. In summary, SMEs lack resources and hence depend on external organizations for technological learning. Networking can help leverage local firms' capabilities by exposing them to new technical and managerial knowledge sources.

A knowledge network can be defined as the collaboration of partners that aim to increase the innovation capabilities or to generate innovation or to pursue "activities centered on a specific technological or problem-oriented topic for the primary purpose of knowledge and information sharing" (Cunningham and Ramlogan, 2012 : 6). A knowledge network can also be defined as a set of nodes either individual or collectives that is connected by the activities to serve knowledge creation, knowledge transfer and learning and knowledge adoption (Phelps, Heidl, Wadhwa, et al., 2012). Knowledge network types can be categorized into inter-firm networks and triple helix networks. Inter-firm networks are categorized into vertical supply chain networks and horizontal industrial networks. Triple helix networks include institutional members besides industry actors, e.g., universities and government actors. The concept of a triple helix network or innovation network and an industrial cluster is sometimes used interchangeably in several studies (Nakwa, 2013). Central to the knowledge networks concept based on the above definitions is the association with learning activities that occur through networks. Network collaboration is proven to benefit the stakeholders involved, for example, the development of new products or services, idea development, and skills development (Christensen, 2011) The network formation can be geographically co-located, such as in industry clusters or non-geographical based networks.

An inter-firm network such as a user-producer or supply-chain relationship is considered a source of innovation through customers' requirements or vice versa, a technology transfer from supplier to a customer such as the Toyota production network case. Horizontal networks are a collaboration among firms within the same industry, eg. collaboration with competitors and industrial associations such as consortia. This network allows sharing of information among members and even reduces the cost and time of conducting R&D by engaging in collaborative research. However, It is often argued that supply chain-based networks can generate incremental rather than radical innovation; linkages with external organizations such as universities or public sector agencies may provide the basis for more radical innovation (Monjon & Waelbroeck, 2003).The possible explanation is that customers or suppliers may provide firms with up-to-date market information which better serves the market's requirements. Another justification is the technological lock-in effect that customers and suppliers who are considered incumbent actors prefer to preserve existing technologies and would rather focus on the development of existing technologies than generate new technologies. Universities or research institutions generate more advanced knowledge, which could provide firms with new competencies, new technologies, and products.

Faems et al. (2005) explored the diversification of partners on a firm's innovation performance and how different partners impact an incremental or radical innovation. The study found that inter-firm partners, i.e., customers or suppliers and universities or research institutions, can effectively support innovation. However, inter-firm partners tend to support the existing product improvement while universities and research institutions influence the firm's radical innovation performance. Nieto and Santamaría (2010) also confirmed the previous study and suggested that cooperating with firms or academia both positively affects SMEs innovation performance. Zeng et al. (2010) also investigated the different collaboration partners on a firm's innovation performance. They argued that vertical cooperation or inter-firm network plays an essential role in firm's innovation performance for SMEs more than cooperation with universities or research institutions. In contrast, the study by Shu et al., (2007) suggested that horizontal linkages representing the collaboration between firms and cooperating firms, research institutes, and universities have a positive impact on firm's capacity to develop new products.

In summary, studies on the pattern of collaborative partners and innovation performance show that different R&D partners may produce different innovation results, thus suggesting that whom one partner within a network would make a difference in terms of one's innovation performance. A partnership can be between firms and through the supply chain or between firms and research institutions (Faems et al., 2005; Nieto & Santamaría, 2010; Shu et al., 2007). Different industrial sectors with diverse technologies may also have different kinds of linkages with external firms/organizations to acquire knowledge. However, due to the inconsistency of the study of collaborative partners and innovation performance, later studies bring in another variable that believes in having a mediating effect between partners and innovation performance, that is absorptive capacity. Absorptive capacity is deemed a prior knowledge important to understanding new external knowledge (L. Kim, 1997; Nakwa, 2013). The mediating effect between collaborating partners and innovation performance is reviewed in the following section.

Government plays a crucial role in facilitating knowledge network development, particularly the development of the triple helix network model. The prominent role of government intervention is in supporting knowledge networks. Acting as an intermediary consist of three prominent roles 1) a sponsoring role by means of formulating policy across industry 2) a brokering role in connecting industry and academia, and 3) a boundary spanning role at an operational level by providing supporting services relating to knowledge sharing or financing network activities (Nakwa, Zawdie, & Intarakumnerd, 2012). There are several examples of triple helix knowledge networks initiated by the government and performed as intermediaries. As in the case of France, interconnectivity between industrial firms, research institutions, and universities across geographical regions is supported by policy to promote social capital and innovation. For example, the innovative clusters project in France established 71 industrial clusters dispersed across the country. Each cluster aims to innovate by supporting collaboration between firms, research institutions, and educational institutions. Each cluster is supported by a permanent coordination office or intermediary, which helps with project selection, coordination of research projects, and bidding for government R&D funding (Potinecke & Rogowski, 2009). A similar policy model but with emphasis on SMEs was developed in Italy as industrial districts. Industrial districts constitute not only production specialization companies within the same geographical area but also exist as inter-dependent entities in terms of work distribution in supply chains. As legitimate entities or consortia, they obtain financial support from regional governments for implementing innovative projects involving several enterprises. In Denmark, the Danish government acts as an intermediary in setting up networks by providing funding and supporting network members to find partners and initiate collaborative projects between businesses or between business and research institutions.

In conclusion, to sustain a firm's competitive advantage, firms cannot learn in isolation but require external partners to expand their knowledge base. The network could begin from existing inter-firm networks such as supplier networks or trade associations to improve existing capabilities and later morphe into triple helix networks. To bring in universities and government institutions into existing networks, may require intermediaries to support the formation and operation of the network; where government could take this role by providing budget and resource.

2.5 Absorptive capacity as the firm's ability to learn

It is confirmed that for a firm to develop innovation apart from harvesting its own internal effort, it requires tapping knowledge from external sources and knowledge networks, either from other firms or academic sources. However, acquiring outside sources of knowledge requires an ability that allows firms to recognize, assimilate and apply such knowledge to the firm's use, called "absorptive capacity". Dyer and Nobeoka (2000) studied the knowledge-sharing process of Toyota Production Network (TPS) and its suppliers. They found that the knowledge-sharing process in the inter-firm network positively impacts both customers and suppliers. However, the transfer of knowledge through supply chain-based networks may effectively impact suppliers (SMEs) when suppliers develop their own capabilities through individual and organisational learning, i.e., absorptive capacity. Thus, SMEs' absorptive capacity is crucial in internalizing the intra-organisational learning process (Ernst & Kim, 2001). Therefore, SMEs need to develop learning strategies and learning abilities to maintain a competitive position in a value chain (Carrizo, 2009).

Absorptive capacity can be explained as one of the core learning abilities of firms. It describes a firm's ability to identify external knowledge and comprehend and apply such knowledge to the firm's use to sustain the firm's competitive advantage. Absorptive capacity is also recognized as a dynamic capability which is the ability to adapt to the fast-changing market conditions by valuing and recognizing external knowledge and ability to adapt and exploit external resources to outperform competitors.

Absorptive capacity is a significant factor that affects the technological learning of firms by converting external knowledge and internalise it for firm's use (Cohen & Levinthal, 1989; L. Kim, 1997; Moeini & Zawdie, 1998). In other learning processes of a firm, such as learning-by-doing, the emphasis is on developing the current practice while absorptive capacity is an integral part of a learning process that enhances the firm's ability to create new knowledge (Lane et al., 2006).

Kim (1997) emphasises the importance of a firm's absorptive capacity as an element that can increase a firm's technological learning and, after that, competitive advantage. Kim (1997) specifies two factors necessary to technological learning: existing tacit knowledge and intensity of effort or absorptive capacity. The intensity of effort refers to firm's ability to convert or internalise the knowledge that leads to firm's technological learning. The two-by-two matrix was developed to explain the dynamics of technological learning by indicating how the level of two elements would affect a firm's technological learning (Figure 2.4). For example, if a firm has high tacit knowledge and high absorptive capacity, technological capability is high and would increase rapidly. When existing knowledge is high, but the intensity of effort is low, it can also decrease a firm's technological capability in the future. However, suppose tacit knowledge is low, but the intensity of effort is high. In that case, this suggests that the firm might have a low technological capability but be able to increase it through external acquisition rapidly. Thus, to firm, the essential element to compete and sustain its competitive advantage is the ability to learn or absorptive capacity more than existing knowledge.

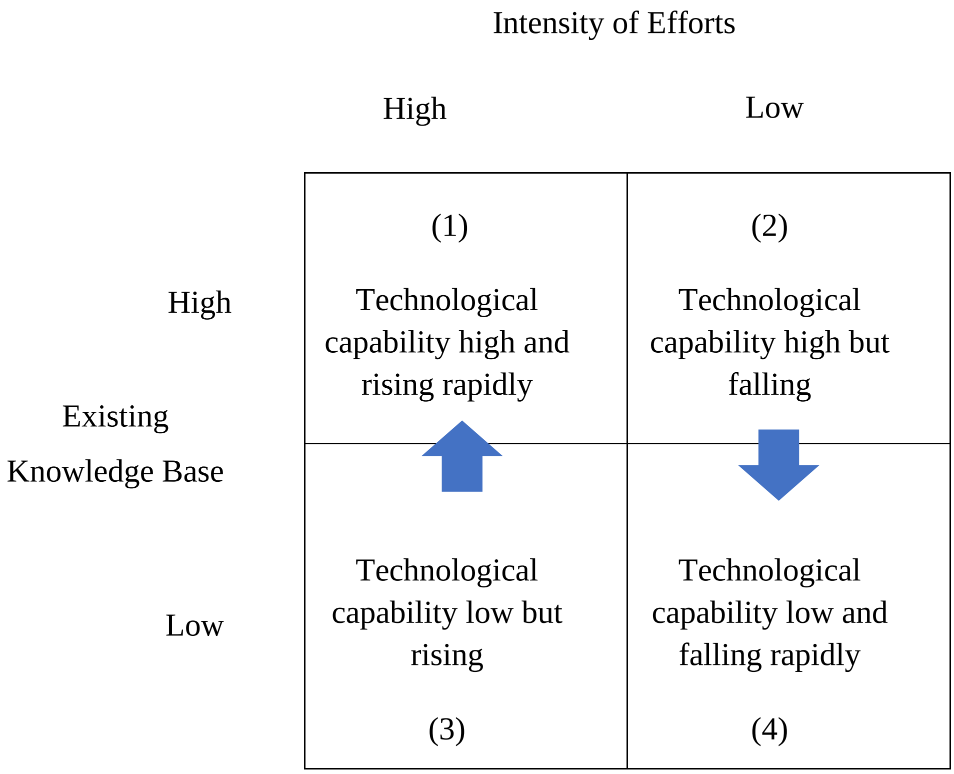

Figure 2.4 Dynamics of Technological Learning (Kim, 1997 : 98)

The definition of absorptive capacity defined by scholars mostly follows Cohen and Levinthal (1990) as a firm's ability to identify and value external knowledge, ability to integrate knowledge into firm knowledge stock and ability to make use of such knowledge into products or processes that would support the firm's competitive advantage. Cohen and Levinthal (1990:128) define absorptive capacity as the "ability of firm to recognize the value of new external information, assimilate it, and apply it to commercial ends". Absorptive capacity is mainly concerned with three factors: a firm's ability to identify external knowledge, assimilation of knowledge, and exploitation of knowledge. It is recognized as a firm's prior knowledge that could assist firms in recognizing the value of new information and exploiting it. However, exposure to external knowledge is insufficient; it requires knowledge transfer across the organization. At the same time, Zahra and George (2002) reconceptualize absorptive capacity as a dynamic capability that maintains and increases a firm's competitive advantage. Identifying absorptive capacity as dynamic capability allows the exploration of its antecedent and outcome and also imply the managerial action of such capability. A reconceptualization characterizes absorptive capacity as organizational routines and processes consisting of four capabilities; acquisition, assimilation, transformation, and exploitation, with each capability complementing the other. The constructs emphasize the importance of bringing in new knowledge, comprehending and modifying knowledge, and applying knowledge to its operation. Combining these constructs builds absorptive capacity into a dynamic capability that promotes organizational change. The four capabilities can be categorized into two subsets potential and realized absorptive capacity.

Potential absorptive capacity (PACAP) denotes a firm's ability to acquire and comprehend external knowledge (acquisition and assimilation) , and realized absorptive capacity (RACAP) denotes the ability to make use of the absorbed knowledge (transformation and exploitation). These capabilities lie in the organizational routines and processes of a firm. The complementary role of potential and realized absorptive capacity suggests that firms may have different performances due to the distinction of each capability. Firms with high PACAP but low RACAP may not achieve a competitive advantage. Firms with high ability of PACAP may be able to notice the changing trends and be able to acquire and update their stock of knowledge. Lane et al., (2006) adopted the notion that absorptive capacity is an ability, implying the process perspective and defining absorptive capacity into three sequential learning processes: exploratory, transformative, and exploitative learning. (1) Explorative learning denotes the ability to recognize and value external knowledge (2) Transformative learning implies an ability to assimilate external knowledge, and (3) Exploitative learning refers to the ability to utilize and create new knowledge within a firm.

There is some concern with respect to the measurement of absorptive capacity, particularly using innovative activities such as R&D intensity or patents as an indicator. The early study of absorptive capacity by Cohen and Levinthal (1990) suggests R&D activities as a measurement of prior knowledge or absorptive capacity. Moreover, absorptive capacity is a byproduct of such R&D activities. When the new required knowledge is complex, the more critical R&D investment is to develop an absorptive capacity to learn new knowledge. A firm that increases its ability by conducting R&D can also utilize knowledge produced by others, such as universities or research institutions.

Zahra and George (2002) described absorptive capacity as a dynamic capabilities which should involve organizational routines and processes, however in their study they still suggested R&D as a measurement. Using R&D expenditure as a measurement is criticized because it is static while absorptive capacity is perceived as a process or capability (Lane et al., 2006). The study by Lane et al., (2006) that reviews studies with respect to their absorptive capacity construct suggested that recent studies mostly deviate from Cohen and Levinthal (1990) in using R&D expenditure as a construct to view absorptive capacity as a dynamic capability.

Identifying absorptive capacity as an ability suggests that the construct would involve processes within an organization. Lane et al. (2006) further suggested that the measurement of absorptive capacity should be explored beyond the R&D dimension and capture absorptive capacity as a dynamic capability. Hence the constructs could be further explored with respect to each dimension as a process in a non-R&D context.

Attempts to measure the absorptive capacity of a firm primarily use innovation inputs and outputs as indicators such as R&D intensity, the number of patents, R&D employees (Cohen & Levinthal, 1990; Mowery et al., 1996; Muscio, 2007). However, the use of innovation input and output such as patents constitute a redundancy in empirical research; for example, the measurement of absorptive capacity and its outcome both use patents as dependent and independent variables in other research (Lane et al., 2006). The other concern is using R&D activity as a proxy, constituting the unidimensional view of absorptive capacity as a knowledge ability and disregarding other abilities such as management.

This concern leads to the development of absorptive capacity measurement beyond innovation activities measurement. Camisón and Forés (2009) developed variables using a process perspective to measure absorptive capacity based on reconceptualization by Zahra and George (2002) , namely potential and realized absorptive capacity. This study adopted a concept of absorptive capacity as a dynamic capability that links the ability with the organizational routines and strategic processes that allows firms to capture and manage external knowledge for their competitive advantage. The multi-dimensional measurement Likert scale was developed to have firm's manager reflect the ability of a firm to acquire, assimilate, transform and apply new external knowledge. The scale validity was tested with 952 Spanish industrial firms in fourteen sectors and four size groups (micro, small, medium, and large firms). It was found that the scale developed met the confirmatory factor analysis, demonstrating the scales' reliability, validity, and dimensionality. Flatten et al. (2011) also incorporated the idea of absorptive capacity as a dynamic capability and developed a validated scale for measuring absorptive capacity. These constructs development capture the organizational processes that occur within a firm based on a reconceptualization of absorptive capacity by Zahra and George (2002) that divide absorptive capacity into four complementary processes. The scale measured four processes: acquisition, assimilation, transformation, and application. This study developed scale items using four research streams, organizational learning, strategic alliances, knowledge management, and resource-based view, to develop a measurement for each process. The final test of the constructs was tested by 646 firms in research-intensive industries, namely mechanical, chemical and electrical engineering in Germany. It was found that a set of fourteen items classified into four dimensions utilizing a Likert scale can be applied to measure absorptive capacity. Together these studies provide multi-dimensional constructs to measure absorptive capacity with emphasis on organizational processes rather than innovative capabilities.

The study of the antecedents, which allows researchers to understand the key drivers of absorptive capacity or how a firm could increase its absorptive capacity, has also been empirically explored. Several studies suggest the role of absorptive capacity as a mediating role by exploring its antecedents and the impact of absorptive capacity on innovation performance. Zahra and George (2002) introduced the antecedents of the absorptive capacity concept by suggesting that the diversity of external knowledge sources may impact the level of PACAP. The antecedent refers to the firm's past experience in technology search, which implies that PACAP is a path-dependent capability and can have an influence by the previous knowledge search experience. For RACAP, social integration or a process that improves interaction within a firm may increase the knowledge-sharing activities, increasing the application of knowledge. The concept with respect to antecedents of absorptive capacity is empirically investigated by several studies (Ferreras-Méndez, Fernández-Mesa, & Alegre, 2016; Fosfuri & Tribo, 2008; Jansen, Van, Bosch, & Volberda, 2005).

Fosfuri and Tribo (2008) studied antecedents of absorptive capacity, particularly potential absorptive capacity (PACAP), and its impact on innovation performance. The study employed interaction with external knowledge sources and experience with knowledge search as antecedents of PACAP. Based on the reasoning that innovation development process includes internal knowledge and acquisition of external knowledge, thus it is an essential part of innovation capability. Fosfuri and Tribo (2008) explain PACAP as a path-dependent ability that could accumulate through organizational experience-based learning.

Factors that influence the development of PACAP are interaction with external knowledge sources and organizational experience with knowledge search. An example of interaction with external knowledge sources includes a knowledge-related relationship between firms and industry or academia. The more intense the relationship a firm has with partners, such as in R&D collaboration or licensing, the more the firms gain by experiential learning and identifying sources of knowledge to support the firm's competitive advantage. Experience of knowledge search refers to the past organizational experience in knowledge searching that influence how firms would search and how firms identify and assimilate such knowledge. The study used the importance of external knowledge flow to measure PAC, which is a dependent variable, and interaction with external knowledge sources, namely contract R&D and R&D collaboration, as independent variables. As for knowledge search experience, it is measured by firm's stock of nonexpired patents. It was found that interaction with external sources of knowledge, mainly via R&D collaboration and knowledge search experience, has a significant impact on potential absorptive capacity and, subsequently, innovation performance.

A similar concept to antecedents of absorptive capacity concerning an interaction with external knowledge sources is also discussed as the knowledge search strategies. The concept of external search strategies was developed by Laursen and Salter (2006) to investigate why some firms' innovation performance is different from others. Searching strategies refer to how firms develop external linkage to different sources of knowledge due to the insufficiency of internal resources. The external search process includes open-search breadth and open-search depth; the concept follows the previous theories relating to network and open innovation. It emphasizes the role of networks and linkage in supporting firm's innovation performance since exploiting only internal R&D may be insufficient.

Laursen and Salter (2006) used a sample of UK-based firms and found that searching broadly and deeply can impact a firm's innovation performance. The difference in searching strategies explains why some firms achieve greater innovative performance. Laursen and Salter (2006) also explore the influence of search strategies on absorptive capacity by identifying absorptive capacity as a variable complementary to innovation performance. The ability to search widely or deeply may impact a firm's ability to adapt to change. However, firms can be trapped in over-searching activities from both external search breadth and external search depth and become a disadvantage in innovation performance. Searching broadly can be time-consuming, and investing deeply in external resources requires adequate resources.

Ferreras-Méndez et al. (2015) advanced the study of Laursen and Salter (2006) by incorporating the concept of searching strategies to explain innovation performance by using absorptive capacity as the mediating variable. The notion of using absorptive capacity as a mediating variable comes from studies showing that the acquisition of external knowledge does not directly lead to innovation performance. However, it required organizational processes to incorporate and apply such knowledge for commercial purposes. This study captures absorptive capacity as a dynamic capability and measures it using a process perspective. The measurement of absorptive capacity used organizational activities concerning three learning processes, namely exploratory, transformative and exploitative learning, based on Lane et al. (2006) as constructs. This is different from the previous study by Laursen and Salter (2006) that used R&D as a proxy for absorptive capacity. The proxy for the external search breadth used several search channels, including eight external partners that firms engage with to explore knowledge such as customers, suppliers, competitors, etc.

External search depth used the intensity of interaction that firms have with the previous external sources as a proxy and measured the intensity using an eight-point Likert scale. This study used a sample of Spanish biotechnology firms and found that intensive interaction with a limited number of partners or the effect of depth influences learning processes of absorptive capacity. The study confirmed the role of absorptive capacity in mediating innovation and firm performance levels.

In 2016, Ferreras-Méndez et al. (2016) investigated further concerning a direct relationship between searching strategies and absorptive capacity to confirm the role of absorptive capacity as a pre-condition ability to capture the maximum benefit of external knowledge before converting knowledge into innovation performance. The study focused on factors that influence absorptive capacity development by using a sample of 467 Spanish manufacturing firms ranging from high-tech, middle-tech, to low-tech firms. They employed multiple regression analysis to explore the effect between breadth and depth searching strategies (independent variables) on learning processes of absorptive capacity (explorative learning, transformative learning, and exploitative learning). The two control variables also include firm size and environmental turbulence, such as the uncertainty in the market and technological change, which could affect a firm's decision to search for external knowledge. The study found that searching widely and deeply significantly impacts explorative learning. The result implies that having broad relationships with several partners allows firms to access a variety of knowledge and invest in deep relationships with external partners, which also supports firms in transferring external knowledge and information. As for transformative learning, a deep relationship with external sources can support firms in internalizing the knowledge retrieved.

The time that partners spend together developing co-specialization in information or language results in effective communication between partners (J. H. Dyer & Singh, 1998).

Furthermore, when firms would like to exploit knowledge, it is found that both broad and deep relationships positively affect the firm’s exploitative learning processes. However, the study also investigates the possible effect over search activities have on three learning processes. The results show interesting implications that when firms spend too much time and resources on external partners, it may negatively affect the firm's absorptive capacity. In summary, firms need to develop a relationship or collaborate with external partners to acquire the necessary knowledge and bring it into use, but when firms search widely or deeply this may influence a firm's absorptive capacity differently.

To sum up, absorptive capacity is an important ability that supports firms in coping with technological change or industry changes. Having high absorptive capacity allows firms to recognize where to search for knowledge, assimilate new knowledge into the firm's repository, transform new knowledge and integrate existing knowledge and finally exploit new knowledge for the firm's commercial purpose. These internal learning capabilities are a prerequisite that helps translate knowledge into innovation performance.

2.6 Conclusion

It has become evident that global climate change leads to large-scale changes, such as the global need for sustainable technologies in several industrial sectors. The automotive industry is one of the major industries that is facing the challenge of technological transitions in responding to the climate change problem. However, the change does not only involve a single transition in technology, but transitions intertwined with other changes such as user practices, policy, and regulations, infrastructure. This study employed a multi-level perspective as an analytical lens to explore the socio-technical transition in the automotive industry, particularly the shift that involves a technological change from internal combustion engines to electric vehicles. The multi-level perspective helps explain the transition that occurs as a result of the dynamic interaction between socio-technical levels, i.e., landscape, regime, and niche. The most important is the socio-technical regime level representing the established system that tends to prevent changes due to its stability. Regime stability comes from various elements that are linked and aligned. One of the significant obstacles to transition seems to come from the incumbent's firm that has already invested a large sum of capital and assets, including accumulated knowledge, into developing existing technologies. The emergence of new technologies is believed to be generated in a bottom-up manner or from niche level and new entrant actors. For niche development to emerge depends on regime stability and the exerting of pressure from the landscape to the regime. However, technologies developed from niche can be co-existed with the dominant regime, as in the automobile industry case. Alternative energy such as biofuel, hydrogen, or electricity is currently co-existed with the regime technology, i.e., the internal combustion engine.

New research suggests the incumbent actors' role in supporting niche development as a way to adapt and diversify their activities from the original sector. Government policy intervention plays a vital role in supporting incumbent actors to respond to changes in a mobility regime due to the economic contribution of the automotive sector in terms of GDP and employment contribution. Thus, this study is interested in firms adjusting to engage in new technology development to maintain their competitiveness. Based on the assumption that firms are locked-in to existing technologies, the study of a firm's technological learning could provide direction for firms to cope with the transition challenges and also provide policymakers with the point of intervention. Technological learning is the basis of the technology capability development which is necessary to build a firm's competitive advantage. Technological learning is an essential process in accumulating knowledge either from within firms, such as by conducting internal R&D or external to firms by collaborating with partners such as suppliers, customers, government labs, universities, etc. However, scholars believe that to stay competitive in a world where technology is changing rapidly, internal knowledge alone is insufficient and acquiring knowledge from external sources is crucial.

Furthermore, not all firms can conduct in-house R&D activities by themselves, particularly SMEs. Knowledge networks are proven to provide complementary resources to internal knowledge and lead to innovative capabilities. However, not all types of partners would lead to the same results. Several studies investigated the pattern of collaboration between inter-firm knowledge networks and triple-helix knowledge networks and found that triple-helix knowledge networks may provide firms with radical innovation while inter-firm networks deliver incremental innovation.

Acquiring external knowledge from a knowledge network requires another element: an absorptive capacity or learning ability; this ability would allow firms to internalize inter-organizational learning. Absorptive capacity can be deemed a dynamic capability that allows firms to adapt themselves to changing circumstances, particularly technological changes in the socio-technical transition. This learning ability would lead the firm to identify a variety of external knowledge sources necessary for a firm to adjust or diversify the firm's strategy and later exploit such knowledge. Government policy can support the technological learning processes of firms in the transition, particularly in supporting the development of a triple helix knowledge network. In Chapter 3, learning processes and collaboration with the knowledge network of firms in the Thai automotive industry are reviewer.

CHAPTER 3
Research context: Overview of the Thai automotive and parts industry and the development of electric vehicle industry in Thailand

This chapter aims to provide the context of the Thai automotive and parts industry, focusing on industry structure, the status of the firm's technological capability, and the technological learning approach of the industry. This chapter also provides the context of the advent of electric vehicles, showing how the change in technology, particularly to vehicle parts, would impact firms that produce conventional vehicles and parts. The policy support for the production and the use of electric vehicles is also explored to provide a view of the possible transition from employing internal combustion engines to electric mobility in Thailand.

This chapter is divided into six sections. Section 3.1 describes the introduction and background of the Thai automotive industry. Section 3.2 explained technological capability of firms in the automotive and parts industry. Section 3.3 describes the global challenge of electric mobility entrance and its impact on automotive and parts industry. Section 3.4 presets the impact of EV entrance on the Thai automotive and parts industry. Section 3.5 reviews related Thai policies support and key EV statistics. And the last section is the conclusion of this chapter.

3.1 Introduction: The development of the automotive industry in Thailand

The issue raised by this research study is particularly crucial to the automotive industry in Thailand, which is the main industry with a significant contribution to the country's economy. Thailand is a global automobile production hub for multi-national companies (MNCs) throughout Southeast Asia. Automotive is the second-largest sector in terms of foreign direct investment (FDI), which has amounted to over 7,000 million USD in the past ten years. In 2018, Thailand was the 12th largest car producer in the world. Moreover, The Thai automotive industry has been a major contributor to the national GDP, being the third rank, accounting for 10.7% of Thailand's GDP or approximately forty-four billion GBP. In 2017, the export value of this industry was ranked 1st in the world with the value amounting to over 28 billion USD[2]. Internationally, the top producing countries account for 90% of global production, and in 2018, Thailand took up about 2.06% of the global market. According to Figure 3.1, the capacity to produce cars each year from 2012 is approximately 2 million cars per year, of which over fifty percent are for the export market and the rest for domestic consumption. The industry also accounted for a vast number of employments, about 850,000 jobs, accounting for 5.5% of Thailand's employment. Automobiles and parts are the second largest export products of Thailand, valued at approximately 37,723 million USD in 2018 (See Figure 3.2). The main export products of the industry are completely built unit (CBU) and auto parts.

[2] Statistical data of Thai automotive industry derived from Ministry of Commerce

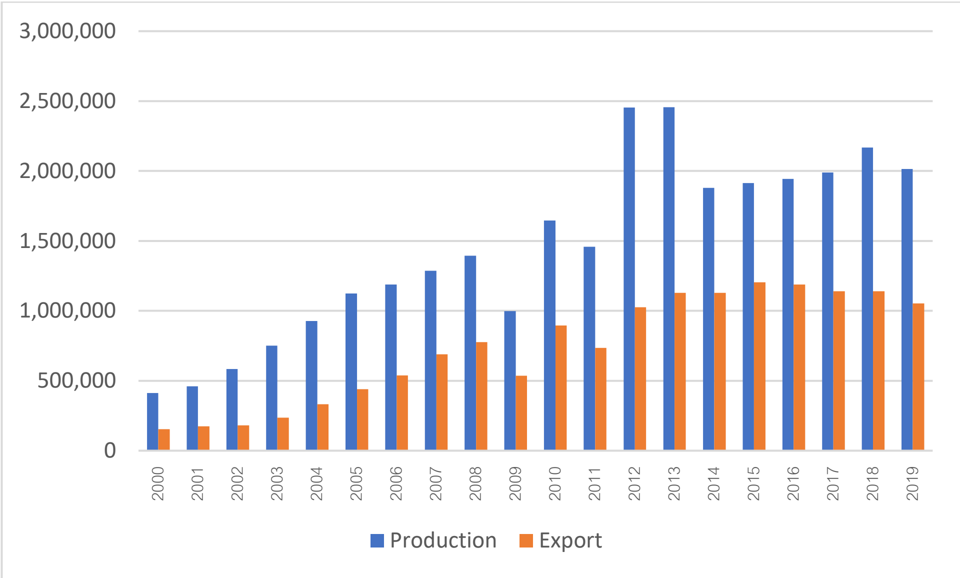

Figure 3.1 Production capacity and export volume of automobile from 2000-2019 (Source: Author adapted from data of The Federation of Thai Industries)

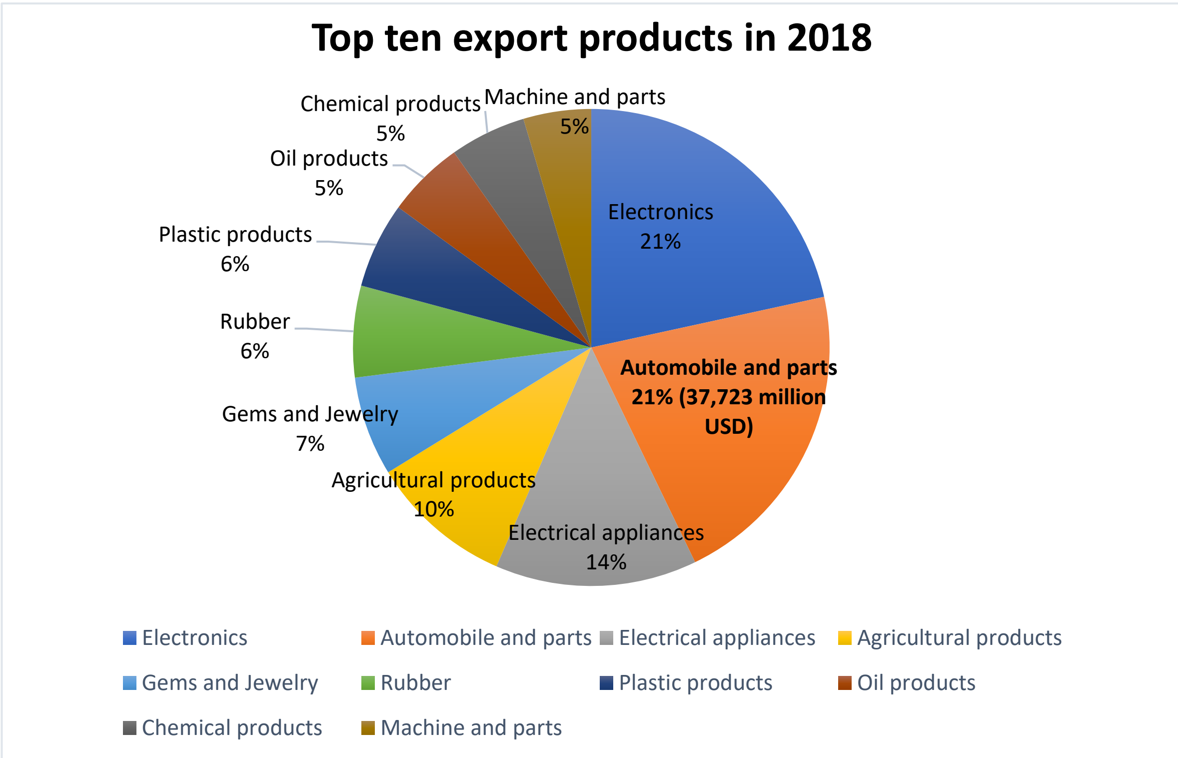

Figure 3.2 Top Ten export products of Thailand in 2018

The Thai automotive industry was established in 1961 according to the country's investment promotion policy. Beginning as an import substitution industry to stimulate the domestic production, the Thai automotive and parts industry established its root in Thailand six decades ago. Prior to the establishment of the industry, Thailand needed to import full-assembly vehicles from abroad.

Multi-national car manufacturers from Japan, Europe, and America established their production plants in Thailand to initially serve the domestic market. The Thai automotive and parts industry is mostly dominated by the leading Japanese automakers that shifted their production base to Thailand during the 1970s.

Later, the industry shifted towards being export-oriented and eventually became a regional production hub in Southeast Asia. The development of the Thailand automotive industry can be divided into three major phases according to the technology development stages, 1) Thailand 2.0: local production 2) Thailand 3.0: Production base, and 3) Thailand 4.0 Innovation base.

(1) The first phase: Local Production (1965-1997), begins with an objective of import substitution and reducing the amount of trade deficit from importing foreign technologies. As a result, several multi-national enterprises started investing in Thailand, where the local production of simple auto parts takes place. Afterward, to also enhance local industry competitiveness, the government imposed a local content policy in 1972 by mandating twenty-five percent of local content and increased it to fifty-four percent during 1987-1997. During this period, local suppliers were established and proliferated to support the production of foreign car companies. In this period, the investment had increased dramatically due to the strengthening of the yen in 1991-1992, which caused Japanese automakers to relocate their production base to Thailand. And in 1997,

during the Asian financial crisis, the government relaxed the ownership rules by allowing a majority of a foreign shareholders in Thai companies. This leads to the proliferation of foreign carmaker companies in Thailand and Thailand also positioned itself as the "Detroit of Asia"

(2) The second phase: Production base (1998-2016) is considered a substantial exportation period of the Thai automotive industry. The government emphasises a foreign direct investment policy to draw capital from abroad and focus on exportation. From serving the domestic market, in 1996, the industry began to move towards being export oriented. The increase in the number of export from 1996 - 2000, from 14,000 units (vehicles) to 152,800 in 2000, has changed the industry structure dramatically (Kohpaiboon, 2007). From the 1990s onwards, Thailand has become a crucial exportation base of the Southeast Asia region due to the trade liberalization policy. The joining of the World Trade Organization (WTO) and the signing of the Free Trade Agreement (FTA) increased foreign direct investment. Despite the Asian economic crisis in 1997; the depreciation of the Thai currency and the overcapacity truly resulted in an increase in exportation. In 2013, Thailand was in the top-ten rank of automotive global production countries with the capacity to produce over two million cars. The main export product was completely built-up (CBU) vehicles. There are two product champions: one-ton pick-up truck parts production and eco-car. During 1997-2007, the One-ton pick-up truck is the main product manufactured in Thailand, approximately seventy percent of the total production. Thailand has become the second largest production base for one-ton pick-up trucks after the US. In comparison, passenger car is approximately thirty percent of the total production. The change in environmental trends brings Thailand to produce another product champion. In 2009, Thailand introduced the "eco-car" as a second product champion

which is an international standard energy-efficient vehicle. The major exportation destination for the Thai automotive industry is Asian countries and Oceania, such as Australia, the Philippines, Vietnam, Japan, New Zealand, and China. One-ton pick-up truck is the major export item, followed by passenger cars. The Thai automotive and parts industry is mostly located in the industrial districts in the central and eastern part of Thailand.

(2) The innovation phase (2017 onwards): Thailand is facing a challenge of upgrading the automotive and parts industry from being only a production base to offer high value-added activities such as design and R&D. Being a global production base, although it creates economic prosperity, Thailand is still a middle-income country. With the change into the fourth industrial revolution worldwide and the environmental trends, Ministry of Industry introduced a twenty-year roadmap for the industry 4.0 model and ten S-curve industries. Thailand's 4.0 model incorporates innovation as a driver of the economy, moving from a productivity-driven to an innovation-driven economy to overcome the country's middle-income trap problem. Ten industries were selected as the targeted industries, including the next generation automobile covering automotive and auto parts production and components for hybrid and electric vehicles. In 2017, the cabinet approved policies supporting the production of electric vehicles in Thailand. Thus, during this phase, the industry has to raise its technological capabilities for the future industry. At present, Thailand does not possess proprietary knowledge of internal combustion engine technology. The transition into electric mobility could offer both threats and opportunities to firms in the automotive and parts industry.3.2 Structure of Thai automotive and parts industry

The structure of the industry is hierarchical. It consists of MNCs (assemblers/automakers), foreign and local large enterprises (First tier), and local small and medium enterprises (SMEs) (Second and Third Tier). In 2019, 18 car assemblers were all MNCs. Firms in the first-tier supply five main components, which are functional parts to assemblers, i.e., chassis, powertrains, electrical & electronic, body, and other parts, while second and third-tier firms supply related parts to first-tier firms. In 2019, there are approximately 523 first-tier suppliers. Local SMEs are second and third suppliers, and represent about 1,700 firms, as illustrated in Figure 3.3. Most car producers are dominated by multi-national companies, mostly Japanese car companies and a few American and European companies. First-tier firms are also predominantly foreign companies and joint ventures, while lower tiers are Thai suppliers that supply non-functional parts.

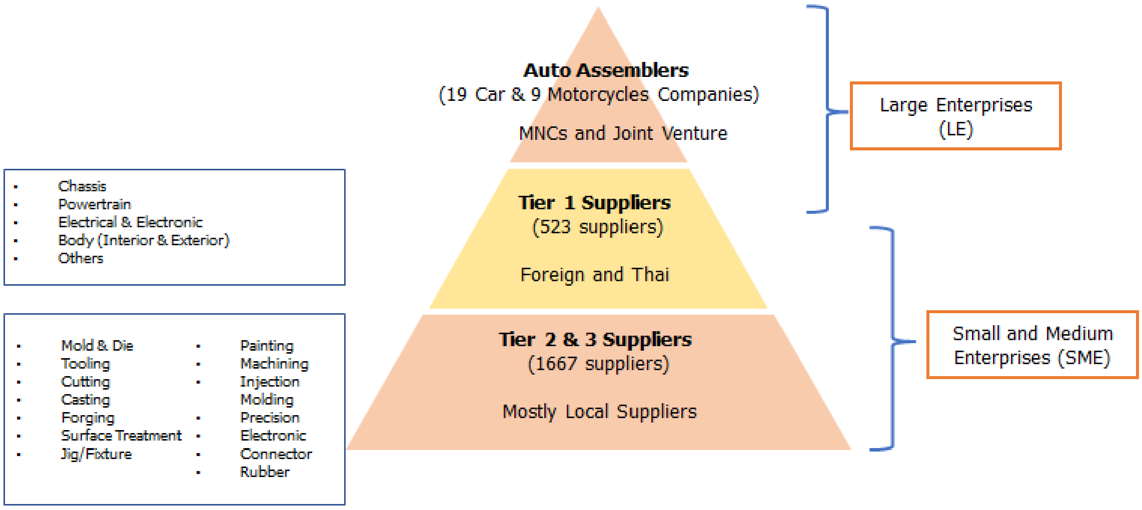

Figure 3.3 Structure of Automotive Producers 2019
(Source: Thailand Automotive Institute)

The auto parts industry is a supporting industry of the automotive industry. The localization policy in the 1970s helped develop the establishment of the local auto parts industry. Approximately eighty percent of parts produced in Thailand are supplied to the domestic car and motorcycle production. Passenger cars contain approximately 60-80% of locally-produce parts. Eco-car type uses domestically produced parts up to 90%. The market type of the auto parts industry can be categorized into two segments,

1) Original Equipment Market (OEM), in which parts suppliers provide parts to global carmakers or tier 1 firms; this market accounted for approximately 30-40% of the auto parts market. The rest of the imported parts are sophisticated parts that depend on the high technology of carmakers' parent companies or suppliers.

2) Replacement Equipment Market (REM) is a market to replace wear and tear parts. This market represents 60-70% of the parts market. The distribution of REM goes to aftersales service centers, wholesalers, retailers, or garages.

Besides the exportation of CBU, Thailand is also a significant exporter of auto parts. In 2019, the total export value was approximately 20,000 million USD, accounting for nine percent of the country's total export value. The main export products are original equipment (OEM), engines, spare parts or REM, and body parts.

According to Thailand Automotive Masterplan, the structure of the parts and component industry can be divided into five categories, namely 1) power train, 2) suspension, 3) electrical and electronic 4) body and 5) other. Using the tier system, we can categorize components produced by each tier as shown in Table 3.1. Tier 1 supplies functional components such as engine system, power train, suspension, brake, and electrical system to car manufacturers. And tier 2 and 3 provides other non-functional parts and accessories to the tier 1.

Table 3.1 Automobile Parts According to Firm's Tier manufacturing and number of workers producing parts

Tier 2 and 3	Tier 1	Assembler
Stamping, Plastics, Rubber, Machining, Casting, Forging, Electrical, Trimming ⇨	Vehicle parts includes Engine, Power train, Steering, Suspensions, Brake, Wheels, Tires, Bodyworks, Interiors, Electronics and Electric systems ⇨	Passenger Car Pick-up
Parts Manufacturers 450,000 workers		100,000 workers

Later in this chapter will discuss in detail which parts suppliers would be affected by the production of electric vehicles including the introduction of new parts that would substitute conventional vehicles.

3.2 Technological learning and technology capability of firms in the Thai automotive and parts suppliers

Thailand was considered a latecomer country meaning that the development of industry and technological capabilities of firms are dependent on technology that had developed in advanced economies. Thailand saw a lack of capital and technology during the early stage of industrialization, so attracting foreign direct investment (FDI) is the mean to develop local industry and promote economic development. The Thai automotive and parts industry is considered an FDI lead industry, which draws a significant investment from multinational corporations (MNCs) to Thailand. Thailand's government does not have the policy to develop a national car brand but instead attracts transnational companies employing industrial policy to establish manufacturing plants in the country. The automotive industry is both a capital-intensive and technology-intensive industry. Thus, the establishment of the Thai automotive industry primarily brought in capital investment, and the indirect benefits were the technology transfer and skills development of the local industry (Techakanont & Terdudomtham, 2004).

One of the primary factors contributing to the development of technological learning and technological capability of local firms is government policies supporting the development of the local industry. Policy plays an essential role in establishing the Thai automotive and parts industry. Thailand succeeded in establishing a local auto parts industry and developing local firms' production capability. The country employed several policies, such as tax and industrial policies to protect and develop the local auto parts industry. The most impactful policy that helped root the local auto parts industry was local content requirements (LCRs). The LCRs policy demands that a specific number of automobile components must be produced locally.

During 1971-1986, this was a localized period that aimed to promote auto parts produced locally. The use of LCR policy was in effect in 1974 by requiring that the production of passenger cars must contain twenty-five percent of local contents. Before LCRs, Japanese component makers were already established in Thailand. With LCRs, automakers need to purchase locally built auto parts. In 1982, The requirement was raised significantly to forty-five percent and subsequently to the highest rate of fifty-four percent in 1986. The requirement for the country's product champion, a one-ton pickup truck was raised to the highest rate at seventy-five percent. To support the effectiveness of the LCR policy, the ban on a completely built unit (CBU) or a ready-to-use car and the increase of tariff on completely knock down (CKD) were also in place. During the period of local content requirement, the number of local assemblers and local suppliers increased significantly. However, as Thailand joined the World Trade Organization (WTO), the country's commitment to non-discrimination against foreign products led to the abolishment of local content requirements in 1999. The local content requirement policy evidently promotes local firms' establishment and production capability.

Technological learning in the emerging economy may occur in several ways, such as learning by doing, learning by imitation, and learning by reverse engineering (Guo & Guo, 2011; Moeini & Zawdie, 1998). The sources of technological learning can be from international sources, domestic sources, and internal efforts (L. Kim, 1997). However, technology transfer from foreign companies to local suppliers has been a significant factor that helps develop the technological capability of local firms. MNCs bring capital investment, skills, and technologies to the host country. Suppliers or subcontractors of MNCs can receive production technology from their customers.

The transfer of technology can occur through formal and informal mechanisms, formal technology transfer mechanisms such as joint ventures, technology licensing, and technical assistance agreements. The informal mechanisms occur through being subcontractors and receiving technology transfer and technical support from customers.

Thai automotive and parts industry has been dominated by primarily Japanese automakers. Japanese Automakers such as Toyota and Nissan established manufacturing plants in Thailand during the 1960s. The appreciation of the yen also brought a shift of auto production based in Japan to Thailand. They also brought along first-tier suppliers located in Thailand to minimize importing costs. However, due to the local content requirement, automakers must also acquire components from local firms.

Local firms' technological learning and capability has been developed through manufacturer-supplier relationships. Local companies and subsidiaries are subcontracting original equipment manufacturers (OEMs) of multinational corporations. Generally, the knowledge linkage between MNCs and domestic firms was established through subcontracting agreements (Punyasavatsut, 2008). Technology transfer occurs based on a customer-supplier relationship through advising and information sharing (P. Intarakumnerd & Techakanont, 2016).

Customers are one of the most critical learning mechanisms for firms, as attempt to meet the demands of customers leads firms to upgrade their technological capability. Firms that have a good relationship with customers can exploit know-how relating to work processes or sometimes even product development. In the Thai automotive industry, MNC car assemblers and their first-tier suppliers mostly occupy core knowledge of the industry. The learning, on occasion, takes place through a technical assistant in suppliers' factories or a training team in which carmakers or higher tier firms send their team of engineers to train engineers and technicians at the suppliers' factory (P. (Ed.). Intarakumnerd, 2011). Technology assistance provided by car producers to their suppliers plays a vital role in advising the company in supporting firms in implementing a new process or product technologies and ensuring the efficiency to meet customer's demand. Intarakumnerd (2011) shows that large firms that have relationships with foreign firms would employ technology assistants of customer's firms to transfer innovative technologies required by a customer.

Firms in the first tier, which mostly are foreign firms or joint ventures, have the highest ability to win exclusive contract from automakers and to supply major components to car producers. They have a better learning opportunity to learn directly from car producers than firms in lower tiers (Samarnbutr, 2012). Thus, most of the technological learning of first-tier firms occurs through the transfer of knowledge from customers to suppliers' firms which are their parent companies, or through the setup of a joint venture.

The knowledge sharing between customers and suppliers in the automotive industry also occurs through network-level learning. Leading Japanese carmakers such as Toyota developed their knowledge-sharing system called Toyota Cooperation Club (TCC). TCC helps a network of suppliers strengthen their capabilities by sharing explicit knowledge with member suppliers who have a long-term relationship with Toyota. Suppliers of Toyota need to implement a production management system called "Toyota Production System" (TPS), which required specific management capabilities to meet Toyota's needs, such as a just-in-time delivery system. TCC members are entitled to receive a free consultation and knowledge from engineer experts at their plants. This system creates an open atmosphere within the supplier's network and allows Toyota's suppliers to share best practice with each other.

During 1970-1990, the technology transfer to first-tier suppliers covered establishing a production facility. Foreign engineers undertook the designing and the setup of the production process, and the local staff were later trained to operate the machine and perform quality control. This implies that activities during the early stage of the industry that are performed by local staff are limited to operational activities. After 1990, first-tier suppliers required more than operation and quality control abilities , including process engineering and design abilities. In 2000, car assemblers incorporated a global sourcing strategy into their operation, which required good parts and the lowest price. Integrating into the global production networks impacts the improvement of suppliers' technology capability in the Thai automotive and auto parts industry. The production networks set out that the sourcing of components is open to any suppliers who can provide the components at the given quality and price (P. Intarakumnerd & Techakanont, 2016). MNCs no longer provide suppliers with design blueprints which imply that suppliers need to develop their design capabilities. This strategy required higher technological capabilities from part suppliers, particularly design ability and product engineering. However, the same system also forces unqualified suppliers to move from first-tier suppliers to lower tiers. After the 2000s, MNCs; Toyota, Nissan, Isuzu, and Honda, began to increase sophisticated activities in Thailand by setting up R&D and technical centers since Thailand is their regional export hub. The activities include advanced engineering, process, and product design, and advanced testing (Lee, Wong, Intarakumnerd, & Limapornvanich, 2020).

Technology capability of auto parts suppliers can be distinguished based on tier level. First-tier suppliers are mostly subsidiaries of automakers and some large Thai firms responsible for supplying high-technology engines. Second-tier suppliers are sub-contractor of first-tier suppliers and provide less sophisticated parts, such as body parts, and rubber parts. Third-tier suppliers supply low-value-added parts that do not require high technology (Samarnbutr, 2012). In General, foreign suppliers are asked to supply critical components to carmakers, while local supplies provide other peripheral parts with low value added.

Second and third-tier firms that are primarily Thai suppliers, unlike first-tier firms, lack an opportunity to access know-how from carmakers because of an inability to win supplier contracts. Thai suppliers' technological capability mainly focuses on a basic level of product and quality control (Samarnbutr, 2012). Lower tiers supply non-sophisticated parts to the first tiers; the learning approach occurs between the first tier and lower tiers through bilateral relationships. Learning channels of lower tiers mostly take place through technical support by training at their plants, seminars at a first-tier plant, or providing codified knowledge such as manuals. The most effective approach seems to be the visit of technicians or engineers at second/third tier plants to provide tacit knowledge due to technological capability heterogeneity and learning ability (Punyasavatsut, 2008). Evidently, linkage and knowledge transfer between first tiers and lower tiers exist. However, the problem of lower tiers in technological learning comes from the low absorptive capacity and willingness to learn and upgrade their product and process (Scott-Kemmis & Chitravas, 2007).

Besides inter-firm learning, technological learning of domestic suppliers that are mostly SMEs may also occur within firms employing a firm's internal effort such as training, the acquisition of new machinery, hiring of experienced employees, or the accumulation of experience of employees. Lall (1992) described technological learning as an accumulation of a firm’s experience in problem-solving coupled with an external source of input or a firm’s research and development. This concept emphasized the firm’s input and internal effort before external output.

A study of Techakanont and Terdudomtham (2004) shows that internal efforts and building employee experience are the fundamental learning approaches for firms to develop their technological capability.

Ownership also influences the firm's technological learning; firms with foreigners as a majority may have a better opportunity to receive intensive technical support from their foreign partners. Techakanont and Terdudomtham (2004) explore the case study of a Thai supplier previously owned by a Thai majority and later have Japanese partners who become the majority party, and the learning opportunity has increased noticeably. There was an increase in the number of Japanese expatriates providing technical advice and installing a new production line as a long-term plan to support the auto assembler to meet future demand, technology which would not be feasible to acquire without a Japanese partner. Companies in the auto parts industry, particularly in the first tier, are approximately forty percent foreign companies and joint venture companies, so are therefore prone to more advanced technological learning opportunities. However, it is worth mentioning that the liberalization of ownership that allowed foreign firms (majority foreign-ownership > 50%) to establish in Thailand after 1997 resulted in a proliferation of foreign-owned suppliers. Thus, technology transfer is sometimes still limited to foreign-owned firms more than locally owned firms.

Despite the long-term establishment of the automotive industry in Thailand, local supplier firms' technology capability is still confined to the basic and intermediate levels (Gerdsri, Teekasap, & Virasa, 2012; P. Intarakumnerd & Techakanont, 2016; Sadoi, 2010). Most of the local suppliers have exceptional production capability, however, the advanced ability relating to R&D capability is still extremely limited (Samarnbutr, 2012). Lall (1992) defined technological capabilities as an investment and production capability and categorized technology capabilities into three-levels: basic or routine, intermediate or adaptive, and advanced or innovative. Basic capability refers to routine capabilities such as quality control, maintenance, or minor adaptation of a product; intermediate refers to the ability to adapt to an existing process or product improvement; innovative capability refers to basic research and design ability or in-house process or product innovation.

A study by Sadoi (2010) investigated the technology capability of supplier firms in Thailand, focusing on five abilities to serve the requirement of car assemblers, namely, quotation making, supplier drawing, prototype making, die and tool making, and technical follow-up. Four types of firms were investigated based on the firm's ownership, i.e., Japanese-owned firms, Joint-ventures, Thai-owned firms with technical assistance, and Thai-owned firms without technical assistance. The result shows that Japanese-owned firms, joint ventures, or those receiving technical assistance from Japan conducted most of the required activities in Japan or they were performed by Japanese engineers. For Thai-owned firms with the foreign technical assistance, they perform the quotation making and dies and tool process by themselves locally. Interestingly pure Thai-owned firms undertake most of the activities, namely quotation, prototyping, and capability to reduce defects and raise efficiency, except for drawing, which is not a requirement for pure Thai firms; Japanese engineers perform the drawing of parts. This study shows that ownership structure and relationship with Japanese firms play a crucial role in dominating supplier firms' activities. However, the independent Thai firms also show increased capabilities in conducting quality control and product development.

A study by Gerdsri et al. (2012) explores the technological ability gap of firms in the Thai automotive sector; the sample firms are mostly first-tier firms. Technology ability studied includes investment ability, project management, product, and process organization, product-centered, linkage ability, and capital goods. The results show that surveyed firms still do not reach the ability to develop new products by themselves; the most robust ability is in project management and quality control. A lack of linkage with an academic institution to create new products or processes seems to be their weakness. A study by Intarakumnerd and Techakanont (2016) also confirmed the previous studies that most of the firm's technological capability is at the basic and intermediate levels. Firms that achieve innovation tend to be foreign owned.

Although the implementation of LCRs gives rise to the local auto parts industry, the value-added that local firms have generated is unclear. The measurement of technological upgrading in Thailand still indicates that the value-added components produced domestically are relatively low. Lee et al. (2021) studied the development of the Thai automotive industry compared with China, Malaysia, and Korea, and found that Thailand has provided little local value-added for several decades compared to China and Korea. Using a share of foreign value-added embodied in the gross export (FVA), this measurement denotes the amount of foreign intermediate parts in the export amount. Thus, the higher the FVA, the lower the local value-added. Thailand's ratio of FVA was relatively high, approximately forty percent, from 1995-2011, although the LCR policy was in place. Another indicator is the share of domestic value added embodied in foreign exports of a foreign country. This indicator represents global competitiveness. Thailand had a low ratio of domestic value added to foreign exports, which means most of the exports contain foreign components. Since Thailand has been successful as an exporting country of automobiles, this suggested that the part produced locally only serves the domestic market.

Scott-Kemmis and Chitravas (2007) studied firms' learning strategies and learning mechanisms by interviewing firms from the first tier to the third tier in the Thai automotive industry. This study suggests a framework of a learning system that incorporates a firm's competitiveness and learning strategy, firm learning activities, and a firm’s learning mechanism. This study suggests that firms that can develop their technological capability to deal with technological change but first need to set a specific target of knowledge based on their current capability gaps. The balance between existing capability and the ability to recognize possible opportunities or an absorptive capacity is essential for technological learning, and to develop such capabilities, the balance between internal effort and external knowledge needs to be considered. This study reported that firms that can develop a better linkage with foreign firms resulted in an improvement in their production capabilities.

In contrast, firms that fail to create a linkage with foreign partners take longer to achieve even an intermediate level of production capabilities. Firms were divided into three types, proactive firms, parochial firms, and active firms. The results show that a firm's ability still varies according to its goals and the commitment to implementing its learning strategy. Proactive firms tend to set a clear goal of specific knowledge they need to acquire based on their capability gaps and balance between internal effort and external knowledge. While active firms set an ambitious goal, the actual learning activities were not executed, and they only exploited a partial external source of knowledge discontinuously. The parochial firms do not set a specific target for their knowledge acquisition acquire an external source of knowledge.

Scott-Kemmis and Chitravas (2007) identify three characteristics of strong learner firms, 1) realization of the firm’s capability gaps, 2) set learning strategies, and 3) exploit the external network. Firms that tend to achieve in their technological learning should be able to realize their capability gaps and set learning strategies according to their capability gaps. The ability to make use of linkages with other firms and collaborate with external sources also makes firms a strong learner and able to achieve technological capabilities.

The government is also one of the crucial actors in supporting technological learning and developing the technological capability of firms, particularly the development of human resources. Because the automotive and parts industry is a major industry involving multinational companies and numerous Thai firms, cooperation at the government level between major stakeholders which are the Thai and Japanese government, has been established. One of the crucial programs is the Automotive Human Resource Development Program (AHRDP) initiated in 2006, aiming to develop a skilled workforce in the supplier networks. AHRDP is a bilateral collaboration between Thailand and Japan governments, including the private sectors of both countries. It is led by the Thailand Automotive Institute (TAI) and Japanese partners; Ministry of Economy, Trade, and Industry (METI), Japan chamber of commerce, and four Japanese car producers, namely Toyota, Honda, Nissan, and Denso. The program includes developing training courses such as Toyota Production System, technical knowledge on mold and dies making, and management and skilled manufacturing. Auto parts companies were requested to join this program. Once the training is finished, certification is also issued. However, the result of the program is on a case-by-case basis.

In summary, firms in the Thai automotive industries have developed their technology capabilities to date between basic and intermediate levels. Thailand has created a pool of skilled labour and extensive suppliers' networks to offer being a strong production base for MNCs.

The government intervention in LCRs helps develop advanced production capabilities. The development model is a dependency development that primarily relies on foreign technology. The dependence on foreign technologies has brought the country benefit, particularly as the global production hub of transnational companies. In contrast, the competitive advantage of the Thai automotive industry has been challenged by neighboring countries that compete to be the production hub such as Indonesia, Malaysia, Philippines, and Vietnam. These countries also offer a lower labour-cost compared to Thailand, where wages have increased. To substitute for the rising wages, upgrading to a higher global value chain is considered the next step for Thailand. This should be done by investing in technological learning and developing technological capability to innovate, not just achieve higher efficiency. The technology disruption of electric mobility also creates significant challenges for the Thai automotive and parts industry. New technological knowledge and capabilities to serve the development of the EV industry are required. Firms need to expand sources of technological learning to acquire new skills and technologies to cope with upcoming challenges.

3.3 Automotive and parts industry and the global challenge towards electric mobility: impact on supply chain and production process

Electric mobility is considered a global megatrend. The sustainable environmental trend, the development of technological innovations, and the international policy toward greenhouse gas zero emission support the proliferation of electric mobility. External pressure from the landscape level is one of the catalysts that drive the automotive industry to develop electric mobility. At the global level, several countries commit to the aim of the Kyoto protocol: an international treaty on the reduction of greenhouse gases (GHGs). The GHGs include carbon dioxide (CO_2), which is a major global concern, particularly from the emission of an automobile. Environmental regulation put enormous pressure on the auto industry; in response to such pressure, automobile industry needs to develop vehicles that would be efficient in terms of CO_2 emission.

International Energy Agency report in 2020 identified that the transportation sector is accountable for 24% of CO_2 emissions. The automotive industry is the key industry being disrupted by the arrival of electric mobility. The advent of electric vehicles introduces many changes to the traditional automotive industry value chain, from changes in raw materials, production line, supporting infrastructure, and aftermarket services (Valentine-Urbschat and Bernhart, 2009).

Electric vehicles are vehicles that can be driven partially by electricity and entirely driven by electricity. Electric vehicles can be categorized into four types which are 1) Hybrid Electric Vehicle (HEV), 2) Plug-in Hybrid Electric Vehicle (PHEV), 3) Battery Electric Vehicle, and 4) Fuel Cell Electric Vehicle (FCEV). HEV and PHEV still have a combination of internal combustion engines, while BEV and FCEV are driven fully by an electric powertrain. The main difference between an electric vehicle and an internal combustion vehicle is the powertrain and driving system in which EV will be driven by an electric motor. The power source of the electric vehicle comes from energy storage, or battery pack Sources of energy can be divided into externally generated and internally generated electricity. Externally generated energy will be stored in batteries, without electricity generation within a car which refers to battery electric vehicle type. While on-board electricity generation uses fossil or non-fossil fuel as a source of electricity generators such as petrol or hydrogen, which refer to PHEV and FCEV.

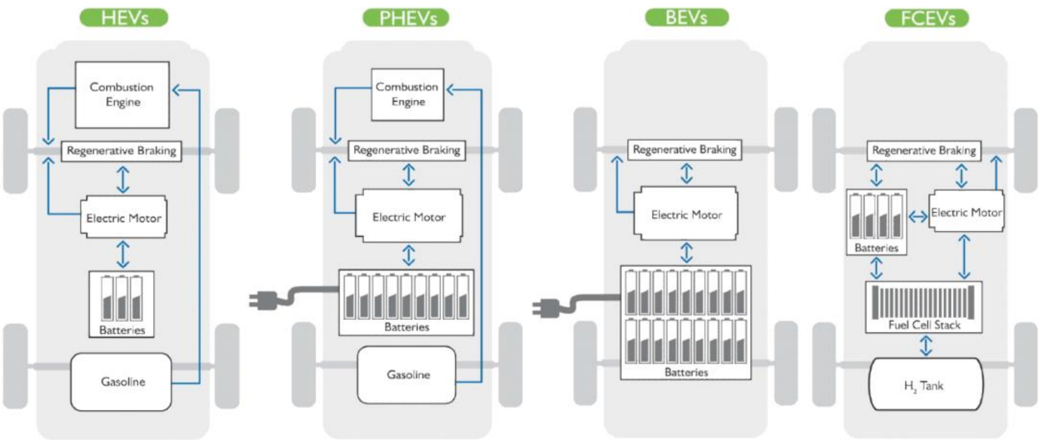

Figure 3.4 Types of Electric Vehicles (Laoonual, 2015)

In fact, electric vehicles are not new to the automobile industry; the development of electric vehicles has preceded gasoline since 1896. But due to the limitation of electric vehicles and the high gasoline efficiency, the internal combustion engine has become a dominant technology (Schot et al., 1994). Through time internal combustion has prevailed and has been adapted incrementally to support the ongoing technology choice. In 2000, an electric vehicle was still considered a niche product. The automobile sector had not yet been affected by rapidly changing technology.

EVs offer several advantages superior to ICE in terms of energy saving, low maintenance, and a solution to environmental problems regarding GHG emissions. But there are some limitations of EV in terms of driving range due to the energy capacity of the battery. However, the development in EV technologies is becoming more advanced and provides future EV with competing ability to ICE. The development of lithium-ion batteries to use with EV instead of the former lead acid batteries helps reduce the primary limitation of EV by increasing driving range and having a lighter weight. The development of charging infrastructure also improved significantly, such as fast-charging infrastructure.

Several car manufacturers that produce traditional internal combustion engines continue to make both conventional and electric cars. However, several countries have a strong international policy signal, particularly the EU, to move towards carbon neutrality in 2050. Banning internal combustion engine vehicles is a targeted policy to achieve carbon neutrality with a specific due date. This led to the proposal for producing fully electric vehicles to come into full operation. Thus, the leading automakers companies have started investing in alternative powertrain technology, i.e., Electric vehicles.

As the automotive industry is experiencing the radical technological change from internal combustion engine (ICE) to electric mobility technology, it will require a new knowledge base and new production processes (Hill & Rothaermel, 2003). New technologies used in electric vehicles are different from the internal combustion engine. The development of radical innovation affects primary stakeholders such as customers and suppliers in terms of a change in competencies (Hall K. & Martin J.C., 2005). Generally, the number of parts used in electric vehicles will decrease dramatically from that used in conventional vehicles. Transitioning to electric vehicles, the estimation of parts used in EV would be about 1,500-3,000 parts, while the number of parts used in internal combustion engines is approximately 30,000 (Kulkolkarn, 2019). Parts taken out from traditional vehicles are mainly in the engine and transmission system. Other parts such as air-conditioning, brake, and steering systems also require adjustment to fit into an electrified system.

Electric vehicles require new components such as electric motors and batteries. This would lead to a new production process and change the current value chain. Existing supply chains, particularly the engine, gearbox, and other parts such as air-conditioning, brakes will require an adaptation (Klug, 2015; Sadovnikova, Pujari, & Mikhailitchenko, 2016; Valentine-Urbschat & Bernhart, 2009).

The auto parts industry will transform into a high technology auto parts industry which will include the development of core engine parts such as the motor, battery, and electrical control units. Chassis and tank will be developed from a lightweight material such as carbon nano or fiberglass. Other related components are also parts of EV, such as software, sensor, and system related to safety or infotainment. In addition, new actors to support the production of electric vehicles will be added to a new value chain. The addition to EV would also include electrical components, electronics components, and software for the user interfaces, which would be independent of vehicle value chain. The production line of EV will focus less on mechanical activities and will be highly automated. The shift from mechanical engineering will be replaced by electro engineering and informatics (Lindström & Heimer, 2017).

The battery which is the critical component of EV will also be the main part of the value chain. The traditional approach that automakers dominate all proprietary technologies such as core engines will also be changed. Battery may be produced by carmakers or outsourcing to a company that specializes in battery production. Collaboration with other specialized companies will be the new norm for making electric vehicles.

An electric motor will eventually replace parts manufacturers that produce parts relating to power train and engine, these activities are mostly performed by OEM firms in the first or second tier. Firms that produce replacement parts or REM will be effected because the reduced number of conventional cars will also decrease the demand for car maintenance.

These challenges pose many concerns to countries with traditional automotive and parts industries locally, such as Germany, Italy, and Thailand. Based on the characteristics of conventional automotive supply chains, the industry is controlled by lead firms or OEM companies such as BMW, Volkswagen, Toyota, Honda, and their established relationships with companies in the production network. Lead firms designate suppliers to deliver components based on their specific design. Suppliers depend on the volume and purchasing power of lead firms. Thus, in the traditional automotive industry, component suppliers are in a "captive" relationship in which small suppliers are highly dependent on large OEM firms. An expected EV adoption represents a major concern for dependent suppliers in experiencing a potential market loss (Schwabe, 2020). It is interesting to explore how suppliers consider their strategies and options in positioning themselves in the alternative automotive industry. A study by Rossini et al.,

(2016) explored firms in the Italian automotive industry and the potential changes for the advent of EV. The study categorized changes in firms into minor changes, significant changes, and radical changes. The study founds that according to firm size, large firms identified that the introduction of EV would induce a radical change in the supply chain. SMEs indicate significant changes but less than large firms, followed by micro-SMEs showing minor changes. Radical change would involve introducing new production lines and new collaboration to acquire knowledge and capabilities, including the addition of new suppliers. Major changes impact suppliers to modify existing production lines and adding new production lines. Research and development of new products would be essential elements for firms that experience major and radical changes.

A study by Schwabe (2020) explored German firms in the forging and foundry sector with a potential risk of market disruption by EV and also confirmed that the traditional supply chain would be impacted. Germany, a leading country in producing ICE vehicles, also expected that some of the supporting sectors of the automotive industry, such as forging and foundry, would be heavily disrupted by EV. The study investigated firms that produce parts related to ICE which may not be required in an EV using in-depth interviews. The study found that suppliers agree that EV will disrupt their production volume in the long term. However, the impact varies based on the company's current product portfolio and whether it is highly dependent on ICE. Companies producing specialized components for ICE are likely to cease their operation when the market share of ICE is declined. At the same time, generic suppliers may adapt their products to the EV requirements. Companies' strategies vary based on ICE dependency; highly independent companies consider diversifying their product portfolio and still use existing production facilities. The diversification can be categorized into 1) delivering existing products to new markets such as agricultural machinery, 2) delivering products to the automotive market that does not depend on ICE 3) delivering products to EV market. In comparison, other components suppliers with less impact start developing new products by investing in small-scale EV products or upgrading their products. Despite different companies' strategies, the common perspective for all firms is the adjustment of their internal capabilities. In summary, firms with a substantial risk of market disruption tend to resort to sectoral diversification by delivering the same products to new markets. Firms with minimal risk of EV disruption tend to adapt or upgrade their products to fit with new markets.

Despite the impact on existing supply chains, EV also bring new opportunities for SMEs because of the new technologies and services of EV. In comparison to the traditional ICE automotive industry, is highly complex in terms of technologies and dominated by limited organizations. EV offers opportunities for old and new players to act as suppliers of services and parts or even vehicle producers in a low-speed vehicle sector such as three-wheelers or electric bicycles (Bierau et al., 2016)

3.4 Possible impacts on the Thailand automotive and parts industry

Electric mobility is expected to disrupt the current automotive industry and its supply chain. Thailand is currently a regional production hub for internal combustion engine vehicles for several MNCs from Japan, the United States, and Europe, such as Toyota, Nissan, Honda, Isuzu, Mitsubishi, BMW, Mercedes Benz, Volvo, Ford, Scania, etc. Approximately 1,700 supply chain companies supply auto parts to auto assemblers. This section analyses the possibility of disruption based on current production, export markets, and the global trend on zero-emission vehicles.

The production of traditional internal combustion engines vehicle and electric vehicles show a significant difference, as mentioned in section 3.4. The impact on the car and parts manufacturers in Thailand can be divided into 1) short-term impact (3–5-year period) and 2) long-term impact (Five years onwards).

Short-term impact: parts suppliers in Thailand are not yet affected by the transition and continue producing ICE vehicles and related parts. Laoonual (2015) studied the implication of EV to the Thai automotive industry and found that the industry and government representatives foresee that there would be a minor impact within ten years (2015-2025). Justification of the low impact is based on global EV trend in ASEAN and Thailand. Concerning EV trends, ultimately, there will be a need for EV domestically. Industry representatives believe EV product proliferation would begin from HEV or PHEV before BEV. The transition from HEV/PHEV to BEV implies that there would be a transition time since HEV/PHEV contains internal combustion engine technology.

In terms of EV investment from MNCs, several companies identified that Thailand could produce EV. However, the development of EV industry in Thailand includes many factors such as the decision of car manufacturer parent's companies towards EV investment, clear government policy on EV, customer demand, regulations, subsidies and incentives, and availability of charging infrastructure. The establishment of the battery industry in Thailand is one of the requirements for the industry because of the price and the safety of battery transportation. In terms of customer demand, domestic sales volume could not yet stimulate investment in EV manufacturing. Thus, it requires government subsidies to boost demand for EV. During the early stage of EV market, Thailand would import EV primarily from China because of the free trade bilateral agreement, which imposes zero percent import duty for several products, including EV. One of the main reasons that EV will not impact the current production is because the country’s product champion, the pick-up truck, will continue to use internal combustion engine technology for some time. Also pick-up trucks use mostly parts produced locally, therefore this should not affect pick-up parts suppliers. Thus, the arrival of EV does not impact the current production of firms in the automotive and parts industry within the short period.

However, considering the long-term period, regulations to ban internal combustion engines for many countries will be in effect, including some of the country’s export markets such as Europe and the US. The earliest regulation will be in effect in the year 2025 in parts of European countries (See Table 3.3). The global demand may also rise due to the environmental trend, and the global demand for ICE vehicles will decline in due course.

Table 3.2 Country's target to phase out Internal Combustion Engine (ICE)

Country	**ICE passenger cars phase out target**
The European Union	No new ICE sales after 2034
United Kingdom	No new ICE sales after 2030
Ireland	No new ICE sales after 2030
China	End production and sales of ICE by 2040
Denmark	No new ICE after 2035

Country	**ICE passenger cars phase out target**
France	No new ICE after 2040
Germany	No new ICE after 2035
India	No new ICE after 2030
Ireland	No new ICE after 2030
Israel	No new ICE after 2030
Japan	Incentives program for EV
Netherlands	No new ICE after 2030
Norway	No new ICE after 2025
Portugal	Incentives program for EV
Scotland	No new ICE vehicles sold after 2032
South Korea	Official Target: EV account for 30% of auto sales by 2020
Spain	No new ICE after 2040
Singapore	No new ICE after 2030
Taiwan	No new ICE motorcycles by 2035 and ICE vehicles by 2040
Thailand	No ICE phase out target but setting a production target of zero-emission vehicle at 30% by 2030

The level of impact can be categorized into 1) high impact parts, 2) medium impact parts, and 3) low impact parts. Firms that produce parts in Table 3.4 will face the possibility of an impact on their operation at a different level based on the firm's current products. Firms that manufacture high-impact parts such as engines and suspension may need to cease manufacturing certain products or require a significant adaption. At the same time, firms that produce medium and low impact may need to adjust their operation to the new requirements.

Table 3.3 Level of impact categorized by auto parts relating to EV production, Adapted from Kulkolkarn (2019)

High Impact parts	**Medium Impact parts**	**Low Impact Parts**	**Positive impact parts**
Engine parts - Catalytic convertor - Engine components - Radiator **Transmission system** - Drive shaft - Clutch and components - Transmission controller **Chassis** -Exhaust system -Fuel Tank	**Steering system** - Brake system - Electronic controller module - Lubricant	**Body parts** - Colour - Windshield - Interior accessories - Seat - suspension	Electrical and Electronics Parts such as semi-conductor, PCB

According to Figure 3.4, approximately 816 auto parts manufacturers out of 2500 (33%) firms in the automotive and parts industry in Thailand would be impacted by the advent of full EV. The majority of affected manufacturers would be firms producing engine and related components at approximately 418 firms accounting for over fifty-one percent, followed by brake (140) and transmission manufacturers (136), and parts manufacturers relating to aftersales services (122). In terms of employment, impacted firms employed approximately 326,4000 people (Kulkolkarn, 2019). Besides the entry of EV, the automotive industry is moving towards adopting automation and robotic systems; this issue also impacts some labours that would be replaced by automation systems.

Firms that produce high-impact parts are mostly in the first tier, which are large foreign and joint venture firms, while the second and third tiers, which are SMEs, produce medium to low-impact parts. SMEs are primarily in the second and third tier and account for approximately sixty percent of overall parts suppliers. Seventy-five percent of SMEs mainly produce parts and accessories or low-impact parts, while twenty-five percent produce parts in a transmission system, suspension, and electrical system, which will be affected by the change in production.

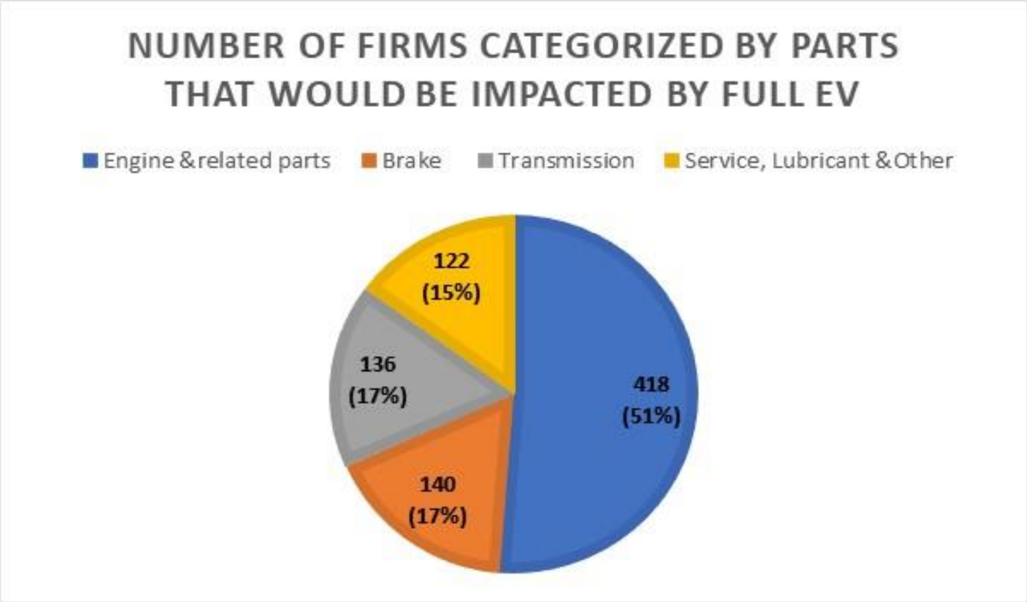

Figure 3.5 Number of auto parts manufacturers impacted from the entrance of full EV, Sukpisal, Supoj, The adaptation of auto parts manufacturers to the arrival of electric vehicles, Thai Auto Parts Manufacturers Association, 2016

According to Kulkolkarn (2019), the view of the auto parts association is that investment in a production line for one car model can be used for ten to fifteen years. Thus, auto parts suppliers will not be impacted during those periods. However, during the transition period, the production line adjustment should involve adopting an automation system to increase overall efficiency. Eventually, the auto parts suppliers should expand their products to cover aftermarket by producing REM or spare parts, due to the global demand from old vehicles that require maintenance after the cease of ICE sales in several countries. Diversifying to other industries such as medical devices, robotics, or aviation should consider manufacturing firms that cannot adjust to the EV industry.

Figure 3.5 and Table 3.5 shows that the primary automobile exports market are Asia, Australia, New Zealand, and Oceania, the Middle East, and Europe, respectively. Asia and Australia markets dominate approximately almost sixty percent of the total export market. The main export product to every exporting country is pick-up truck and pick-up passenger vehicle (PPV), followed by passenger cars (See Table 3.5).

In terms of the export market of auto parts produced in Thailand, it represents approximately 30-35% of the total sales and can be categorized into five export markets: ASEAN, Australia and Oceania, the middle east, Europe, and others market. The most important markets are Australia, ASEAN, middle east, respectively. In major markets such as ASEAN, many countries continue to use ICE, such as Malaysia, Indonesia, or even Thailand, because of the lack of regulation banning ICE, as in Europe. However, in the case of Thailand, the plan for EV is aiming to increase the ratio of EV production to thirty percent of overall vehicle production capacity by 2030.

The potential future decline in demand for internal combustion engine vehicles in the export market would derive from national policies on EV promotion in exporting countries such as Australia or European countries. Australia, the second largest export market, has announced a national target to use EV at the one-million car by 2030. Several European countries also set a numeral target of banning the use of internal combustion engine vehicles within ten years. The United Kingdom, one of Thailand's top-ten exporting countries, announced the goal to ban the sale of new ICE vehicles in 2030. Therefore, Thailand will lose some export markets during the transition period.

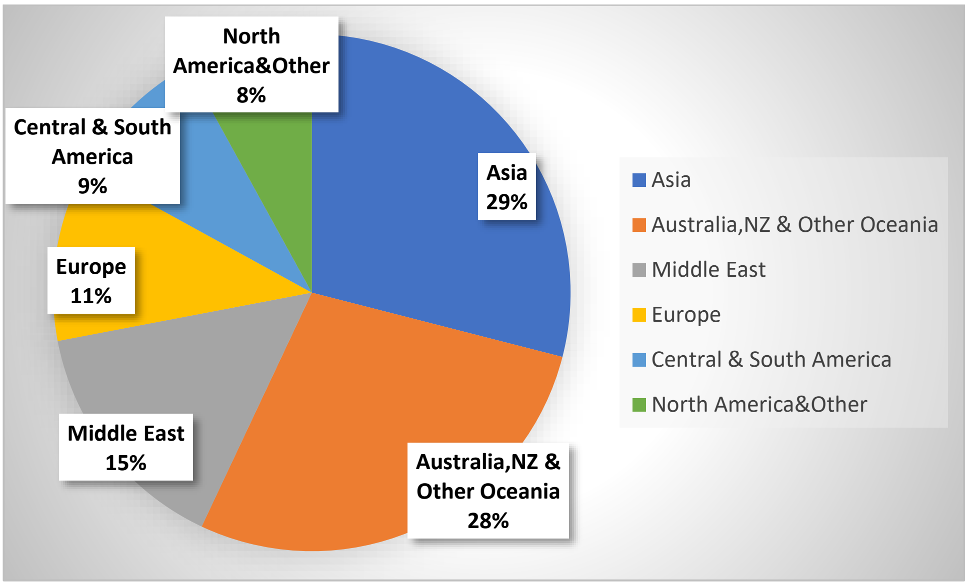

Figure 3.6 Accumulation of automobile export units (Passenger cars and Pick-up truck) between 2014-2022 (data source from Thailand Automotive Institute)

Table 3.4 Number of car units export to each region (Data Source: Thailand Automotive Institute)

Year	Asia		Australia,NZ and Oceania				Middle East		Europe	Central &South America
	Passenger car	Pick up and ppv	Passenger car	Pick up and ppv	Passenger car	Pick up and ppv	Passenger car	Pick up and ppv	Passenger car	Pick up and ppv
2014	126,624	146,573	75,766	155,443	66,668	220,840	39,903	56,137	41,256	79,987
2015	137,048	160,901	85,306	198,657	38,276	191,271	89,632	56,121	36,335	94,212
2016	145,507	180,826	107,931	205,297	29,158	126,228	80,353	67,999	37,447	66,970
2017	121,504	183,086	100,695	236,986	18,782	93,255	64,092	79,563	37,975	55,943
2018	113,786	207,673	88,974	247,477	28,985	79,581	63,537	59,579	37,564	56,324

Year	Asia		Australia,NZ and Oceania				Middle East		Europe	Central &South America
	Passenger car	Pick up and ppv	Passenger car	Pick up and ppv	Passenger car	Pick up and ppv	Passenger car	Pick up and ppv	Passenger car	Pick up and ppv
2019	107,349	211,403	76,845	225,078	24,815	107,455	59,939	56,428	25,930	45,237
2020	118,496	114,921	36,774	177,581	21,535	89,889	32,288	28,334	14,413	26,508
2021	155,534	160,362	28,162	244,464	14,313	103,708	39,227	51,254	21,774	43,959

Unit: car unit

In summary, in the short-term (five to ten years), the arrival of EV will not yet directly impact the operation of firms in the Thai automotive and parts industry. The sales of internal combustion engines and related components can continue for at least ten years. The sale of REM parts for internal combustion engines can continue to serve after-sale markets. However, the possibility of impact occurs from global policy trend on banning the use of fossil fuel vehicles which tends to expedite the due date. This will impact some of the export markets, such as European markets. Moreover, the changing trend of customer preference coupled with government incentives for EV may also expedite the transition to EV.

3.5 The Thai EV industry, Policies and Key Statistics

The global agenda moves toward a greenhouse gas net zero policy, and the technological trend responds to the plan by developing environmentally friendly vehicles. At the global level, Thailand as a signatory to the Paris Agreement, committed to limit the global temperature to below 2 degrees Celsius, and a party to the United Nations Framework Convention on Climate Change (UNFCCC) committed to decreasing greenhouse gas, including CO2, by twenty percent to twenty-five percent by 2030. Thus, Thailand, as one of the global automotive production hubs, needs to maintain the country's competitiveness and transition toward new technology trends.

According to Figure 3.6, Thailand issued a series of policies to support the development of the EV industry. At the country level, in 2015, the government set the next-generation automotive industry as one of the country's target sectors as a potential sector to support future economic growth. The next-generation automotive industry is considered a new industry that includes electric vehicles of all four types, namely HEV, PHEV, BEV, and FCEV. In 2016, to support the development of ten targeted industries, the government set up the Eastern Economic Corridor (EEC), covering three provinces in the eastern area of Thailand, namely Chachoengsao, Chonburi, and Rayong. EEC is aiming to be the production hub of EV industry by providing special incentives for manufacturing firms located in the area.

In March 2017, the Thai cabinet approved the policy to create Thailand as a production base to produce motor-driven vehicles and related parts and stimulate domestic demand for electric vehicles. The goal is to be EV production hub in the ASEAN region. The promotion of the next-generation automotive industry is to maintain the country’s competitiveness in the former automotive sector, which is a source of economic growth.

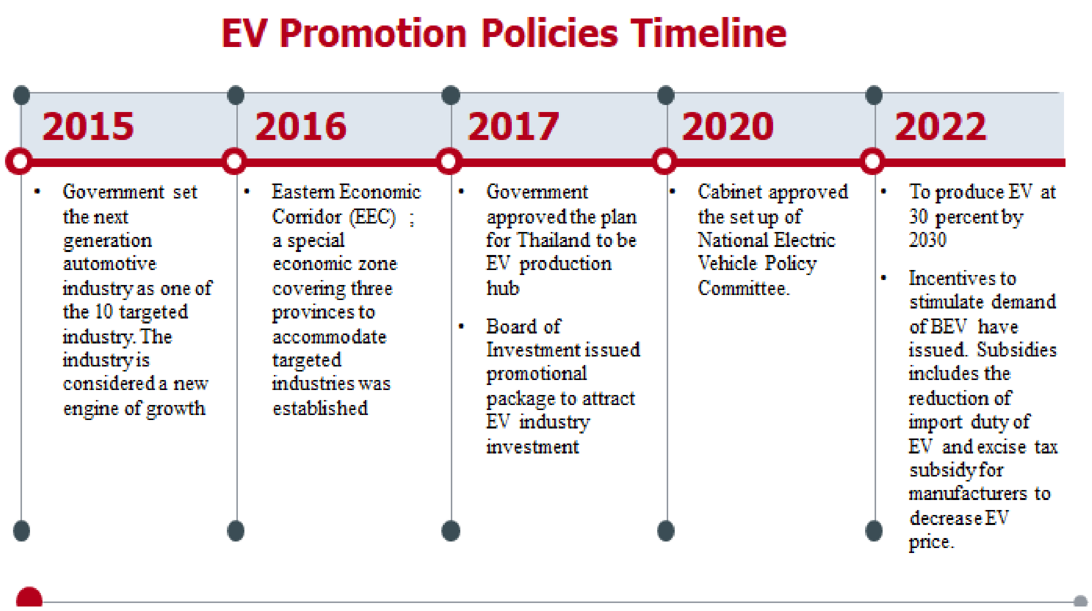

Figure 3.7 Timeline of EV promotion policies in Thailand

The Thai government issued related policies to support Thailand as an electric vehicle production hub. Policies can be categorized into 1) EV Investment policy, 2) Domestic market policy, 3) Infrastructure preparation, 4) EV standard policy and 5) Human development policy.

(1) EV investment policy: This policy is entrusted to the Board of Investment of Thailand (BOI) to issue a promotional package to attract car manufacturers and the battery industry to invest in manufacturing HEV, PHEV, and BEV in Thailand. The promotional packages reduce or exempt import tax and the exemption of corporate income tax. Excise tax reduction will also be imposed for BOI-approved projects by reducing 50% excise tax for HEV and PHEV and reducing excise tax for BEV down to 2%.

To attract the production of EV and critical parts locally, the investment incentives do come with conditions. Conditions are to support local supply chains of EV by mandating local production of essential parts and the plan to support local suppliers who must be Thai majority firms by providing technological training and technical assistance.

The critical parts receiving tax incentives include the battery, traction motor, air conditioning system, drive control units (DCU), onboard charger, inverter, EV charging system, reduction gear regenerative braking system etc. Besides passenger cars this also include a range of other vehicles, namely buses, trucks, motorcycles, tricycles, and electric ships.

As the country's direction is going towards fully electric vehicles, incentives for EV are greater than for HEV and PHEV receiving eight years of corporate income tax exemption with the possible extension in the case of having technology transfer cooperation with academic or research institutions. In addition, to support the production of batteries locally, the incentives also include a ninety percent reduction of import duties on raw materials to produce batteries unavailable in Thailand.

As of 2020, twenty-four car manufacturers are approved for BOI incentives to produce HEV, PHEV, and BEV in Thailand and two e-bus projects. The approved projects comprise the production of HEV, PHEV, and BEV. Most approved projects tend to invest in HEV (Nissan, Honda, Toyota, Mazda, and Mitsubishi) and PHEV (BMW and Mercedes-Benz). Thirteen companies are approved for BEV projects (Toyota, Mitsubishi, Nissan, MG, Honda, Audi, Mercedes Benz, Fomm, Takano, Sammitr, Skywell, and Mine Mobility).

Table 3.5 Board of Investment incentives in promoting EV and related industry

Type of Business	Incentives
Manufacture of Battery Electric Vehicle (BEV), Hybrid and Plug-in Electric Vehicles (HEV and PHEV) Total investment not less than 5 billion Baht (investment > 5 billion baht)	**Corporate Income tax exemption (CIT)** HEV: No CIT PHEV: 3- year CIT exemption BEV: 8-year CIT exemption
Manufacture of Battery Electric Vehicle (BEV), Hybrid and Plug-in Electric Vehicles (HEV and PHEV) Total investment less than 5 billion Baht (investment < 5 billion baht)	**Corporate Income tax exemption (CIT)** HEV: No CIT PHEV: 3- year CIT exemption BEV: 3-year CIT exemption
• Exemption of import duties on raw materials used in production and R&D • Exemption of import duties on machinery • Other non-tax incentives • Grace period: Within 3 years after the date of promotion certificate issuance: manufacture of all categories of electric vehicles must be started, and electric battery must be started from module manufacture.	
Manufacture of EV Critical parts (17 parts)	

Type of Business		Incentives
• Air conditioning system • DCDC Converter • Front/Rear axle for EV bus • Electrical Circuit Braker • EV Charging Equipment/Smart charge • On-board charger • Traction Motor	• Portable EV Charger • Inverter • BMS • DCU • Battery • High Voltage Harness • Reduction Gear • Battery Cooling System • Regenerative Braking System	8- year CIT exemption *Pack assembly: 5- year CIT exemption Module production: 8-year CIT exemption Cell production: 8-year CIT exemption
EV Charging Stations		5-year CIT exemption for at least 40 chargers 25% of which are fast chargers 3-year CIT exemption for other cases

(1) Domestic market stimulation includes the procurement of EV by government authorities setting the target of 20% of the government budget for new vehicle procurement for BEV. And the pilot use of BEV in specific industrial estate areas such as the Eastern Economic Corridor (EEC).

(2) Infrastructure preparation includes planning EV charging station locations carried out by the Ministry of Energy and Ministry of Transport. Another infrastructure is to set up the National Automotive and tire testing facility, which is managed by the Thai Industrial Standard Institute, and to develop related human resources to support the standard testing for EV.

(3) EV standard setting for four main types of EV, EV charging system, electromagnetic compatibility, battery for EV, and DC meter standard for the billing system.

(4) End of life management plan for EV batteries will be enacted as a plan and regulation by the Department of Industrial Works and Pollution Control Department.

(5) Other measures such as the development of human resources and productivity improvement within five years by the Thailand Automotive Institute (TAI) to support the next generation automotive industry.

To prepare the development of new human resources for the new targeted industry. Three related ministries, namely the ministry of economics, the Office of Vocational Education Commission under the ministry of education, and the ministry of higher education, science research and innovation, signed a memorandum of understanding in developing study programs for students.

To drive the development of EV concretely and effectively, in February 2020, the Prime minister appointed a national electric vehicle policy committee. The EV committee approved a roadmap that set up a national target to produce EV at thirty percent of the total vehicle production by 2030. This is a three-phase plan:

Phase 1 short-term plan (2020-2022) is to produce EV cars for the government fleet, public EV buses, e-motorcycles, and passenger cars, approximately 60,000 – 110,000 cars.

Phase 2 medium-term plan (2021-2025) is to have 100,000-250,000 EV and smart city buses for 1,000-3,000.

Phase 3 long-term plan (2026-2030) will drive toward zero-emission by having 750,000 EV and a production target of EV at 30% of total production.

In February 2022, the cabinet approved a resolution of the EV committee to produce EV at thirty percent by 2030 and approved a tax incentives package to stimulate the demand for BEV. To promote the adoption of EV, the government tries to lower the EV price by providing incentives to car manufacturers, including the reduction of import duty for completely built-up BEV by forty percent for BEV prices up to fifty- five thousand (55,000) USD during 2022-2023. Also, there are excise tax reduction to manufacturers from 2,111 to 4,523 USD for each passenger car EV unit. This subsidy allows car manufacturers to decrease the sales price but are not directly aimed at the customers. For each BEV car sold to customers, car manufacturers can claim the same amount of subsidy.

Despite numerous government policies to promote EV, including local investment in EV industry and the latest EV adoption incentives, the adoption rate is relatively low. According to Table 3.7, the registration of new EV in Thailand is relatively low compared to the registration of ICE. However, EV registration has noticeably increased each year, particularly from 2019 onwards. Compared to 2018, EV had exponentially risen by over 1,040 percent, and the total share of EV was at 3.66 percent in 2019. As of December 2021, Thailand has electric cars of all types at 214,214 cars, while ICE cars were at 18,094,204. The percentage of EV cars was at 1.18% of ICE cars. The sales of HEV/PHEV are still significantly higher than BEV. Since HPEV shares some similar components to ICE this implies the continuity and demand for an internal combustion engine.

Table 3.6 Comparison between the registration of new internal combustion engine vehicles and electric vehicles (Data source from department of land transport, Thailand)

Year	**ICE Vehicles**	**Electric Vehicles**			
		HEV/PHEV	**%YoY**	**BEV**	**%YoY**
2014	914,288	9101	-43.73	6	-53.84
2015	891,871	7629	-16.2	14	133.3
2016	820,939	9577	25.53	2	-85.71
2017	929,169	11944	24.7	27	1250
2018	1,003,831	19967	67.17	57	111.11
2019	1,018,962	26424	32.3	650	1040.35
2020	819,081	28338	7.24	1267	94.92
2021	780,068	41399	46.09	1992	57.22

Globally, there are barriers to the shift from ICE to EV, namely financial, vehicle performance, and infrastructure (Kongklaew et al., 2021). Financial costs include EV, battery, maintenance, and electricity prices. Vehicle performance relates to the range of an EV on a full charge, quality, and stability of EV, charging time, battery life span, and maximum speed. Infrastructure barriers involve the availability of charging stations for both public and housing areas.

In the Thailand context, studies focusing on customers' adoption of EV in Thailand mostly found that customer acceptance of EV in Thailand, particularly BEV seems to be positive. Panson and Choojarukul (2019) found that over sixty percent of 401 samples using personal cars regularly within the Bangkok area have positive attitudes toward using battery electric vehicles. Rungsuriyawiboon et al. (2019) studied consumer behaviours in Thailand on the adoption of EV, using 463 samples within Bangkok, which also confirmed the positive EV adoption attitude.

In most of the studies regarding EV adoption in Thailand the main factor for Thai consumers to adopt EV is the price of EV (Panson & Choojarukul, 2019; Rungsuriyawiboon et al., 2019). EV purchase subsidies and incentives from the government are also the motivation for consumers to adopt EV (Kongklaew et al., 2021). Other factors that affect the decision to purchase EV include performance factors (driving range, speed, range per single charge, safety) (Thananusak, Rakthin, Tavewatanaphan, & Punnakitikashem, 2017), charging infrastructure, maintenance expenses, and manufacturer brand.

The EV price in Thailand is considered expensive compared to ICE cars due to the lack of an economy of scale. While ICE is an old technology with an existing production investment, thus can offer a more affordable price. The price of BEV models is mostly expensive, ranging from 14,5000 (2-seat model) to 168,730 USD for BEV with five seats. The retail price of the five-seat model starts from around 66,688 USD.

Most of the affordable EV models comes from China due to the bilateral free trade agreement with Thailand, in which EV also receive zero tariff. Branding or the trust in car manufacturers is one of the consideration factors (Rungsuriyawiboon et al., 2019). Thus, although EV from China can offer a lower price than Japanese or European car manufacturers, people are still quite reluctant to purchase. As mentioned previously, in February 2022, the government issued a subsidy to car manufacturers to decrease the sales price. However, the provision of direct subsidies to EV users, such as purchase subsidies or tax exemptions, is not yet available in Thailand. The direct purchase subsidy policy for EV is deemed effective in several countries, such as China and the US, and some EU countries, in stimulating the penetration rate of EV (Kester, Noel, Zarazua de Rubens, & Sovacool, 2018; Liu, Sun, Zheng, & Huang, 2021; Wee, Coffman, & La Croix, 2018).

The limited range of EV batteries is one of the significant factors of EV buyers, which requires installing a charging infrastructure to increase the widespread EV adoption. As of March 2022, Thailand has 944 EV charging stations across the country, which are mostly located in Bangkok and adjacent areas (473 stations). The number of charging stations is still limited compared to petrol stations of which there are approximately 30,000 across the country. In contrast, the critical issue for the limited charging network in Thailand tends to be a problem of chicken and egg. EV charging operators in Thailand see that the limited number of EV adoption provides a negative effect, and the demand-pull incentives for customers could increase the adoption (Thananusak, Punnakitikashem, Tanthasith, & Kongarchapatara, 2021).

In summary, policy development indicates the efforts of the Thai government to create a new EV industry in Thailand. The central policy tends to focus on subsidies, particularly the investment incentives of the Board of Investment, to attract and facilitate MNC and local EV manufacturers to build EV production lines in Thailand. The government expected that the existing automotive and parts industry would adjust and transform to be part of the new EV industry. However, there is no government mechanism relating to the automotive and parts sector transition. The policy regarding the development of human resources to support the new EV industry is only mentioned as part of the main policy without further details such as investment policy. The demand-pull incentive to increase EV adoption rate is still very limited. In Thailand's context, the main barriers to EV adoption are price, infrastructure, and EV performance. And the number of new EV registration is still low compared to new ICE registration. Thus, Thailand is facing a paradox; while trying to establish itself as a host for the new EV sector, the existing automotive and parts industry is facing a challenge in adapting itself to enter the new market.

3.6 Conclusion

Thailand's automotive and parts industry has been rooted in Thailand for over half a decade and is one of the top industries that support the country's economic wealth. The country has gained a reputation as a regional production hub for ICE vehicles. The local firms have built up technology capability to a certain level, particularly basic and intermediate technology capability. However, technological capability of firms is still different among tier levels; first-tier firms possess higher technology capability than lower tiers due to the hierarchy in technological transfer from automakers to their first and sometimes to second-tier suppliers. First-tier firms have high to medium technological capability, including high production capability and innovation capability such as design capability. In comparison, third-tier firms own basic technological capability.

The global automotive industry is experiencing the radical technological change, from producing internal combustion engine (ICE) vehicles to electric mobility technology. This transition also causes concern for the Thai automotive industry. The projected impact due to the advent of EV is on parts manufacturers that produced parts that are no longer required in EV. This would be firms producing engine and related components at approximately 418 firms, mostly large and medium firms, followed by small firms. The transition to EV industry would require new knowledge and capabilities. The critical question is how the traditional automotive industry will respond to these challenges of shifting technological knowledge to electric vehicles. While owning a certain degree of technological capability from the traditional automotive industry, EV industry requires new skills and knowledge. This requires policy support to equip firms with knowledge and technological capability that is consistent with the new industry.

Because the Thai automotive sector is the source of the country's economic growth and employment. To maintain the country's competitiveness, the government has set the target that Thailand would join the global trend by aiming to be the hub for EV production in the ASEAN region. The promotional packages have been offered to attract EV manufacturers to locate in the country. Regarding domestic EV adoption, the number has increased steadily but is still relatively low compared to ICE vehicles. Despite the small number of EV adoption, the country aims to promote the transition from ICE to EV.

The above-mentioned presents several challenges for Thailand in transitioning to EV, particularly for the existing automotive and parts industry on whom the transition would highly impact. In the next chapter, we discuss the research design and methodology of this study and later in Chapter 5, we discuss the quantitative results relating to the impact on the Thai automotive and parts industry of the advent of EV and its responsiveness to how they would adapt to the transition to EV.

CHAPTER 4
Research design and methodology

This chapter discusses the study's research design, including the design of data collection and data analysis. The data collection is from the selected sample of firms from the Thai automotive and parts industry, government agencies, industrial associations, universities, and research institutions. The data collection was retrieved through document reviews, administration of the questionnaire, and a face-to-face interview.

This chapter discusses the study's research design, including the design of data collection and data analysis. The data collection is from the selected sample firms of the Thai automotive and parts industry, government agencies, industrial associations, universities, and research institutions. The data collection was retrieved through document reviews, administration of the questionnaire, and a face-to-face interview.

A self-administered questionnaire was used to collect data from firms, indicating the firm's responsiveness to change, current technological learning process, and network. The interview was used to elicit data from government institutions, universities/research institutions, industrial associations and sample firms representing firms in different tier groups. The quantitative data were analysed using statistical techniques, descriptive and inferential statistics to answer the research objectives. The qualitative data from the interview was analysed using the thematic method. Published documents of government agencies and consultant reports relating to electric vehicles' current development in Thailand were reviewed to develop questionnaires and interview questions.

This chapter is divided into four sections. Section 4.1 describes the research approach and framework. Section 4.2 explains the research design. The third section describes target population and sampling. The fourth section describes data collection methods. The fifth section discusses the data analysis method.

4.1 Research approach and research framework

The main research question of this study is, "How do small and medium firms in the automotive industry adjust to the technological change in technology from an internal combustion engine to electric mobility?" In other words, is there any evidence to suggest the viability of such technological transition across SMEs in the automotive sector in Thailand? According to the research question, this research aims to explore the extent and direction of technological learning and the development of SMEs' knowledge networks in the Thai automotive and parts industry. The identification of the extent and direction of technological learning and the utilization of knowledge network indicates the capability to change or a transition of auto parts suppliers from producing internal combustion engine-related parts to electric vehicles related technology.

This study is based on the MLP approach, which believes that the process of sustainability transition is complex; it involves an interaction between multiple actors and institutions for the transition to occur. There is no single driver that can create a change, but it is a linkage and reinforcement among three socio-technical levels ; namely landscape, regime and niche-level that bring the change (Frank W. Geels, 2002). The transition would involve multiple actors such as industry, governments, consumers, and society. This research use MLP as a framework and map context of the study into the MLP background. The transition theory is applied to explore how the possible transition of suppliers towards technological learning to produce EV could happen. The focus of the transition in this study looks from the supplier side of auto parts manufacturers that would need to adjust their technological learning to be consistent with upcoming EV technologies. This study focuses on car producers and suppliers in the course of the transition, with emphasis on SMEs suppliers.

The regime transition from ICE to the production of EVs involves top-down pressures from the landscape-level such as pressure of supra-national and national policies and the bottom-up stimulation from niche activities to destabilize the existing regime. In addition, government policy is recognized as an essential driver of socio-technical transition. This study employs multi-governance concept focusing on government policy intervention; considering that policies support would exist in all three MLP levels and the interplay of policy supports in all three level would enable system change. Top-down policy would give pressure to regime-level while regime-level policies would provide a room for incumbent regime actors to gradually change and niche-level policies which could support niche activities to be progressed.

Therefore, data collected covers the data from actors at each level of the MLP framework, i.e., regime, landscape, and niche, the actors at the regime-level can also be the same in niche-level but conduct a different activity.

The collected data include responsiveness of firms, the present status of SME suppliers' technological learning processes, the current linkage and knowledge networks of suppliers and partners, or the current regime. Furthermore, institutional data relating to plans and policy support for EVs of different agencies were explored. The research design is shown in Figure 4.1

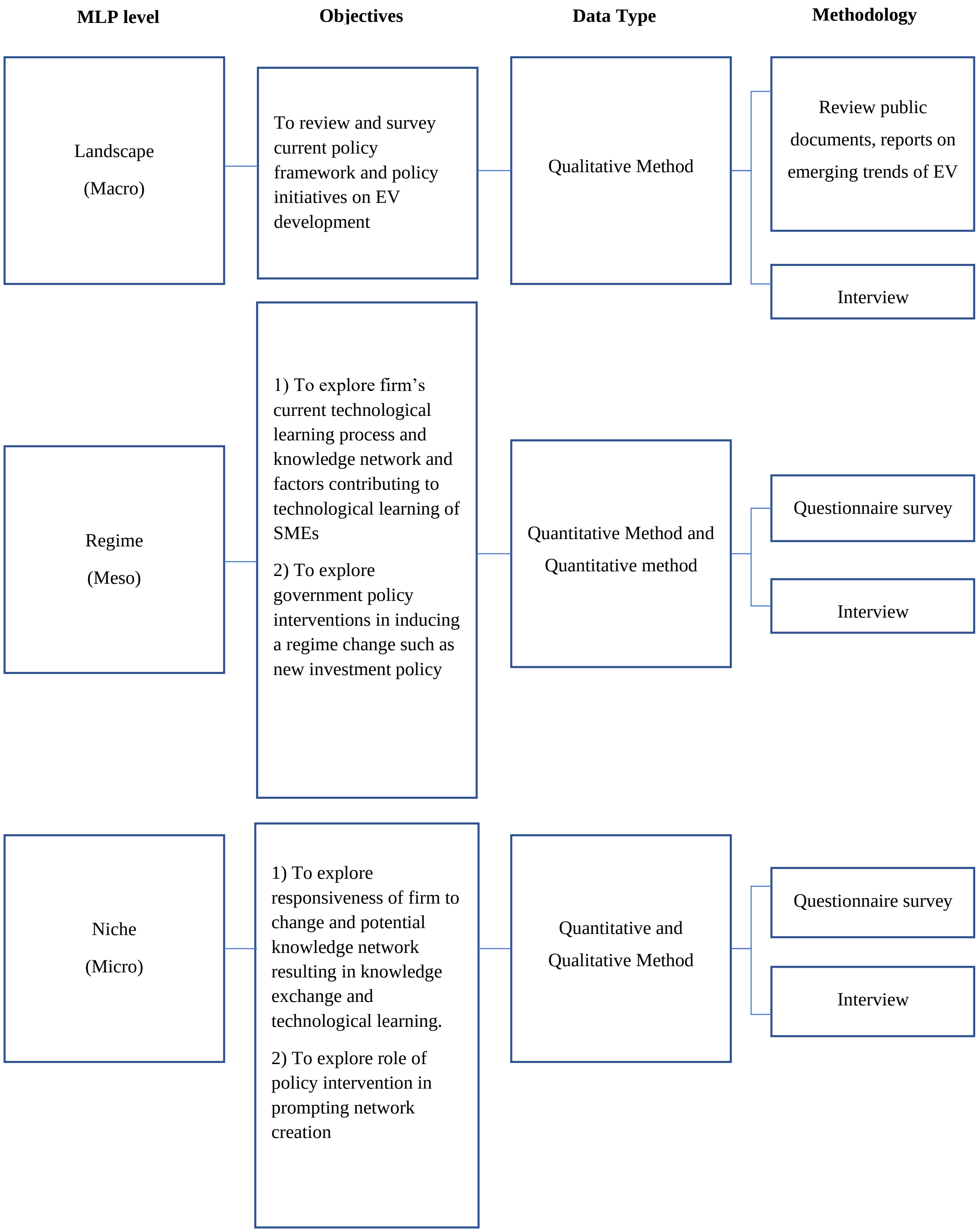

Figure 4.1 Research Design and data collection methodology based on Multi-Level Perspective Framework (MLP)

4.2 Research design of the study

The mixed-method involving quantitative and qualitative method is used in this study to explore evidence to suggest how do small and medium firms in the automotive industry adjust to the technological change in technology from an internal combustion engine to electric mobility. The MLP is adopted as a framework to identify factors, actors, and governance interventions in each socio-technical level regarding the transition of the automotive and parts industry towards the learning and manufacturing of EV.

Most of the studies using MLP as a conceptual framework focus on using the qualitative method; however, this study also applied the quantitative method. This study used a questionnaire survey to provide empirical evidence focused on incumbent regime actors and their responsiveness and technological learning readiness whether firms are willing and can potentially later transform into the new EV industry. Simultaneously, the qualitative method using semi-structured interviews provides a view of governance issues and policy interventions at each socio-technical level. The qualitative method tries to identify policy from the landscape-level that influences incumbent regime actors to move to a new regime of producing EV while exploring policy instruments that could support technological development for existing incumbent actors and niche actors to move towards developing new EV technologies.

According to the research question, the aim of this research is to explore the extent and direction of technological learning and the development of knowledge networks of SMEs in the Thai automotive and parts sector. The identification of the extent and direction of technological learning and the development of knowledge network indicates the capability to change or a transition of auto parts suppliers from producing internal combustion engine-related parts to electric vehicles related technology. This research focuses on the supply side of the electric vehicle production, i.e., suppliers and producers of EVs in the transition, emphasizing SME suppliers.

This study used a triangulation design, which collects different data in one phase, i.e., quantitative and qualitative data but complementarily. The multi-level model, which is a subcategory of triangulation design, is chosen in this study. This model uses quantitative and qualitative method for different stakeholders and later combine the finding of each level of stakeholders into the overall analysis (Creswell & Plano Clark, 2007). Both questionnaire administration and interviews were conduct at the same time in the process. Each type of data's results will be analysed separately and later an overall interpretation is conducted.

According to Figure 4.1, this study collects data in relation to MLP socio-technical level, landscape-level data relating to policy framework and initiatives, regime-level data focuses on current practice of firm's technological learning and knowledge network and niche-level data explores potential niche activities and network. In addition, governance interventions which affect all socio-technical lever were also explored.

4.2.1 Landscape-level data

Landscape-level refers to an external environment or exogenous factors that influence or create a top-down pressure on a regime-level to create a transition such as a global environmental trend, political climate, demographic change, lifestyle change, international treaties or international markets. Socio-technical landscape has two main roles; exerting pressure on regimes and providing a protective space at niche-level to incubate and develop innovation. Since one of the critical roles of landscape-level is to protect niche to create innovation or provide new opportunities, the protection can come in the form of new rules or regulations that provide a favourable condition for niche actors (El Bilali, 2019). According to Geels (2011), sustainability transition is goal-oriented; the change is intended and purposive. The goal-oriented nature involves public authorities in setting a goal and government policies which will destabilize established practice at a regime-level and to support niche players which is a locus of innovation to overcome a barrier and induce change. Thus, the data collections are relating to policy framework or policy goal that tends to support the overall development of EV in Thailand.

Data collection at a landscape-level used qualitative methods by means of document reviews and a semi-structured interview with relating government institutions.

4.2.2 Regime-level data

A socio-technical regime refers to an incumbent system, established practice, established technologies, norms, and regulations. A transition occurs when there is a shift in the current socio-technical regime to another, which is a result of interaction between landscape, regime, and niche-level. Thus, data collected at the regime-level is referred to as an established practice of firms in terms of their technological learning process and their existing knowledge network. It is commonly believed that technological learning may occur both from the internal effort of firms and from linkage with an external source of knowledge, either inter-firm or in a triple helix network (Brink & Madsen, 2016b; Ferreras-Méndez et al., 2016; Laursen & Salter, 2006). Therefore, to explore the status and level of their learning can imply a firm's ability to learn and exploit new knowledge. In addition, policy initiatives that would support incumbent firms in developing EV technologies are explored.

Regime-level data used a questionnaire survey to elicit information and data from respondents. The self-administered questionnaires were sent through postal and online platforms. The questionnaire survey was aimed to retrieve information on the firm's current learning processes and their networks. The governance data was elicited from government agencies responsible for the development of the automotive and parts industry using semi-structured interview. In addition to the survey, the interviews were also conducted with the selected firms as representative of each tier group.

4.2.3 Niche-level data

According to the MLP framework, the niche-level is considered a protective space that shields from regime pressure and a place where innovation occurs. Niche-level is a seed of change that can grow by a driving force of policy intervention.

Niche-level data indicates how niche innovation could occur due to new opportunities arising from policy support from the landscape-level. Data collected is sought to explore the evidence of the possibility that transition could happen by focusing on a firm's ability to change and a potential network of firms and related actors such as universities or research institutions including government new initiatives. Thus, niche-level data collected refer to the firm's responsiveness to technological change and a potential knowledge network that could support firms interested in developing EV technology to grow.

Niche-level data are retrieved partly from the firm's questionnaire survey and from an interview with industrial associations, universities, research institutions and governments that would form a network to overcome the regime barrier. Universities and research institutions that are associated with EVs development projects or with the automotive and parts sector are selected. Interviews were also carried out with chosen Industrial Associations which support the development of knowledge networks relating to EVs and the automobile industry.

4.3. Target population and sampling

The study focuses on firms in the Thai automotive and parts industry, particularly SMEs firms. However, this study uses MLP as a framework and explores from the transition theory perspective, which happens due to reinforcement and coevolution among three socio-technical levels. Therefore, firms also include all firm size and tier group in the industry structure from car producer, tier 1, tier 2, and 3, which play a dominant role in the existing regime.

In Thailand, there is no central database of firms for a specific industry. The database mostly gathers by industrial associations or specialized institutions. For the automotive and parts industry, there are several industry associations; since this study is focusing on suppliers' firms that produce auto parts, the suitable industrial association is the Thai Auto Parts Manufacturers Associations (TAPMA). TAPMA is an industrial association that represents a firm in the Thai auto parts industry for over forty years, and most of the firms in this industry are members of TAPMA.

The list of firms was retrieved from the 2019 directory of Thai Auto Parts Manufacturers Associations (TAPMA). As for car producer firms they were recommended by a personal connection. The total number of TAPMA members is 662 companies but the sample population was based on firms that produce automotive parts, which could be impacted ranging from high to low impact, which means parts that could be obsoleted or adjusted during the transition to EVs technology such as engine parts, fuel tanks, exhaust systems, radiators, etc.

The TAPMA directory categorized firms by name and by parts production and type of business. This study uses purposive sampling by choosing firms based on the auto parts category that would be impacted by EV technology production. The selection process of the category of firms was based on the consultation with an experienced automotive engineer and a researcher working in the automotive industry. Only 408 firms were selected out of 662 firms. Selected firms include SMEs and large firms that are car producers, firms in tier 1 and tier 2 and 3.

Subsequently, self-administered questionnaires were sent to 408 firms by postal survey and an online survey. A response was received from 42 firms representing a response rate of 10.3%. The response rate in the automotive sector is relatively low due to the postal survey, which is a limited approach but is needed because of the limited time and resources of the researcher. The low response rate in the Thai automotive and parts sector is quite common for researchers who studied this industry. The firm-level qualitative data was also retrieved through structured interviews with selected firms (see section 4.4.3.2 Firms interviews).

4.4 Data Collection

This section explains the data collection process, conducted using document review, questionnaire survey, and semi-structured interview. A questionnaire survey and interview were conducted in Thailand from 9th July-10th October 2019. The questionnaire survey was targeted on firms, while semi-structured interview was targeted on institutional actors namely government agency, university and research institution, industrial association and also firm's representatives.

4.4.1. Documents Review

Documents review, which is a secondary source of data, was retrieved from published documents of government agencies such as an office responsible for formulating policy supporting the development of the automotive and parts industry and EV industry. It including agencies that are accountable for research and innovation promotion or research reports of research institutions or universities. Documents review also includes consultant reports and articles that help to understand the characteristics and current states of the automotive and parts industry and the current trend and future conditions of EV development in Thailand. Documents review can provide a view of national policies regarding EV industry development at the landscape-level. The document reviews also help identify key players and related interviewees namely government agency, university and research institution which support the development of networks for technological learning of firms. Table 4.1 shows the list of reviewed government documents.

Table 4.1 List of reviewed government documents

Documents	Responsible Agency	Type of document	Electric Vehicle Key Point Address
National Strategy (2018-2037)	Office of the National Economic and Social Development Council	National Strategy	Promote the shift from conventional automotive industry to EV industry
Thailand 4.0 Model	All government agencies	National Policy	Next Generation Automotive Industry is considered an industry built on existing industry's strength to be promoted
National Industrial Development Master Plan (2012-2031)	Office of Industrial Economics	National Sectoral Plan	The development of manpower in the Automotive industry
Twenty-Year Energy Efficiency Plan (2018)	Ministry of Energy	National Plan	Promotional of EV is part of the master plan focusing on pilot using EV buses, the provision of charging infrastructure, smart grid etc.
Next-generation automotive industry promotion and development (2020)	The office of National Higher Education Science Research and Innovation Policy Council	Published Government White Paper	Policy recommendation for government to set a clear goal and long-term vision by setting a zero emission vehicle target and a roadmap for achieving the target.
EV industry white paper (2017)	National Science Technology	Published Research Institution Study	EV development promotional roadmap for EV bus, EV

Documents	Responsible Agency	Type of document	Electric Vehicle Key Point Address
	Development Agency		conversion and passenger EV
BOI promotional package for EV	Thailand Board of Investment	Investment Policy	Policy incentives which support the production of EV and related technologies in Thailand

4.4.2 Questionnaire survey

Questionnaires were administered to a firm’ s managing director in the Thai automotive and parts industry, attached with an introductory letter from the National Science Technology and Innovation Office (STI). The questionnaires were sent out by pos and accompanied with a return envelope and postage stamp for the convenience of respondence. To offer more channels for respondents to answer the survey, the researcher also creates an online questionnaire and attached a barcode within the introductory letter.

Before conducting a survey, a draft questionnaire was reviewed and tested by 7 people working in science, technology and innovation policy from the National Science Technology and Innovation Policy Office (STI) and from firms in the automotive industry. Three people were from the STI office, and four people from four companies in the automotive sector. The questionnaire was revised according to recommendations by adjusting the structure to make it easier for the respondent, remove the repetitive questions and remove questions that would not answer the study's objectives. The researcher also attended the focus group regarding the formulation of the Higher Education, Science, Research and Innovation Strategic Plan organized by the Thailand

Science Research and Innovation Office (TSRI) on 18th July 2019. The workshop includes the topic of next-generation automotive, which covers EVs research and development support strategy, and experts and industry representatives attended. The input from the workshop also uses to improve the questionnaire to be more relevant to the current situation of EVs development in Thailand. The questionnaire used in this study is shown in Appendice C.

4.4.3 Semi-structured interview

A semi-structured interview is used in this study to elicit data from government agencies, industrial associations, academic and research institutions, and selected companies. The method that was used was face to face interview with one conducted by telephone to save time.

The interviews were conducted with sixteen-person representing thirteen organisations (See Table 4.2 and Table 4.4). Six were from industry, and ten were from government agencies, universities, and industrial associations. Fifteen were face-to-face interviewed, and one-person was interviewed by telephone. The interviews period was between 45 minutes to 90 minutes.

Representatives from public agencies are in the position that can provide policy insight and direction towards the development of EV in Thailand. The interview was held with executives (president, vice presidents, or division directors) or senior researchers responsible for the development of the automotive and parts industry and EV industry. At the same time, interviews with firms were held with the company's top managers. Data from the interview is used to support the survey result in an analysis chapter.

4.4.3.1 Government agency and academic institution interview

Institutional actors are essentials in terms of being an enabler of change by providing supporting policies and programs for niche innovations. Therefore, key actors representing policy makers, regime and niche actors - i.e., firms and industry associations, university and research institutions, government agencies were chosen for the interview. The government agency interviewees were selected using purposive and snowball sampling method. The purposive sampling is used to determine the most relevant interviewees to answer the research's objectives. Snowball sampling was also used by asking some interviewees to introduce other important actors that would benefit the study.

Policy information retrieved from the landscape-level would provide pressure to the existing regime and policy initiatives that provide new opportunities to niche-level. The policy explored includes a policy framework relating to the development of EV in Thailand to identify the effect or a pressure of policy framework on the current operation of the Thai automotive industry. This study also explores policy initiatives that would drive regime-level change or support the Thai automotive industry towards the transition to the new EV industry. The most important point was to explore the policy initiatives that would allow niche actors to adjust and transform their technological learning in EV technologies. It also explored the role of government and other network members in encouraging network creation and networking status between industry government and academia and the challenge of growing knowledge networks. Interview scripts were adjusted for each category, firms, university/research institutions, and government agencies to suit each actor.

The key government agencies who play an essential role in formulating policy that supports the development of EVs in Thailand were selected for an interview. Table 4.2 provides the list of public agencies, university and research institution that were interviewed.

Table 4.2 *Interviewees* List for Government Agency, University and Research Institution

Agency	Code used thesis	Description	Justification for selection for interview	Interview Date
1) Office of the National Higher Education, Science Research and Innovation Policy Council	Gov 1	Senior Policy Specialist	The agency is responsible for formulating plan supporting research and innovation according to the national plan. And the next generation automotive industry is one of the national strategic industry.	26 August 2019
2) Thailand Science Research and Innovation Agency	Gov 2	Executive	The agency provides funding to collaboration project between university and industry including the automotive and parts industry.	6 September 2019

Agency	Code used thesis	Description	Justification for selection for interview	Interview Date
3) Board of Investment Thailand	Gov 3	Executive	The agency provides packages of incentive to support the production of EV and related components.	5 September 2019
4) Thailand Automotive Institute	Gov 4 Gov 5	Executive	The institute responsible for the masterplan of the automotive and parts industry.	9 August 2019 and 13 August 2019
5) Fiscal Policy Office: Division of Sectoral Industrial Policy 1	Gov 6	Executive	The agency works closely with the automotive and parts industry in providing direction	15 August 2019
6) National Science and Technology Developme nt Agency (NSTDA)	Resea rch 1	Project Manager	The agency is conducting collaboration projects with industry regarding electric mobility programs	16 August 2019
7) Chulalongk orn University	Uni1 and Uni 2	Associate Professor s	Associate professors involved in many EV policy development projects	7 August 2019

Agency		Code used thesis	Description	Justification for selection for interview	Interview Date
8)	King Mongkut's University of Technology North Bangkok	Uni 3	Associate Professor	Associate professor works closely with several automotive suppliers.	17 September 2019

The interview questions with government agency and academic institution (See Table 4.3) were aimed to collect and analyse data relating to the role of the agency and its policy intervention which would support firms in the automotive and parts industry in transitioning to develop EV technologies. The knowledge network between government agency, academic institution and industry was also explored. Interview questions were slightly adjusted for each agency to suit the roles and responsibilities of the institutions.

Table 4.3 Set of Questions for Government agency and research institution

Items	Objectives
Q1-Gov - What is the main goal of supporting the development of EV in Thailand?	To identify policy landscape for EV which would provide pressure to the current regime-level
1. What are your organization policy priorities in order to promote the development of EVs?	To investigate responsibilities of a government agency in supporting the development of EV
2. What specific policy mechanisms are being provided to help firms particularly SMEs suppliers in automotive industry to overcome the challenges of transition from internal combustion engines to EVs?	To explore specific policies that would help firms in the automotive industry to develop their technological learning, particularly SMEs firms
3. What is current policy in your organization to promote the collaboration among universities, industry and government which can support the technological capability of local suppliers? And how effective?	To explore government policy that support the creation of knowledge network between government, academic institution and industry

Items	Objectives
4. What are critical success factors affecting collaboration among government, university and industry?	To identify factors which support the development of knowledge network

4.4.3.2 Firms interviews

The purpose of the firm interview was to gain better insight from firms in addition to the survey data; in-depth interviews were conducted with top management staff such as Chief Executive Officer (CEO) and senior managers of firms. The introductory letters from STI were sent to firms. All interviews were conducted using face-to-face interviews, except for one interview that was achieved through telephone.

The interview was aimed at a few selected firms which could represent the automotive and parts industry structure, namely car producer, tier1, tier 2, and 3. The Industrial Association was interviewed as a representative of the majority of firms in the automotive and parts industry to gain a broad perspective and elicit the majority of firms' data regarding impacts on their operation, responsiveness, and the need for policy intervention.

To cover the whole MLP framework, new actors in the EV industry were interviewed to explore potential knowledge network which could develop to achieve Thailand’s goal of being an EV production base. Thus, the Electric Vehicle Association of Thailand (EVAT) was interviewed; the interview took place with the president of the association to provide the current situation of EV development, including barriers. EVAT also provided data on the current activities of firms working as a network to develop EV project.

This information would help the researcher understand the niche activities and give a view of niche-in -the-making which would answer part of the research question of how firms would adjust to the change.

An electric vehicle producer developing EV in Thailand was interviewed; this was to elicit data from the perspective of a new player in the industry of the current situation of EV development and barriers in developing EV in Thailand. Overall, five firms and two industrial associations were interviewed. Table 4.4 shows the name of firms and industrial associations which were interviewed.

Table 4.4 List of Firm and Industrial Association Participants

Firms	**Position**		**Interview date**
1) Somboon Advance Technology Public Co., LTD	Vice Chairman of the Executive Board	Firm 1	14 August 2019
2) Thai Summit Autopart Industry Co., LTD	Vice President	Firm 2	2 October 2019
3) BMW (Thailand) Co., Ltd	Director Corporate Communications	Firm 3	30 September 2019
4) FOMM (ASIA) Co.,Ltd	General Manager	Firm 4	1 October 2019

Firms	Position		Interview date
5) Thai Car Show Automotive Products Co.,LTD	Office manager and Factory Manager	Firm 5	8 October 2019
6) Thai Autoparts Manufacturers Association (TAPMA)	President	Indus 1	5 October 2019
7) Electric Vehicle Association of Thailand	President	Indus 2	20 September 2019

Firm interviews were aimed at retrieving more in-depth information beyond the questionnaire survey, with interview questions relating to the impact on firms, adjustment to the transition, firm's linkage and knowledge network and requirements for policy support. The information retrieved from firms' interviews was used for a qualitative analysis to complement to the survey data.

The Industrial Association's interview was aimed to retrieve information which could represent an industry perspective regarding the current situation of EV development, potential transition of the industry and current policy intervention and expected policy initiatives. The set of interview questions for firms and industrial associations are shown in Table 4.5 and Table 4.6 respectively.

Table 4.5 Interview questions for firms

Items	Objectives
1. Please explain, how the transition to EVs might affect your company?	To explore impact of EV on firms
2. How does your company plan to adjust during the transition period from internal combustion engine to EVs?	To explore the responsiveness of firms
3. Who are the most important partners when it comes to technology development for your firm? How and why?	To identify firm's learning process and its knowledge network
4. What is your experience on networking with other firms, government, universities and other public agencies?	To explore firm's experience on exploiting knowledge network
5. How do you provide technical assistance or technology transfer to firms in the lower tier?	To identify technological learning process between large firms and SMEs

Items	Objectives
6. Do you have any recommendations for the government incentives to support technological learning of firms in EVs development, for Thai firms to gain sustainable competitive advantage?	To explore firm's policy requirement in supporting its transitioning activities

Table 4.6 Interview questions for Industrial Associations

Items	Objectives
1. What is your opinion regarding policy in Thailand that promotes EVs? What has been done? What is still missing? What should be in place first?	To identify existing policy intervention and potential policy initiatives
2. What is the tendency of car producers in investing in electric vehicle in Thailand?	To explore a potential regime, change which could lead to a transition of parts suppliers
3. What are impacts of shifting to EVs on the automotive industry particularly parts supplier and supporting industry?	To explore impact and responsiveness of EV entrance on the industry from the viewpoint of its representative

Items	Objectives
4. Do you think Thailand can still maintain status as world class suppliers for automotive industry with a change from internal combustion engine to EVs? And how?	To explore the possible transition of suppliers towards EV development and production
5. Does the association initiate program to support members particularly technological learning of SMEs which will support the transition from internal combustion engine to EVs? In what way?	To explore a current policy initiative supporting technological learning of firms in adjusting from producing conventional vehicle to EV
6. Which policies are required to support SMEs/niche to promoted technological learning and achieve sustainable competitive advantage?	To explore the required policy which should be in place to support the technological learning of firms
7. On a basis of your experience, do you have any recommendations to strengthen linkages among firms, academia and governments to support the development of technology and innovation network for industry?	To understand the strength or weakness of current knowledge networks

4.4.4 Questionnaire structure and content

This section discusses the questionnaire structure, content, and the adequacy of the questionnaire.

4.4.4.1 Questionnaire Structure

The questionnaire was divided into four parts. The four parts include (1) General Information on firm characteristics (2) Firms responsiveness to the transition to EV (3) Technological learning of firms and knowledge networks, and (4) supporting policy for the firm's technological learning of EVs (See Table 4.7).

Table 4.7 Structure of Questionnaire

Structure of the Survey	**Survey Questions**
Part 1 General information: Firm's characteristic	• Name, year of establishment, number of employees, number of R&D employees, R&D budget, fixed assets, ownership structure, Tier status in the supply chain, main products, technology capability, suppliers for firms
Part 2 Firms transitioning to EVs	• Perception on government policy and factors to support the development of EVs • EVs impact on the firm's operation

Structure of the Survey	Survey Questions
	• Responsiveness to developing new technologies or diversifying their experience • Skill needed (or gaps to fill) to transition to EVs • Factors supporting the decision to develop EVs
Part 3 Technological learning of firms and networks	• Sources of technological knowledge • Firm's linkage with triple helix (other firms, government agencies, academia) • Potential sources/networks to develop EVs • Knowledge linkage with car manufacturers/suppliers • Firm's absorptive capacity
Part 4 Supporting policies for EVs production	• Ranking of policies that could support the development of EVs • Opinion on a current policy that supports knowledge networks

Part 1 of the survey includes questions to help identify the firm's general characteristics such as firm size, tier group of firms, and ownership structure (see table 4.7). These questions would provide information on which categories they fall into. Categories such as firm size, ownership, or tier groups are used as independent variables. It also provides the status of a firm on their technology capability level and R&D development by asking about a number of R&D employees and R&D budget percentage compared to sales. This part used multiple choices and open-ended questions to retrieve data.

Part 2 aims to explore firm responsiveness to the transition from an internal combustion engine to an EV. As firms in the automotive and parts industry are bound by their established practice, technologies, and existing resources (infrastructure, manpower, finances, etc.), the entrance of EVs brings in new challenges. This section explores how firms respond to the challenge and what is their direction in implementing change. This section also asked firms to identify what are opportunities or threats in developing EV related technologies. The elicited data can be used to analyse barriers in the socio-technical regime.

According to Geels (2018), incumbent regime actors may respond to change differently, either resist the change, delay or obstruct the change. But incumbent actors can also accelerate the shift towards the niche innovation by readjusting their goal or strategy and their resources. Thus, the questions asked to indicate the industry's perception and how they will respond towards the transition and how firms commit to the transition. This section also identifies technological gaps that firms must fill to readjust their operation.

The questions in part 2 ask firms regarding their perception of EV national policy and how much the EV entrance would impact their current operation. Firms were asked to rate using a five-point Liker scale their perception and impact. Questions also asked the firm's direction whether they will follow the niche, which means to develop related EV technologies, or they would diversify and use their experience in other industries using multiple choices.

Firms were asked to identify their learning requirements, which would equip them with knowledge and technology towards the niche innovation. This data would support policymakers in designing appropriate policy which serves the needs of incumbent firms.

Part 3 aims to understand the established practice of firms in terms of their technological learning and knowledge network. Learning ability or ability to acquire knowledge is an essential capability in responding to change. And a major factor that affects the technological learning of firms is their absorptive capacity (Cohen & Levinthal, 1989; Moeini & Zawdie, 1998). The relationship between absorptive capacity and learning is that a firm with better absorptive capacity can recognize new knowledge or technology with the result that learning becomes effective. The ability to absorb external knowledge is crucial for firms to adapt themselves to the fast-changing environment (Camisón & Forés, 2009). Thus, this section tries to explore whether firms possess technological learning abilities that allow firms to seize new opportunities or reorganize themselves to meet with the changing circumstances.

The questions in part 3 were associated with the firm's source of knowledge, networking with other organisations and absorptive capacity. These questions were based on a presumption that linkage with other organisations leads to technological learning activities and knowledge sharing.

Questions on sources of knowledge were adapted from the previous study of Samarnbutr (2012) and Ferreras-Méndez et al. (2016). Firms were asked to rate sources of knowledge from which they generally acquire knowledge through five-point Likert scales. This data could provide information relating to the depth of relationship with or intensity of sources of knowledge.

Questions on a firm's linkage and interaction with other firms, universities and governments were adapted from Nakwa (2013) These questions have firms choose which organisations they have linkages with and identify activities they conduct with that organisations. The identification of linkage with several partners helps determine the breadth or broad connection with external organisations.

In the questionnaire, to measure absorptive capacity, we drew from previous studies using the constructs of absorptive capacity by Camisón and Forés, (2009) and Flatten et al., (2011) and adapt items to explore four dimension of absorptive capacity (acquisition, assimilation, transformation and application), which are based on the concept developed by Zahra and George (2002).

Questions relating to the breadth and depth of a firm's engagement with external partners and absorptive capacity are used to identify factors that support a firm's technological learning in the analysis section.

Part 4 aims to identify policy initiatives that firms would require in leveraging the EV technology development. Also this was to specify the current perception of firms and government policy relating to knowledge network development. The questions are based on the MLP concept that policy initiatives would provide window opportunities to firms in adjusting to the transition. Firm were asked to identify policy initiatives which could support firm's EV development project, while the interview with government agencies, university/research institution, and industrial associations provided information on the institutional aspect. These views of firms on policy initiatives would be beneficial for policymakers to develop a policy that meets the demands of firms.

Table 4.8 presents items that were measured according to the study's objectives in the questionnaire survey and its sources. Questions to elicit firm's responsiveness ; question 12,13,14,15 and 16, were developed based on Geels (2018) concept which indicates that the transition might also occur from regime to niche if there is a development or reorientation of regime actors. Firm's learning requirement questions were based on the study of Scott-Kemmis and Chitravas (2007) that for firm to achieve technological learning, firms have to realize capability gaps. Firm's technological learning questions were aimed to elicit data relating to a firm's learning process or how do firms learn, the intensity with knowledge partners and ability to learn new knowledge. The identification of absorptive capacity in the survey was used to identify a firm's learning capability because absorptive capacity is a crucial ability in collecting and exploit new knowledge. While questions relating to knowledge networks were aimed to understand the firm's current network and potential network in supporting the transition.

Table 4.8 Measurement items of the questionnaire survey

Subjects to be measured	**Question**	**Rationale**	**Sources**
1. Firm's responsiveness to the transition from	Q.12 Perception on	This section's questions aim to explore how the	Questions were developed

Subjects to be measured	Question	Rationale	Sources
internal combustion engine to EV	government policy Q.13 Impact on firm's operation Q.14 Continuity of firm's operation Q.15 Interest in developing EV technologies Q.16 Diversification of experience	change would impact firms (regime-level) and how firms would respond to the upcoming change and its direction in implementing the change	based on a concept of Geels (2018) which focus on how regime actors would respond to changes, either being locked-in or readjusting their goals to comply with the shift
2. Firm's learning requirements that would support firms in adjusting	Q.17 Knowledge or skill gaps of firms	This question is to identify technological learning gap of firms since realization of a	Scott-Kemmis and Chitravas (2007)

Subjects to be measured	Question	Rationale	Sources
its learning to develop EV		firm's gap is characteristic of a strong learner. Firms that can realize their capability gaps could lead to setting their learning strategy and achieve their technological learning	
3. Firm's technological learning process 4. Factors contributing to technological learning of SMEs	Q.21 Acquisition of technological knowledge Q.33 Firm's absorptive capacity	These question focus on how firms learn, technological learning is considered a necessary condition for achieving innovation capability (Edquist, 1997). Learning,	Guo and Guo (2011) Forés and Camisón (2016; Flatten et al. (2011) Ferreras-Méndez et al. (2016)

Subjects to be measured	Question	Rationale	Sources
		particularly technological learning, is a process of accumulating knowledge and building the basis for the development of technological capability of firms. This study incorporates absorptive capacity as a measurement for firm's technological learning. Since an ability to absorb external knowledge is considered crucial for	

Subjects to be measured	Question	Rationale	Sources
		firms to adapt themselves to the changing circumstances.	
5. Development of knowledge network	Q.22, Q.23, Q.24, Q.25	Knowledge network plays a crucial role in firm's technological learning. Technological learning is not an isolated process - it occurs through engagement with external organizations. Thus, these questions explore firm's current linkage or knowledge network with other firms,	Nakwa (2013) Nieto and Santamaría, (2010) Clifton et al. (2010) Zeng et al. (2010) Potinecke and Rogowski, (2009) Brink (2017)

Subjects to be measured	Question	Rationale	Sources
		academic institutions, and government. And potential partners or network that firms would engage in developing EV technologies	

4.4.4.2 Adequacy of the questionnaire

The perception or attitudes of firms in this study use Likert scales to measure those constructs. To measure Likert scale reliability, Cronbach's alpha test was applied to test reliability and internal consistency on a set of Likert's scale. Cronbach's alpha reliability ranges from 0-1, the higher the coefficient, the greater the covariance's reliability. The acceptable score is 0.7 or above. This test is only applied to multiple Likert scale items, which according to this study, are in part 3 questions relating to sources of knowledge and sub-categories of absorptive capacity. The Cronbach's alpha scores for a set of Likert's scale in this study are greater than 0.7 which is considered robust. (See Table 4.9)

Table 4.9 Test of Cronbach's alpha on sets of Likert scale

Questionnaire Sections	**Topic**	**Items**	**Cronbach's alpha**	**Reliability**
Part 3	Source of knowledge acquisition	12	0.78	Acceptable
Part 3	Acquisition of knowledge	5	0.86	Acceptable
Part 3	Assimilation of knowledge	4	0.87	Acceptable
Part 3	Transformation of knowledge	4	0.88	Acceptable
Part 3	Application of knowledge	3	0.86	Acceptable

Note: Cronbach's alpha is above 0.7 and therefore is an acceptable value in all the cases.

4.5 Data analysis

This section discusses methods used to analyse quantitative data and qualitative data. Data obtained from the fieldwork can be categorized into quantitative data and qualitative data. Questionnaires were designed to collect mostly quantitative data and partly open-ended questions. Quantitative data were analysed using the SPSS statistical package, employing both descriptive (section 4.5.1) and inferential analysis (section 4.5.2).

Qualitative data were obtained from a semi-structured interview relating to institutional perspective and policy intervention and partly from an open-ended question in the questionnaire survey. Qualitative data retrieved from the interview is analysed using the narrative method (section 4.5.3).

4.5.1 Descriptive statistical analysis

Quantitative data retrieved from the survey was analysed using SPSS (Statistical Package for the Social Sciences). The quantitative data elicited from the questionnaire are both actual numeric values such as number of employees, R&D personnel, R&D budget percentage/sale. Non-numeric subjects such as perception of EVs impact on the firm's operation, sources of knowledge, and level of absorptive capacity are measured using rating scales (five-point Likert scale). The rating scale is as follows

5 score	Very high
4 score	High
3 score	Moderate
2 score	Low
1 score	Very low

Initially, the results were analysed using descriptive statistics to analyse firms' general characteristics such as firm sizes, tier categories, production type, ownership etc., presented in the form of a percentage, mean, and ranking.

To address the research question and objectives, descriptive statistics were also employed to analyse data partly in part 2, 3, and 4. The data relating to firms' response on the transition to EV, firm's perception on adjusting their current operation, firm’s technological learning process, firm’s knowledge network, and technological learning of firms, were presented in the form of mean, mean rank, frequency, and percentage.

A comparative analysis using the crosstabulation function was applied to compare the difference or similarities between firm size, tier group or ownership structure. This comparison helps emphasis whether there is a difference between SMEs or large firms in terms of their technology capability, impacts on firm’s operation, technological learning and its knowledge network.

4.5.2 Inferential statistical analysis

Data from the survey were also analysed using parametric and non-parametric statistical method. Since, the sample size is small (n=42), there is a constraint in terms of the robustness and reliability of using this statistical method. However, this data has value as it can be suggestive and use in complementary with qualitative data.

This research used three main statistical tools for the comparative study namely, Kruskal-Wallis H test, Mann-Whitney U tests and Fisher’s exact test or Fisher-Freeman-Halton test. These statistical techniques are a non-parametric test which are widely adopted in social science research where data are skewed and of non-normal distribution. Kruskal-Wallis H test is used to determine if there were differences between more than two groups of independent variables on an ordinal dependent variable such as perception score, while Mann-Whitney U test was used to compare between two groups. Fisher’s exact test was used to test the association between groups which could be used as an alternative of chi-squared when there is a low expected frequency count that is less than five. Fisher-Freeman-Halton test is an addition to Fisher's exact test which was used for variables with more larger than two categorical groups.

Furthermore, to examine factors contributing to technological learning of firms, regression was adopted. The regression model was used to explore the association between independent and dependent variables, in this study show how absorptive capacity (the dependent variable) is influenced by external knowledge search (independent variables) in terms of breadth and depth of relationships.

Since the obtained data of both independent and dependent variables are from five-point Likert scale which is an ordinal data, thus, the multiple regression model is appropriate. One independent variable is of categorical variable, so prior to enter into the regression model, it is converted into a dummy variable.

Table 4.10 shows the statistical methods used to analyse the survey data.

Table 4.10

Statistical techniques used to analyse topic of the study

Topic of the study	**Statistical technique**	**Application in the study**
General characteristic of firms	Descriptive analysis, frequency, mean, mean rank, percentage, standard deviation	- Compare numerical data among firm sizes and tier categories

Topic of the study	Statistical technique	Application in the study
	Chi-square or Fisher's exact test	- Compare 2 groups on their technological capability
Responsiveness of SMEs on the transition to EVs - Impact on firm's operation - Interest in developing EVs technologies or diverse their experience	Descriptive analysis, mean Non-parametric test, i.e., Kruskal-Wallis H test, Mann-Whitney U test	- Compare the impact on the operation of firms and responsiveness between firm sizes, i.e., SMEs and large firms - Test the difference between firms' size (2 groups, i.e., SMEs and large firms) if there is a significant difference between firm size
The extent of learning requirements	Descriptive analysis, frequency, percentage	Identify the requirement based on firm size or tier groups
To determine technological learning processes of SMEs	Kruskal-Wallis H test, Mann-Whitney U test	Compare means of technological learning processes between 2 groups or more

Topic of the study	Statistical technique	Application in the study
To identify factors contributing to technological learning of SMEs	Multiple Regression	Explore factors affecting technological learning (absorptive capacity)

Technological learning of firms which is a dependent variable is represented by an absorptive capacity level of firms. It is suggested that in firms facing challenges of global competitions, absorptive capacity is crucial for firm's competitive advantage. Absorptive capacity is an integral part of learning process that support firms in developing new knowledge (Lane et al., 2006). However, antecedents to absorptive capacity have been little explored. Thus, this study explored antecedent factors of absorptive capacity, to determine which antecedents influence the development of absorptive capacity or firm's ability to learn.

Absorptive capacity can be categorized into four sub-categories, acquisition, assimilation, transformation and exploitation. And the four capabilities can be grouped into two subsets; potential (PACAP) and realized (RACAP) absorptive capacity. Independent variables or antecedents of absorptive capacity used in this study refer to a firm's previous interaction with knowledge sources including the relationship between firms, academia or government. Independent variables consist of breadth the diversity of firm's relationship with external partners including other firms, academia and governments (BREADTH). THXD refers to the intensity of relationship with universities, research institutions and government agencies. And INTFD refers to intensity of linkage with other firms. Two control variables are also included: firm size and environmental dynamism. Firm size may have an impact on firm's decision to invest in the development of absorptive capacity. And TURBULENCE refers to technological and market change and other factors that impact firm's decision to adapt.

Five independent variables were entered all at once into three regression model to test whether there is an association between independent variables (See Table 4.11) and each dependent variable namely, overall absorptive capacity and two sub-categories (PACAP and RACAP) of absorptive capacity.

Table 4.11 Independent and dependent variables in multiple regression model

Abbreviation	**Definition**	**Value/Units**	**Measurement**
Independent variables			
BREADTH	Diversity of firm's relationship with external partners namely other firms, universities/research institutions and government agencies relating	Number of types of external partners 0 = no relationship 1 = connect with one type of partners	Nominal scale

Abbreviation	Definition	Value/Units	Measurement
	to knowledge creation	2 = connect with firms and triple helix	
THXD	Intensity of linkage with universities/research institutions and government agencies	Number of projects with universities/research institutions and government agencies	Interval scale
INTFD	Intensity of linkage with other firms	Number of projects with other firms	Interval scale
Control Variables			
SIZE	Size of firms	SME firms Large firms	Nominal scale
TURBULENCE	Factors influencing firms to invest in EV	Five-point Likert scale	Ordinal scale (1 - 5) – mean was used for statistical analysis
Dependent Variables			

Abbreviation	Definition	Value/Units	Measurement
APC	Absorptive capacity	Five-point Likert scale	Ordinal scale (1 - 5) – mean was used for statistical analysis
PACAP	Acquisition capacity and Assimilation Capacity	Five-point Likert scale	Ordinal scale (1 - 5) – mean was used for statistical analysis
RACAP	Transformation and Exploitation Capacity	Five-point Likert scale	Ordinal scale (1 - 5) – mean was used for statistical analysis

4.5.3 Thematic method analysis

The thematic method analysis was used to analyse the qualitative data of this study namely interview data. Interviews were conducted with public sectors and academic institutions regarding their policy interventions in supporting the incumbent firms to adjust their lock-in path and supporting niche actors to develop EV technologies. The interview with institutional actors can provide contextual information regarding policy development that would drive or in some case inhibit the transition. The interview data with firm's representative was similarly analysed using this method to analyse responsiveness and their plans on adjusting to EV.

Thematic analysis can be used to analyse various qualitative data collection methods such as interviews, focus groups, or textual data from a qualitative survey (Terry, Hayfield, Clarke, & Braun, 2017). Thematic method analysis can be applied using two main approaches inductive and deductive. Inductive is exploratory in nature; codes and themes deriving from inductive approach are directed by the data's content which reflex reality. In contrast, deductive' s codes and themes are derived from pre-determine concepts, ideas, or hypotheses (Braun, Clarke, Hayfield, & Terry, 2019; Guest, MacQueen, & Namey, 2014).This study employed both inductive and deductive analysis but is predominated by inductive analysis because the study is driven by research questions rather than hypotheses (Guest et al., 2014).

The interviews were audio recorded and verbatim transcribed. Researcher applied six phases of thematic analysis to extract and analyse interview data namely 1) familiarization with data by reading and note-making on data 2) generation of codes 3) searching for themes by analyse if there is a theme occur from codes relating to research questions 4) reviewing potential themes 5) defining themes 6) producing report which is presented in chapter 6 and 7.

This chapter has laid out the research framework, research design, data collection and data analysis. Research framework was based on MLP theory, assuming that sustainability transition is complex and involves multiple actors from each socio-technical level. Thus, the research design was planned accordingly to the MLP socio-technical level, by collecting data from each level. Landscape-level data was aimed to collect data relating to policy frameworks that support the development of EV in Thailand. Regime-level data was aimed to collect data of regime actors regarding their technological learning and current knowledge network. While niche data was collected to present a possible transition of suppliers towards technological learning for the production of EV by eliciting a firm's responsiveness and potential knowledge network. Policy intervention data was explored since government policy is considered a crucial factor in accelerating the transition.

Data analysis was conducted using several methods to answer research questions and objectives. Data analysis and findings are presented in the next two chapters. Descriptive and inferential statistical analysis are presented in Chapter 5 and analysis of government policy intervention and firm's in-depth analysis from the interview are discussed in Chapter 6

CHAPTER 5
Profiling of firms and analysis of a transition of firms and their technological learning towards electric vehicles

This chapter discusses the results of the survey data. The data is presented in both descriptive statistics and inferential statistics. The descriptive statistic provides information on a general characteristic of firms in the Thai automotive industry relating to firm's responsiveness to the transition, learning requirement, firm's technological learning and knowledge network. The inferential statistic is also applied to examines the association between firm size or tier groups and the previous mentioned. It helps identify the difference between firm size, whether there is a significant difference between SMEs and large firms relating to the responsiveness, impact on the firm's operation, which could represent how the EV technology affects particular players. The inferential statistic also devoted to the analysis of factors contributing to the technological learning of firms in the automotive sector. The analysis would lead to the policy recommendation on how to support firms in the automotive sector, particularly their technological learning.

This chapter is organized into seven parts. The first part discusses the general characteristics of respondent firms. The second part discusses responsiveness of firms to the transition to EV. The third part identifies firm's technological capabilities and their learning requirements. The fourth part discusses how do firm learns or technological learning processes of firms. The fifth part discusses the firm's linkages with partners and its knowledge network. The sixth part explored factors that affect firm's ability to learn. And the last part is the conclusion of the chapter.

5.1 The study sample

This section addresses firms' general information regarding firm age range, size of surveyed firms, tier groups, and ownership. This information describes a characteristic of surveyed firms and is used for categorization and comparison between each category.

This chapter's survey results are based on the self-administered questionnaires received from 42 firms in the selective automotive Industry and parts sector. The survey was conducted in Thailand during 9th July-10th October 2019.The survey was sent out by postal survey with an online link to 408 firms, a response rate is 10.3% of the survey that had been sent out.

5.1.1 Age profile of firms

The Thai automotive industry has been in operation for approximately 60 years. Most of the firms are over ten years old, and the oldest firm 57 years old. shows the distribution of firms in the Thai automotive industry across five age cohorts. Most of the firms covered in the survey (81%) fall within the age range 11-40. Only two of the sample firms can be considered to be newcomers to the industry with their ages under ten years, and at the other end of the age spectrum, eight firms are observed with ages over 41 years old.

Table 5.1 Age of surveyed firms

	Firm age range	**Frequency**	**Valid Percent**	**Cumulative Percent**
Valid	0-10	2	4.8	4.8
	11-20	6	14.3	19.0
	21-30	13	31.0	50.0
	31-40	13	31.0	81.0

	Firm age range	Frequency	Valid Percent	Cumulative Percent
	41-57	8	19.0	100.0
	Total	42	100.0	

5.1.2 Size of firms

Firms that responded to the questionnaires administered are mainly those with over 200-million-baht worth of fixed assets, which qualifies them to fall into the large firm category. As shown in Figure 5.1, large firms constitute 57% of the sample's total number. Approximately 43% of the sample firms who responded to the survey questionnaires are small and medium-sized firms (SMEs) with fixed assets below 200 million-baht. Eighteen of these are small and medium firms and the remainder twenty-four are large firms. Firm size categorization based on size of employment and fixed assets is determined following definitions given by the Ministry of Industry, Thailand.

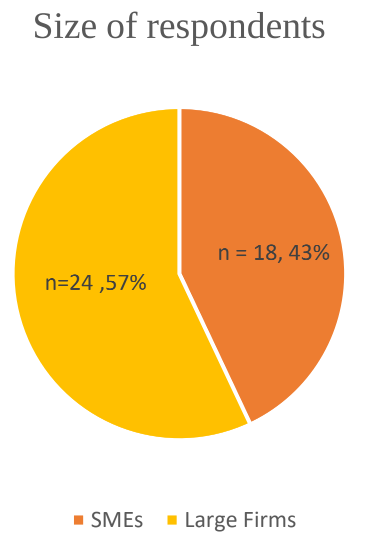

Figure 5.1 Size of respondents

5.1.3 Tier groups

With respect to the place of firms in the tier group category within the industry, Table 5.2 shows the majority of firms that responded to the survey questionnaires are in tier 1, accounting for 41.5% of the total number of respondents covered in the survey. Respondents from second and third tier firms accounted for 51.2% of the total number of respondents. From the car producer category, a total of 3 companies (or about 7.3% of the total number of respondents) responded to the survey questionnaires. The total number of respondents covered in the sample amounts to 42 firms.

Table 5.2 Respondents presented in Tier groups category

Tier Groups	**Car Producer**	**Tier 1**	**Tier 2,3**	**Total**
Number of companies	3	17	21	41*
Percent	7.3	41.5	51.2	100.0
Cumulative Percent	7.3	48.8	100.0	

*Missing data = 1, Total responding firms=41

Table 5.3 shows the composition of tier groups in the automotive industry, which includes car-producing firms, tier 1, tier 2 and tier 3 cross-tabulated with a size of firms. It is shown that, more than 70% of the firms in tier 2 and tier 3 are SMEs, while the majority of firms in tier 1 and car producer categories are large companies and a small segment of SMEs. In addition, a Fisher's exact test for association between groups indicates that there is a statistically significant association between firm size and tier groups as assessed by Fisher's exact test, $p = 0.004$. These are in line with the automotive industry structure in Thailand, where SMEs are primarily in tier

2 and tier 3 categories. In contrast, the population of tier 1 and auto assemblers is predominantly large enterprises. One firm in the sample of firms did not identify their tier groups.

Table 5.3 Percentage of firms based on size and tier group crosstabulation

	SMEs	**Large Firms**	**Total**
Car Producer	1	2	3
Percentage	5.6%	8.7%	7.3%
Tier 1	3	14	17
Percentage	16.7%	60.9%	41.5%
Tier 2/3	14	7	21
Percentage	77.8%	30.4%	51.2%
Total	18	23	41*
	100%	100%	100%

*Missing data = 1, Total responding firms=41

Fisher’s exact test: p-value = 0.004**

**P<0.05 statistical significance at 0.05 level of significant, thus the null hypothesis was rejected we can accept the alternative hypothesis.

5.1.4 Ownership structure

The automotive industry comprises both local and foreign companies, including multinational companies. According to Table 5.4 , Thai-owned firms are dominant in the tier 2,3 category amounting for about 94% of the group's total number. About 53% of Tier 1 firms are Thai-owned, in part or in whole, and the rest (47%) are foreign-owned. A hundred percentage of the surveyed firm in the car producer category are, wholly or partly foreign-owned. The ownership structure in the survey is broadly similar to the ownership structure of the Thai automotive and parts industry, where the car producer's category mostly consists of foreign companies. On the other hand, the supporting tiers of companies (tier 1 and tier2/3) are mostly Thai-owned. A Fisher's exact test for association also indicates that there was a significant association between tier groups and ownership structure which p = 0.016. This underlines the correlation between the roles of different tiers and the ownership preferences of companies operating within those tiers. In conclusion, the ownership structure within the Thai automotive industry exhibits a distinctive pattern: Thai-owned firms dominate the supporting tiers (tier 2 and tier 3), whereas foreign-owned firms dominate the car producer category. This configuration suggests a division of labor and expertise, with Thai companies excelling in supplying components and parts, while foreign companies are more involved in the assembly and production of complete vehicles.

Table 5.4 Tier group and ownership structure of the surveyed firms

	Car Producer	**Tier 1**	**Tier 2/3**	**Total**
Majority Thai	1	8	17	26
Percentage	100%	53.3%	94.4%	76.5%
Majority Foreigner	0	7	1	8
Percentage	0%	46.7%	5.6%	23.5%
Total	100%	100%	100%	100%

*Missing data = 8, Total responding firms = 34

Fisher's exact test: p-value = 0.016**

**P < 0.05 statistical significance at 0.05 level of significant, thus the null hypothesis was rejected we can accept the alternative hypothesis.

5.2 Response of firms to questions on the transition from internal combustion engine to electric vehicles

The aim of this section is to show how firms in the automotive and parts industry respond to the challenge of transition from the internal combustion technology regime to electric driven vehicles (EVs) and related technologies. The way firms respond to this challenge is broadly reflective of their environmental perspective, in general, and their preparedness to comply with government policy supporting the development of EVs in Thailand, in particular, notwithstanding the impact of the transitional challenge on the current operation of firms. The latter is evidently a matter of concern for many firms as the transition process from ICE to EV would not be expected to involve a 'quantum jump' into the new by obliterating existing capabilities.

5.2.1 Responsiveness to the government policy and the impact on firm's operation

This study intends to explore how existing firms in the automotive and parts industry respond to the emerging trend of electric vehicles by investigating firm's awareness of national policy related to EV, the realization of impact on their current operation and their adjustment to new technologies. It was asked in the survey how companies would use their existing capabilities in preparation for the upcoming change. By considering the development of new products relating to EVs or diverting their experiences to other areas if they are not favorably disposed the new EVs technologies. According to observations presented in Table 5.5 , there is evidence to suggest that firms would fall in line with the government's policy commitment to make Thailand a hub for the production of electric vehicles in the region. This is indicated by the 'coefficient of agreement' at 3.71. Regarding the impact of the transition to EVs on firms' operation, the evidence-based on the Likert scale data shows the overall coefficient of agreement at 3.24, which means firms' decision to transition to the EV technology regime would have an impact on their current operation.

Table 5.5 Mean and Standard deviation of perception of government policy supporting EVs and Degree of EVs impact on firm's operation.

Item	**N**	**Mean**	**Std. Deviation**	**Interpretation**
Government Policy on EVs	42	3.71	1.065	Agreed
Degree of EVs impact on operation	42	3.24	1.410	Impact on their operation

When looking into which category of firm size would be affected the most by the change in automotive technology, according to Table 5.6 The analysis of the mean scores indicates that, on average, SMEs perceive a slightly higher impact of EVs on their firm operations (mean = 3.51) compared to Large Firms (mean = 3.04). It seems that SMEs see that the shift in automotive technology from internal combustion to EVs would strongly affect their current production or products. However, the Mann-Whitney U test results show that this observed difference is not statistically significant, as the p-value (0.248) is greater than the commonly accepted significance level of 0.05.

Based on the Mann-Whitney U test, it did not find a statistically significant difference between SMEs and large firms in terms of their government perception and the perceived degree of impact on their operations due to the shift in automotive technology. It is worth considering potential explanations for the lack of significance. Additionally, external factors such as government policies or technological advancements could also play a role in shaping these perceptions which will be later discussed in Chapter 6.

Table 5.6 Comparison of mean on the perception on EV policy and a degree of impact on firm's oepration between SMEs and large firms

Firm Size		**Government perception regarding EV policy**	**Degree of Impact on firm's operation**
SMEs	Mean	3.87	3.51
	N	18	18
	Std. Deviation	0.964	1.146
Interpretation		Strongly agreed	Strong impact
Large firms	Mean	3.58	3.04
	N	24	24
	Std. Deviation	1.139	1.574
Interpretation		Strongly agreed	Medium impact
Total	Mean	3.71	3.24
	N	42	42
	Std. Deviation	1.065	1.410
Mann Whitney U test (Sig)		0.364	0.248

5.2.2 Continuity of firm's operation

Firms were also asked how the new EV technologies would affect their products. The products would be discontinued, or whether they would continue to be produced on a business-as-usual basis, or whether products would need to be adapted to improve their environmental appeal. Table 5.7 shows that among the participating firms, 24% indicated their intention to discontinue their current products in light of EV technologies, while 22% planned to continue their products without any alterations. The majority, comprising 53% of the firms, expressed the intent to adapt their products to align with the emerging EV technology and business environment. This data demonstrates a significant awareness and proactive stance across firms of various sizes to prepare for the forthcoming changes in the automotive sector.

A noteworthy observation is that all sizes of firms, irrespective of their magnitude, recognize the necessity of adjusting their product offerings to accommodate the future EV technologies. This underscores a collective acknowledgment of the industry shift and a willingness to embrace change. Notably, a comparison of discontinuity rates between Small and Medium-sized Enterprises (SMEs) and Large Firms reveals a slightly higher discontinuity rate among SMEs (29%) compared to Large Firms (21%). This trend is consistent with the findings from Table 5.6, where SMEs appeared to experience a more obvious impact on their operations.

To further investigate the potential association between firm size and continuity decisions, Fisher's exact test was employed. Fisher's exact test is an appropriate choice when expected cell counts are less than five, an assumption met in this study due to the categorical nature of the data. The test yielded a p-value of 0.505, indicating that the observed associations between firm size and continuity decisions are not statistically significant. The outcomes highlight a general recognition among firms of all sizes regarding the need to adapt to future EV technologies. Despite SMEs expressing a higher discontinuity rate than Large Firms, the statistical analysis suggests that this observed difference is not significant. This implies that while SMEs might be discontinuing their products at a slightly higher rate, the decision to do so does not significantly correlate with firm size.

Table 5.7 Continuity of firm's operation

Continuity	**SME**		**Large Firms**		**Total Firms**		**Fisher's exact test**
	No.of answers	Percentage	No.of answers	Percentage	No.of answers	Percentage	
Discontinue	5	29%	6	21%	11	24%	Sig = 0.505
Continue	2	12%	8	29%	10	22%	
Adapt	10	59%	14	50%	24	53%	p > 0.05)
	17	100%	28	100%	45	100%	(

*Multiple answers, Total responding firms = 38

$p > 0.05$ no statistical significance at 0.05 level of significance

Among SMEs in the sample, 29% indicated plans to discontinue their products in the wake of the EV transition, while 12% intended to maintain the status quo. The majority, comprising 59% of SMEs, opted for product adaptation. In contrast, the impact on large firms appears less stated, with only 21% indicating potential product discontinuation. A significant proportion of large firms, 29%, planned to continue with business as usual, and 50% expressed intentions to adapt their product offerings.

This pattern of results aligns with the findings related to the impact of EVs on firm operations. SMEs emerge as the segment most susceptible to disruption, consistent with the higher rate of discontinuation among SMEs and the recognition of their increased vulnerability to EV-driven changes.

To examine whether firm size significantly influences continuity decisions, a Fisher's exact test was conducted. The test yielded a p-value of 0.505, indicating that no statistically significant difference exists in continuity decisions between SMEs and large firms. The data reveals that while SMEs are more prone to discontinuation, all firms, regardless of size, acknowledge the importance of strategic preparation for the forthcoming EV technologies. The slightly higher discontinuation rate among SMEs aligns with their heightened exposure to operational impacts. However, the statistical analysis (Fisher's exact test) does not confirm a significant difference in continuity decisions between SMEs and large firms.

While SMEs exhibit a more prominent inclination toward discontinuation, no statistically significant difference is confirmed by the inferential analysis. However, the findings illustrate the preparedness of firms, irrespective of size, to adapt to the upcoming EV landscape. As the automotive industry undergoes transformative change, these insights contribute to understanding how firms navigate the challenges and opportunities presented by the emergence of Electric Vehicles.

Table 5.8 shows relationship between product adaptation and firm tiers in response to EV transition. This study delves into the response strategies of firms in different tiers when confronted with the need to adapt their products in the face of the Electric Vehicle (EV) transition. The analysis examines whether there is a correlation between firms' tier classification and their decisions to discontinue, adapt, or continue their products in light of the EV paradigm shift. Table 5.8 presents a breakdown of firms' product adaptation decisions across different tiers. Notably, car producers exhibit the highest proportion (100%) followed by tier 2/3 (60%) and tier 1 (41%) Interestingly, tiers 2 and 3 exhibit the highest proportion (60%) of firms choosing to adapt their products. Tier 1 firms closely follow, reflecting a comparable percentage of 41%. Additionally, evidence of discontinuation decisions is scattered across various groups, with tier 1 and the combined tier 2/3 category showing notable concentrations. Examining the continuation decisions, it emerges that large firms (32%) lean slightly more towards continuation than SMEs (15%). This finding aligns with the earlier observation regarding the impact of EVs on firm operations, which highlighted SMEs as being particularly susceptible to the changes brought by the EV transition.

To make certain of the existence of a statistically significant association between tier groups and continuity decisions, a Fisher's exact test was conducted. This test is well-suited for categorical data with limited expected cell counts. The resulting p-value of 0.405 indicates that the observed data does not provide sufficient evidence to establish a statistically significant association between tier groups and continuity decisions.

The exploration of product adaptation strategies across different tiers sheds light on the responses of firms to the EV transition. While certain tiers exhibit notable patterns, the statistical analysis does not establish a significant link between firm tiers and continuity decisions. This study contributes to the ongoing discourse on the impact of EVs on different tiers of firms, offering insights into how they are strategically positioning themselves in the evolving automotive landscape.

Table 5.8 Continuity of firm's operation based on tier groups

Continuity	Car Producer		Tier 1		Tier 2/3	
	No.of answers	Percentage	No.of answers	Percentage	No.of answers	Percentage
Discontinue	0	0%	6	27%	5	25%
Continue	0	0%	7	32%	3	15%
Adapt	3	100%	9	41%	12	60%
	17	100%	22	100%	20	100%

Multiple answers, Total responding firms = 38

Fisher's exact test: p-value = 0.405*

*P > 0.05 no statistical significance at 0.05 level of significance, thus we can retain the null hypothesis and reject the alternative hypothesis.

5.2.3 Firm's interest in developing EV and diversification of experience

This study examines how firms intend to adapt their business activities in response to the emergence of the Electric Vehicle (EV) regime. Specifically, the study investigates whether firms aim to explore new opportunities by developing technologies related to EVs or to diversify into other business sectors. This exploration is captured in Table 5.9 and Table 5.10. Notably, 78% of surveyed firms expressed interest in pursuing new opportunities through the development of EV-related technologies.

Analyzing the data by considering firm size reveals an interesting trend that underscores a differentiated response to the EV transition between Small and Medium-sized Enterprises (SMEs) and Large Firms. Table 5.9 illustrates that large firms exhibit a greater inclination towards embracing change and exploring new opportunities within the realm of EVs. Impressively, 83% of large firms indicate their willingness to engage in the development of technologies related to EVs, in contrast to the 71% of SMEs showing interest in new technologies.

To statistically validate the observed relationship between firm size and interest in developing EV technologies, a Fisher's exact test was performed. Fisher's exact test is particularly suited for situations where the expected cell counts are low. The results of the test, however, indicate no statistically significant association between firm size and the expressed interest in developing EV technologies.

This study underscores that, in response to the evolving EV landscape, firms are recognizing the potential for growth through the exploration of new opportunities. Whether by developing EV technologies or diversifying into other sectors, firms are aligning their strategies to the changing industry dynamics.

The subtle differences in response strategies between SMEs and Large Firms provide valuable insights into how varying sizes of firms approach the impending EV era. While large firms appear keener on technology development, the statistical analysis cautions against drawing a definitive link between firm size and the intent to engage in such pursuits. This study contributes to the understanding of how firms are gearing up for the transformative impact of EVs on the business landscape.

Table 5.9 Interest of firms in developing EV technologies

Interest in developing EV technologies	SMEs		Large Firms		Total Firms	
	No.of answers	Percentage	No.of answers	Percentage	No.of answers	Percentage
Yes	12	71%	20	83%	32	78%
No	5	29%	4	17	9	22%
Total	17	100%	24	100%	41	100%

Multiple answers, Total responding firms = 41

Fisher's exact test: p-value = 0.45*

*P > 0.05 no statistical significance at 0.05 level of significance, thus we can retain the null hypothesis and reject the alternative hypothesis.

According to Figure 5.3, most of the surveyed firms (32%) expressed interest in developing other technologies related to the EV regime beside the given categories in the survey. These other EV-related technologies that firms stated in the survey include new components and technologies that would support electric vehicles, such as powertrain for EVs, lightweight materials and advanced materials for EV parts, motors etc. About 25% of the surveyed firms would be interested to engage in battery categories i.e. battery and battery accessories; 20% of firms in the sample would engage in intelligent transport system such as GPS, driving control unit, 16% would be involved in charging systems aligned to the EV technology; and 7% in the production of components based on rubber materials.

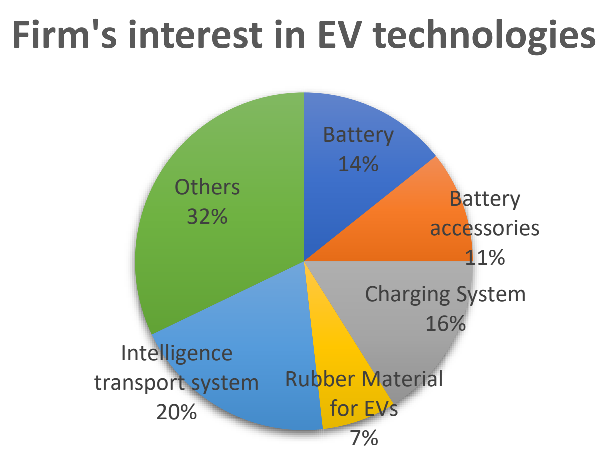

Figure 5.2 Distribution of firms' interests in developinn EV-related technologies

Firm were also asked if they are interest in diversifying their existing experience to other industries. Table 5.10 shows that 78% of the surveyed firms showed interest in diversifying their business experiences by making inroads into new sectors that would allow them to exploit their existing capabilities. Table 5.10 reveals an intriguing dimension to firms' responses by considering their sizes. The data shows that SMEs exhibit a slightly higher interest in diversifying their business experiences compared to large firms. Specifically, 80% of SMEs within the sample express this interest, while 76.5% of large firms indicate a similar intent. It's evident that firms of all sizes are keen on harnessing their existing capabilities towards novel technological pursuits, such as robotic systems, rail technologies, and aviation technology. This collective enthusiasm underscores a proactive approach to adapting strategies in line with technological advancements.

This study underscores that firms, regardless of their sizes, are actively engaging with the prospect of change brought about by technological advancements and industry shifts. While large firms gravitate towards specialized innovation, SMEs are more likely to seek out industries where their established expertise can be effectively applied.

Table 5.10 Interest in diversification of firm's experience to other industries

Diversification of experience to other industries	**SMEs**		**Large Firms**		**Total Firms**	
	No.of answers	Percentage	No.of answers	Percentage	No.of answers	Percentage
Yes	12	80%	13	76.5%	25	78.00%
No	3	20%	4	23.5%	7	22.00%
Total	15	100%	24	100%	32	100.00%

Multiple answers, Total responding firm = 32

Figure 5.3 shows the probable diversion effect of the advent of the EV technology on the activities of the surveyed firms, as some firms would choose to diversify their business experiences by moving into other areas. For instance, the robot sector would gain the most attention from firms in the automotive and parts sector (29%); and 28% of the firms surveyed would be attracted towards business in the rail system. About 19% of the surveyed firms would consider the aviation sector a potential where they could exploit their technological capabilities gained in the automotive industry. And those who would move to the medical device sector count to 12% of the surveyed firms.

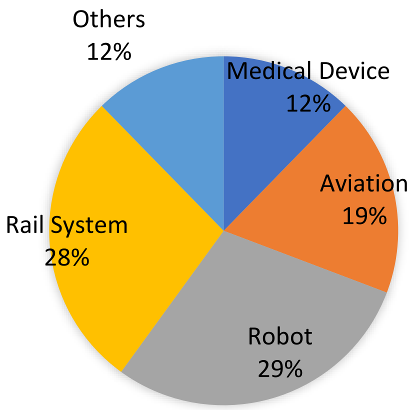

Figure 5.3 Proportion of industries that surveyed firms chose to diversify their experience

At present, related organization that support the development of human resources in automotive and parts sector such as Thailand Automotive Institute (TAI) have started the training program for existing suppliers who would like to switch their technology capabilities to other sectors. The program such as supplier development program towards aviation industry, this supporting program would allow suppliers in automotive and parts sector to use their similar expertise without risking in investing in new technologies. The evidence borne out by the survey data shows that most of the firms on the supply chain would opt to switch.

5.3 Firm's technological capabilities and their learning requirements

The survey asked firms to identify activities that could define their technology capability. This study used Lall (1992) concept in defining technological capabilities as an investment and production capability and categorized it into three levels, namely, basic or routine, intermediate or adaptive and advanced innovative. Basic skill includes quality control, system maintenance or minor adaptation of product or process. Intermediate capability refers to an ability to adapt existing process or product improvement. Advanced capability refers to the ability to conduct basic research and design ability to create product or process innovation.

The results presented in Table 5.11 reveal a consistent pattern across all firm sizes within the automotive sector. Remarkably, firms of all sizes exhibit a comprehensive range of technological capabilities, from basic maintenance and process improvement to advanced capabilities involving basic research and the design of innovative products and processes. This disproves the common misconception that advanced capabilities are exclusively the domain of large firms.

When comparing Small and Medium-sized Enterprises (SMEs) and Large Firms, some noteworthy similarities emerge in terms of basic and intermediate capabilities. These capabilities are almost evenly distributed between the two groups, with a slightly higher percentage in SMEs. The key differentiation surfaces in advanced capabilities, where large firms demonstrate a higher proportion (22%) compared to SMEs (14%).

To statistically validate the observed relationships between firm size and technology capability levels, a Chi-square test for independence was conducted. This test assesses whether two categorical variables, in this case, firm size and technology capability, are associated. The results of this test did not confirm a statistically significant association between technology capability and firm size.

In conclusion, according to the survey, firms in the automotive and parts industry still possess basic and intermediate technological capability levels which in line with previous studies (Gerdsri et al., 2012; P. Intarakumnerd & Techakanont, 2016; Sadoi, 2010). The study provides valuable insights into the technological capabilities of firms in the automotive sector, emphasizing their proficiency across all levels. While there are some variations between SMEs and Large Firms, particularly in advanced capabilities, the data refutes the notion that advanced technological competencies are exclusive to large companies. But overall capabilities of firms are mostly limited to basic and intermediate level. In addition, this data borne some limitation, the findings are reliant on the sample composition and may not entirely mirror the industry's diversity.

Table 5.11 Technological capability level of surveyed firms

	SME		**Large Firms**		**Chi-Square test**
	Responses		Responses		
	No.of answers	Percentage	No.of answers	Percentage	$X^2 = 1.24$
Basic	21	48%	31	42%	Sig = 0.537
Intermediate	17	39%	26	36%	($p > 0.05$)
Advance	6	14%	16	22%	Df =2
	44	100%	73	100%	

*Multiple answers, Total responding firms = 38

P > 0.05 no statistical significance at 0.05 level of significance

Apart from specifying their existing technology capabilities, to support firm's ability to participate in EV projects in the future, firms were also asked to specify their skill gap or skill requirement. According to Scott-Kemmis and Chitravas (2007), the realization of firm's capability gaps is crucial in achieving technological learning. Identification of capability gap help shaping a specific knowledge and skill acquisition goal and leads firms to realistic learning activities based on their skill gaps.

Figure 5.4 shows the skill gaps, which could constrain companies from transitioning to the EVs technology regime. The ability to conduct research and development seems to be significant for all firm sizes which large firm requirement is slightly higher than SMEs; about 53.8% of large firms and approximately 46.2% of SMEs in the sample need supports for R&D capability. The second ability which is considered crucial for firms is engineering designing capability; large firms (27.1%) tend to perceive that this skill is more crucial than SMEs (20.5%). Product design ability is of important for SMEs which accounted for 20.5% of surveyed firms and 16.7% for large firms.

Overall, R&D capability and design abilities which consider an advanced technological capability are requirements of firms in adjusting their learning strategy to cope with future change.

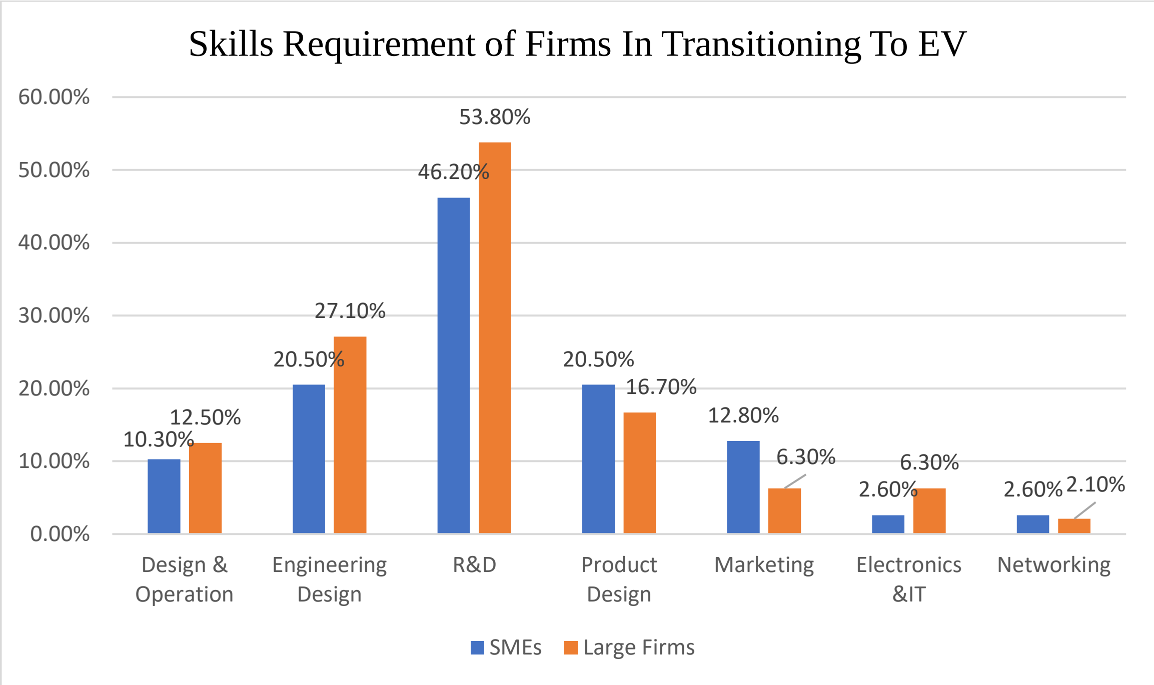

Figure 5.4 Skill requirements of the surveyed firms to support their transition to EV

5.4 Technological learning processes of firms

This section discusses firm's current technological learning process by exploring how do firms learn by identifying their sources of knowledge acquisition. And also explore firm's ability to learn or an absorptive capacity of firms. Technological learning of firms can lead to the development of innovation capabilities (Edquist, 1997); but the essence of learning which could ultimately translate into innovation, depends on the learning processes of firms. Effective learning processes involve interaction with networks. Other factors that impact the effectiveness of technological learning would be absorptive capacity which helps firms to identify, absorb new knowledge, and creatively translate it into new products and processes.

5.4.1 Sources of knowledge acquisition

This section based on the questionnaire survey that ask firm what sources of knowledge they consider important when they develop innovation. Table 5.12 shows the Likert scale-based mapping of the sources of knowledge acquisition as sources of capabilities in terms of their significance for the firms. Firms were asked to identify the importance of the knowledge sources they would consider on a five-point Likert scale (1 least important, five most important). From the average scores in Table 5.13, according to a total score it can be seen that in-house training is the most important source of knowledge (with a score of 3.71), followed by the hiring of employees (with a score of 3.71). SMEs prioritize their knowledge acquisition through an internal effort by using in-house capability development (3.36). Large firms, like small firms, consider their existing resources or in-house capability as the most crucial channel of knowledge acquisition (4.00).

The second important source of knowledge for SMEs relies on the acquisition of external knowledge by hiring employees (3.31). And the third important source is through an external network by collaborating with trade body and university or research institution. For large firms, mainly subsidiaries of multinational enterprises, access to their international network or the knowledge stock of parent companies acts as their second source of knowledge acquisition (3.81). In an automotive and parts sector which the relationship between firms is hierarchical in nature, parent company which mostly foreign company transfers their technology to their subsidiaries in Thailand. Large firms also seek external knowledge sources by means of working with university and research institutions (3.53) as their third source of knowledge.

Thus, it is apparent from the survey data that firms of all sizes would acquire the knowledge underpinning their learning processes first through internal efforts aimed at capability development, and secondly from external sources through mechanisms of technology transfer. In the automobile sector, the main external sources of knowledge for SMEs are through hiring and collaborating with partners namely trade body and university/research institution. While large firms acquire core knowledge from their parent company, where the Mann-Whitney test which used to compare between two groups on an ordinal dependent variable, showed that there is a statistically significant difference in acquiring knowledge from this source between SMEs and large firms.

Refer to the survey results on the source of knowledge of firms, firms tend to focus on firm's linkage and internal effort rather than networking with academic institutions such as universities and research institutions. This could be implied that concentrating on their in-house development, allowing them to develop the strength of their existing knowledge and technology capability. While reaching out to external knowledge sourcing could extend their knowledge base and still able to maintain their internal capabilities. Prior to tapping into an external source of knowledge, firms should possess a particular degree of related technological knowledge. Therefore, in-house research and innovation development is a prerequisite in firm's absorbing external technological knowledge. Different actors in firm's collaboration provide a different advantage. Collaborate with other firms i.e. supplier, customer or competitor may lead to the deepen in firm's existing technological capabilities while working with university of research institutions can support firms in creating new knowledge (Tsai, 2009).

In addition, a Mann-Whitney U test was run to determine if there were statistically differences between firm size and sources of knowledge. The results show that there are statistically different in acquiring knowledge from parent company (p=0.010) and in-house effort (p=0.048) between SMEs and large firms.

Table 5.12 Mean values of sources of knowledge acquisition

Sources of knowledge		SMEs	Large Firms	Total	Mann-Whitney U test (Sig.)
Parent company	Mean	2.38	3.81	3.16	0.010**
	Std.	1.439	1.300	1.527	
Key Customer	Mean	2.86	2.94	2.90	0.832
	Std.	1.257	1.177	1.197	
Trade Body	Mean	3.00	3.13	3.07	0.545
	Std.	0.966	1.047	0.998	
In-house	Mean	3.36	4.00	3.71	0.048**
	Std.	0.939	0.745	0.888	
Collaboration with university/research institution	Mean	3.00	3.53	3.29	0.182
	Std.	1.211	0.889	1.066	

Sources of knowledge		SMEs	Large Firms	Total	Mann-Whitney U test (Sig.)
Collaboration with firms	Mean	2.71	3.19	2.97	0.109
	Std.	0.926	0.831	0.895	
Hiring	Mean	3.31	3.50	3.41	0.367
	Std.	0.847	0.882	0.859	
Reverse engineering	Mean	2.92	3.25	3.10	0.125
	Std.	0.853	1.080	0.983	
Overseas training	Mean	2.33	2.82	2.60	0.161
	Std.	1.282	0.957	1.128	
Foreign expert	Mean	2.92	3.24	3.09	0.367
	Std.	1.236	1.314	1.270	
Codified knowledge	Mean	2.54	3.13	2.86	0.102
	Std.	1.244	0.874	1.084	
Conference and meeting	Mean	2.86	3.60	3.26	0.061
	Std.	1.203	0.869	1.086	
		N=16	N=19	N=35*	

* Total responding firms = 35

** $p < 0.05$ (significance at 0.05 level)

5.4.2 Absorptive capacity level : the ability to learn new knowledge

The absorptive capacity factor is, as already indicated, observed to be crucial for firms in acquiring and managing and internalising new knowledge, particularly external knowledge. Absorptive capacity is a crucial part of firm's learning process in creating new knowledge (Lane et al., 2006). Weakness in firms' absorptive capacity would make it difficult for them to survive and grow in competitive markets. This study follows the constructs of absorptive capacity by Camisón and Forés, (2009) and Flatten et al., (2011) which is based on the concept developed by Zahra and George (2002). Zahra and George (2002) define absorptive capacity as a dynamic organizational capability consisting of four constructs that complement each other, leading to the organization's competitive advantage. Potential absorptive capacity refers to an ability to acquire and assimilate knowledge while realized capability is an ability to transform and exploit such knowledge. The constructs categorizing absorptive capacity into its potential and realized forms to show the capacity of firms in valuing knowledge and in transforming and applying knowledge. However, the complementary role between potential and realized absorptive capacity implies that when firms have strong potential absorptive capacity, does not imply that firms would be successful in applying absorbed knowledge. This study also followed Lane et al. (2006) in recognizing absorptive capacity using a process perspective which measuring absorptive capacity beyond R&D dimension. Identifying absorptive capacity as dynamic capability and organizational routines allows the exploration of antecedents and implies firm's managerial actions of these capacities.

Table 5.13 shows constructs of absorptive capacity based on which firms were asked to assess themselves on activities regarding acquisition, assimilation, transformation and application of knowledge. Overall, the results of the survey show that firms evaluate themselves strongly for the most part of all constructs. This is perhaps hardly surprising as firms, left to their own devices, are highly unlikely to downgrade the strength of their performance. The validity of this observation has, therefore, yet to be verified.

Accordingly, further analysis based on firms' size, Table 5.13 shows that firms' absorptive capacity varies across firm size categories. SMEs are observed identifying themselves as having average absorptive capacity in most of the constructs except for acquisition capacity (3.43). In contrast, large firms identify themselves having strong absorptive capacity in all constructs. SMEs having statistically significant lower score than large firms in three area namely acquisition capacity (3.43), assimilation capacity (3.39) and transformation capacity (3.35). SMEs recognized the ability to identify and acquire external knowledge as their most robust attribute.

In sum, SMEs evaluate themselves as having the highest acquisition capacity following by assimilation, transformation and application capacity respectively. Categorize into two subsets of absorptive capacity, SMEs have higher ability to acquire and comprehend external knowledge or potential absorptive capacity (3.41) than ability to make use of acquired knowledge (3.30).

On the other hand, large firms identify themselves as having robust absorptive capacities in all constructs. Large firms identified themselves as being strong in all aspects of absorptive capacity, both potential (3.88) and realize absorptive capacity (3.67). Application ability which is a capability of firms to incorporate acquired knowledge into firm's operation, is the weakest ability of all firm sizes.

A Mann-Whitney U test was run to determine if there were statistically differences in absorptive capacity between size of firms. The test was statistically significant with p-value = 0.009 which means that absorptive capacity is significantly higher in large firms. Each process of absorptive capacity is also different between SMEs and large firms particularly acquisition (p=0.012), assimilation (p=0.031) and transformation (p=0.003). Application is the only process that was not statistically significantly different which means application capacity is similar between firm sizes. This study reveals the dynamics of absorptive capacity perceptions, particularly in relation to firm size. SMEs tend to emphasize their ability to acquire knowledge, whereas large firms underscore their strengths across all facets. The statistically significant differences underscore the explicit absorptive capacity advantage of large firms. These findings emphasize the pivotal role of firm size in influencing absorptive capacity perceptions and underscore possibilities for strategic enhancement.

Table 5.13 Mean score of absorptive capacity and its constructs

	Acquisition	Assimilation	PACAP	Transformation	Application	RACAP	Absorptive Capacity
SMEs (n=18)	3.43	3.39	3.41	3.35	3.26	3.30	3.37
Std.	0.58	0.77	0.64	0.71	0.76	0.718	0.662
Interpretation	Strong	Average	Strong	Average	Average	Average	Average
Large Firms (n=24)	3.95	3.80	3.88	3.83	3.45	3.67	3.80
Std.	0.51	0.61	0.512	0.47	0.64	0.517	0.499
Interpretation	Strong	Strong	Strong	Strong	Strong	Strong	Strong
Total (n=42)	3.73	3.62	3.68	3.62	3.37	3.51	3.61
Std.	0.59	0.71	0.61	0.63	0.70	0.63	0.61
Interpretation	Strong	Strong	Strong	Strong	Average	Strong	Strong
Mann-Whitney U Test (Sig)	0.012*	0.031*	0.003**	0.003**	0.483	0.074	0.009**

Total responding firms = 42

*p < 0.05 (significance at 0.05 level)

**p <0.01(significance at 0.01 level)

5.5 Linkage of firms and the development of knowledge network

This section discusses the firm's linkage with industry, academic institutions and governments. The identification of connections also includes activities conducted with partners to explore the existent of knowledge network.

Table *5.14* shows the linkages firms of different sizes have forged with external organisations, like other firms, academic institutions and government agencies. An interesting feature of this table is that for all firm sizes, the most frequent interaction of firms is with other firms which SMEs linkage with other firms (41.0%) is slightly higher than large firms (36.5%). And the lease interaction firms have is with academic institutions.

SMEs firms have the highest interaction with firms (41%), following by linkage with government institutions (30.8%) and the slightest interaction with academia (28.2%). Large firms follow the same pattern of interaction as small firms by which frequent interactions are with other firms (36.5%), followed by their interactions with government agencies (33.3%) and academia (30.2%). Links with academia appear to be more important for large firms than for SMEs. Yet another piece of evidence borne out by the survey data presented in Table 5.14 is that linkage with academic institutions such as universities or research institutions is the weakest among all firm sizes. This may not augur well for the development of the triple helix system of knowledge circulation and innovation in the automotive industry in Thailand. However, the evidence for this cannot be claimed to be conclusive.

Table 5.14 Percentage of sample firm's linkage with industry, academia and government by size of firms

Linkages	SME		Large Firms		Total Firms	
	Responses		Responses		Responses	
	No.of answers	Percentage	No.of answers	Percentage	No.of answers	Percent age
Linkage with Firms	16	41.0%	23	36.5%	39	38.2%
Linkage with university/rese arch institution	11	28.2%	19	30.2%	30	29.4%
Linkage with Government agency	12	30.8%	21	33.3%	33	32.4%
Total	39	100%	63	100%	102	100%

* Multiple answers, Total responding firms=40

5.5.1 Inter-firm linkages

Table 5.15 looks into the pattern the firm-to-firm linkages in terms of the percentage distribution of the functionalities of the links sought by firms. The highest frequency of interactions is observed to be between firms and their customers (31.5%), followed by links with their suppliers (29.8%), and with industrial associations (16.6%), competitors (11.7%) and private consultants (10.4%). The firm-to-firm interactions are driven by the need of firms for knowledge sharing, knowledge exchange and inter-firm technology transfer, which involve activities such as giving information or advice, training of suppliers, troubleshooting of technical problems, etc. These activities can feed the learning process and the development of technology capabilities of firms (Techakanont and Terdudomtham, 2004).

Table 5.15 Percentage of inter-firm linkages with partners

Firm Linkages	**SME**		**Large Firms**		**Total Firms**	
	Responses		Responses		Responses	
	No.of answers	Percentage	No.of answers	Percentage	No.of answers	Percentage
Customer	50	29.2%	77	33.2%	127	31.5%
Supplier	51	29.8%	69	29.7%	120	29.8%
Competitor	23	13.5%	24	10.3%	47	11.7%
Industrial Association	30	17.5%	37	15.9%	67	16.6%
Private Consultant	17	9.9%	25	10.8%	42	10.4%
Total	171	100%	232	100%	102	100%

* Multiple answers, Total responding firms=38

Inter-firm linkage can be categorized into two types namely vertical and horizontal linkage. Vertical linkage refers to a business relationship involved trading relationship, testing and consultancy. Vertical linkage is based on a contractual relationship between producers and users or producers and suppliers. Vertical relationship between producers and suppliers or a supply chain network is when producer firms support technological capabilities of their suppliers. This relationship could lead to a reduction of transaction costs, the allocation of insufficient internal resources, provide tacit knowledge and eventually could promote incremental change in product or process or increase efficiency. Based on the characteristic of a relationship, which is contractual and repetitive, this network is considered a dense network with strong ties. Dense network can imply the limitation of locked-in technology trajectories and collaboration since it is lack of array of knowledge.

While horizontal linkage refers to relationship of firms in the same industry focusing on knowledge development namely sharing of knowledge and information, collaboration in the development of new products or processes and the interaction with trade associations. Horizontal linkage could promote innovative activities by having firms sharing common problem, best practices or collaborate in developing technologies. However, inter-firm networks are still considered to be lack of heterogeneity in terms of players and knowledge redundancy.

Table 5.16 indicates that firms covered in the sample mostly have a vertical linkage. Both SMEs and large firms have both inter-firm vertical and horizontal linkage which approximately 60% is vertical and 40% is horizontal. This implies that inter-firm relationships in an automotive and parts industry mainly focus on business relationships; however, about 40% of the relationship focuses on information sharing, collaboration, and interaction through trade associations.

Table 5.16 Percentage of vertical and horizontal linkage of SMEs and large firms

	SME		**Large Firms**	
	Responses		Responses	
	No.of answers	Percentage	No.of answers	Percentage
Vertical Linkage	81	59.6%	114	60.6%
Horizontal Linkage	55	40.4%	74	39.4%
Total	136	100%	188	100%

* Multiple answers, Total responding firms=38

Table 5.17 shows which inter-firm partners that firms engage with for the purpose of creating new knowledge by supporting the development of new product or processes. Evidently, customers and suppliers are the most crucial partners for firms. However, for SMEs the most essential partner is their supplier, while large firms collaborate with customers to create new products or processes. The role of industrial association in supporting firms in product development is slightly more important for SMEs than large firms

Table 5.17 Inter-firm partners in developing new products or processes

Inter-firm partners	SMEs		Large Firms		Total Firms	
	Response		Response		Response	
	No. of Answers	Percent	No. of Answers	Percent	No. of Answers	Percent
Customer	10	28.6%	16	41.0%	26	35.1%
Supplier	12	34.3%	11	28.2%	23	31.1%
Competitor	4	11.4%	3	7.7%	7	9.5%
Industrial Association	5	14.3%	4	10.3%	9	12.2%
Private Consultant	4	11.4%	5	12.8%	9	12.2%
Total	35	100%	39	100%	74	100%

*Multiple answers, Total responding firms =24

5.5.2 Linkage with universities

University-industry linkages and issues about the development of triple helix networks have been at the heart of Thailand's effort to enhance competitive advantage through innovation. However, Thai firms do seldom link with academic institutions. The findings from the survey data corroborate the finding of a previous study that the linkage between university and industry is weak when compared with industry to industry and industry-government linkages (Brimble and Doner, 2007). Overall, Table 5.18 shows that firms utilize most of the support services from universities (48.9%), following by research institutions (28.3%) and technical colleges (22.9%). SMEs seem to have activities with universities (52%) slightly greater than large firms (47.3%), while large firms engage with research institutions (29.7%) more than SMEs (25.3%). However, the emphasis on the type of support services sought varies across the size of firms.

Table 5.18 Percentage of linkage with university, research institution and technical college

Academic Linkage	SME		Large Firms		Total Firms	
	Responses		Responses		Responses	
	No.of answers	Percentage	No.of answers	Percentage	No.of answers	Percentage
University	39	52%	70	47.3%	109	48.9%
Research Institution	19	25.3%	44	29.7%	63	28.3%
Technical College	17	22.7%	34	23.0%	51	22.9%
Total	75	100	148	100	223	100

*Multiple answers, Total responding firms = 29

P > 0.05 no statistical significance at 0.05 level of significance

According to Brimble and Doner (2007), activities that occur between academia and industry can be classified into three groups: 1) training/education consists of university training and university cooperative education;2) services/consultancy consists of technology licensing, university consulting services, testing services; and 3) research consists of university contract research, joint research and R&D personal exchange. Figure 5.6 shows that overall firms engage mostly in training and education activities with universities, which SMEs and large firms are almost equal in engaging in these activities. Training and education activities which consists of training by universities for company's staff and cooperative education are the major activities that both firm sizes participate with universities. Cooperate education is activity that firms collaborate with universities in providing opportunities for students to have hands-on experience at firms or factories to complement their academic education. The second activity that firms collaborate with universities is testing and consultancy services which large firms (37%) seem to exploit these services slightly more than SMEs (31%). The most minor activities firms interact with universities are as expected, the research activities which SMEs (28.5%) are showing preference for such engagement more than large firms (23%).

The survey data presented in Figure 5.6 shows that the links SMEs and large firms forge with universities are predominantly for purposes of training and education services. SMEs appear to differ from large firms in seeking collaboration for research activities with universities more than large firms. This may be because large firms usually have their own in-house R&D facilities and personnel, which, however, would stand to benefit from interaction with university research.

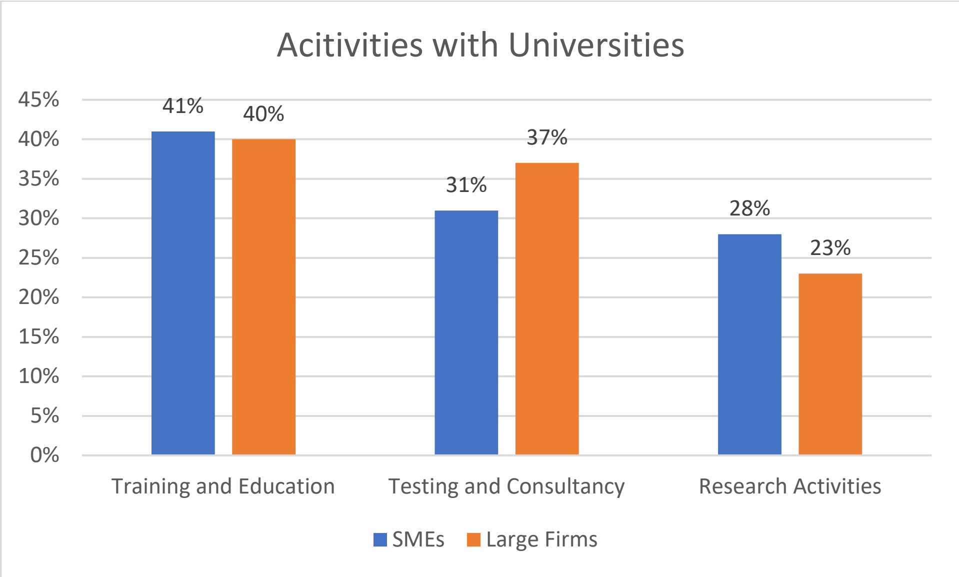

Figure 5.5Activities that firms engage with universities

To investigate into sub-activities of research category, which is the focus of this study, Figure 5.7 shows that interestingly SMEs utilize research services of universities by mostly conducting joint research (18%), contract research (8%) and R&D personnel exchange at 3%. In services and consultancy category, both SMEs and large firms mostly connected with universities by making used of testing service following by consultancy service and technology licensing. The difference in this category is that large firms include technology licensing agreements with universities in their portfolios of transaction, while SMEs have no engagement in this transaction. Training and education category, which is the major transaction between firms and universities, firms covered in the sample for SMEs and large firms equally engage in cooperative education at 21%. Training of firm's staff and seminar and conference activities are similarly engaged by SMEs (21%) and slightly less by large firms (19%). In sum, it is apparent from Figure 5.6 and 5.7 that firms of all sizes would access universities to engage in training and education services. While research services, SMEs seem to exhibit more interest primarily in the research and research-related services of universities. Large firms do not consider the research and research-related activities of universities to be the major driver of their transactions with universities.

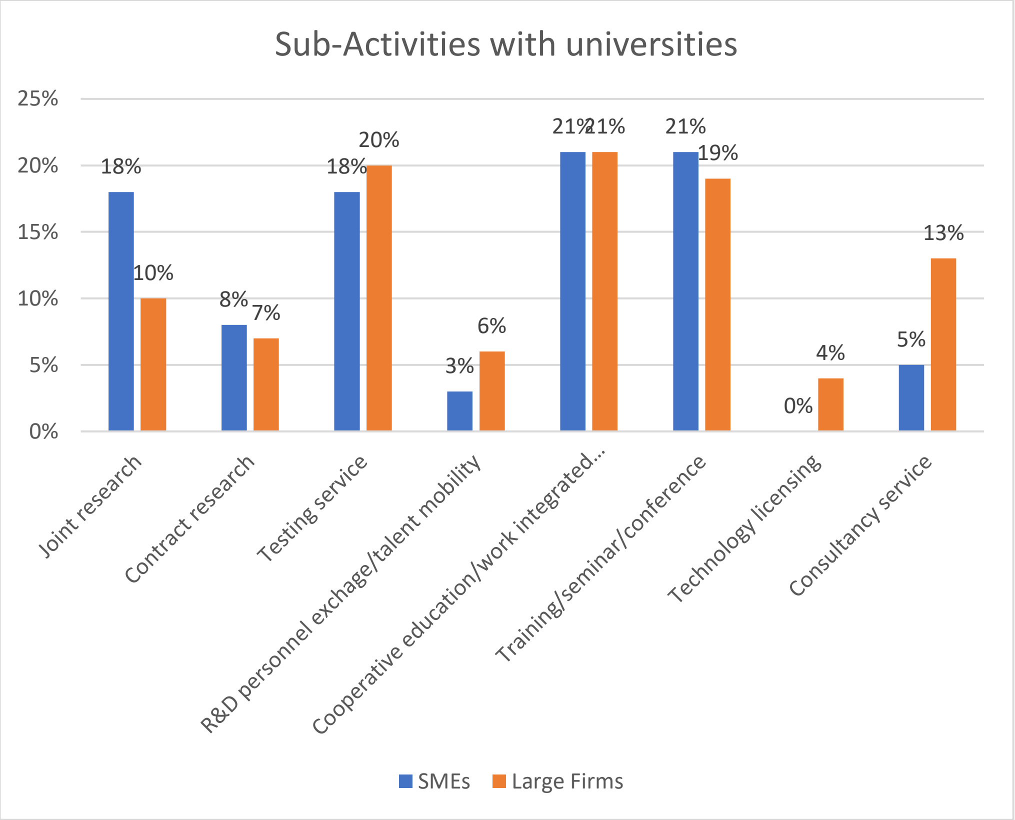

Figure 5.6 Sub-activities with universities

5.5.3 Linkage with research institutions

Besides the universities, research institutions also serve the industry in almost similar ways, albeit without the services of education, but including 1) training 2) testing and consultancy services and 3) research. Figure 5.8 shows that firms utilize services from research institutions differently across firm sizes. SMEs predominantly utilize the research services of research institutions, as in the case of 42% of the SMEs in the sample. Testing services and consulting services of research institutions are used by 37% of SMEs covered in the sample. And the least activities of SMEs engage with research institutions are training and education services at 21%. Large firms link with research institutions mostly for the use of their testing and consultancy services at 57%. The utilization of research services is only at 23% which almost fifty percent less than SMEs. And the least activities that large firms conducted with research institutions are training services which firms sponsored their staffs to be trained by research institutions and cooperative education activities at 20%.

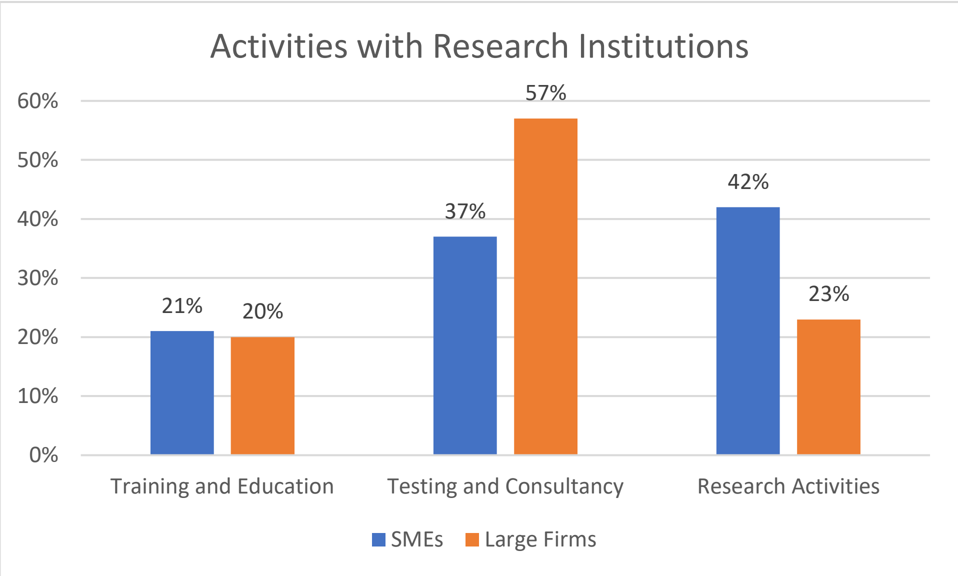

Figure 5.7 Activities that surveyed firms engage with research institutions

Figure 5.8 shows that research related activities are the focused activities of SMEs with research institutions. Figure 5.9 shows that SMEs conducted research with research institutions are joint research and contract research, both at 16%. This differs slightly from research activities with universities that firms mostly conducted joint research rather than contract research. SMEs seem to utilize R&D personnel exchange with research institution higher than large firms at 11% which is different from universities linkage that large firms used this service more than SMEs. In sum, research activities with research institutions seem to draw SMEs attention rather than universities.

Figure 5.9 shows that large firms predominantly utilize the testing services of research institutions by using the testing service (27%), consulting service (18%) and technology licensing (11%). Large firms also engage with research institutions on account of research activities (as in 23% of the large firms in the sample) – i.e., joint research (11%); contract research (9%) and R&D personnel exchange (2%). SMEs exploit testing services less than large firms in all three sub- services. However, SMEs use technology licensing services with research institutions which is different from engagement with universities that SMEs covered in the sample did not exploit this service.

The least dense link SMEs and large firms have with research institutions involves training and education services in which 21% of the SMEs and 20% of the large firms in the sample took part i.e. training (SMEs 16% and large firms 20%) and cooperative education (SMEs 5% and large firms 2%).

Generally, there are some differences between the linkages of firms have with universities and with research institutions. Small and medium firms would conduct more research activities with research institutions than with universities. Large firms tend to use the testing and consultancy services of research institutions more than that of the universities. As for training services, universities would have more appeal to firms of all categories than research institutions.

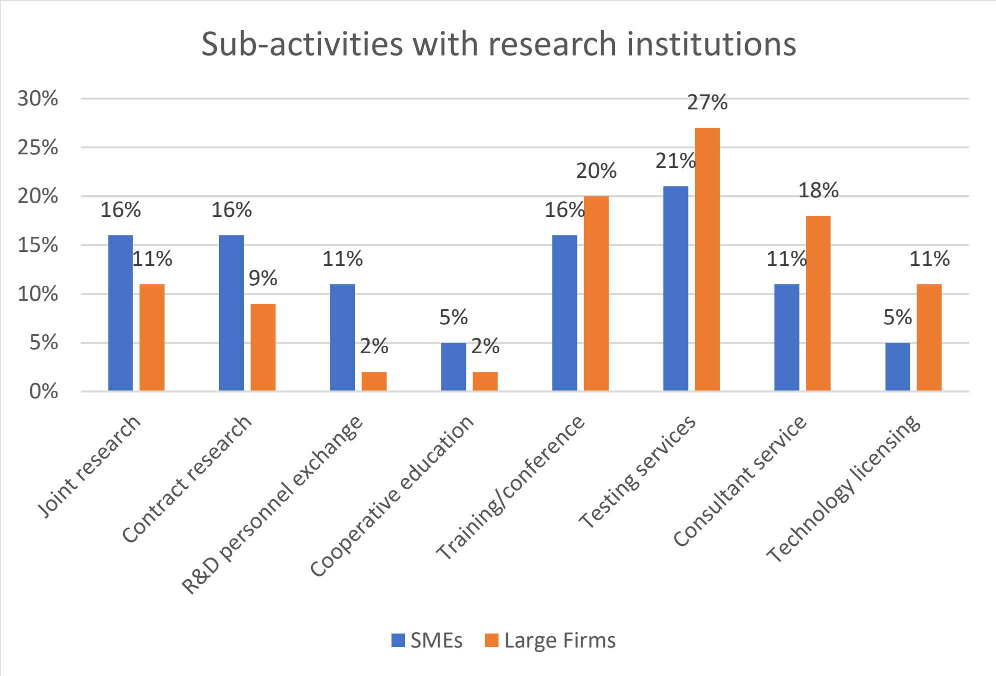

Figure 5.8 Sub-activities surveyed firms engage with research institutitons

5.5.4 Linkage with government agencies

Government agencies have an essential role in providing support to firms in the form of control and regulatory mechanisms and incentive systems. Governments also play a major role in acting as facilitators by providing firms access to other organizations through the development of knowledge networks. The survey data show that SMEs and large firms in the sample mostly participate in government-sponsored and organized seminars, workshops and conferences (SMEs 32%, large firms 27%) and training services provided by government agencies to upgrade the skills of their employees (SMEs 21%, large firms 23%). Another area of engagement is consultancy service provided by government agencies (as in the case of 16% of the large firms and 11% of the SMEs in the sample)

Both SMEs and large firms utilize the intermediary role of government agencies by connecting to other organizations via the liaison of government agencies (as in the case of 11% of the SMEs and large firms in the sample). The survey data presented in Figure 5.10 also show that SMEs and large firms benefit from the financial incentives provided by government agencies through the funding of collaborative projects and other financial support schemes. Large firms benefit from their link with government agencies through funding support for collaborative projects (as in the case of 13% of the large firms in the sample), and other financial supports (as in the case of 5% of the large firms in the sample). While SMEs utilize less of funding support for collaborative projects (as in the case of 5% of SMEs in the sample) and other financial supports (as in the case of 5% of SMEs in the sample). The least activity that firms engage with funding agencies is the exchange of R&D personnel with universities or research institutions which run by government agency which SMEs seem to deploy more than large firms (as in the case of 6% of SMEs and 5% of large firms in the sample).

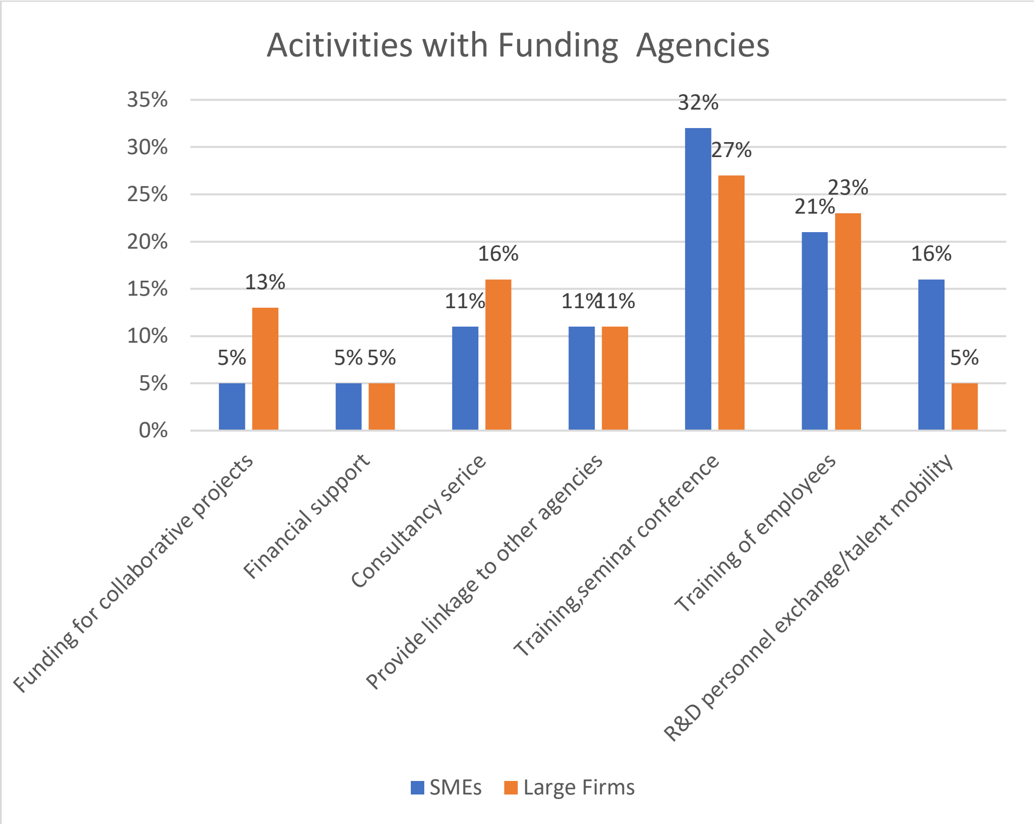

Figure 5.9 Firms linkage with government agencies

5.5.5 Linkage between firm, university and industry

Apart from inter-firm linkage namely vertical network and horizontal network, is a triple helix network. Triple helix framework refers to the networks of collaboration among university-industry-government in supporting the development of knowledge creation and innovation. Triple helix network is deemed to be a dynamic network consists of heterogeneous actors namely institutional actors such as universities or research institutions, government agencies and industries. Each institution serves a different function but synergize, the interaction between three domains is expected to create a competitive knowledge creation and utilization.

University would serve the triple helix model by embracing the knowledge producer or the research role of the university. While government agencies act as a resource provider in supporting policy intervention, financial resources or provide linkage to other actors. The different of actors and their roles are complementary in terms of resources and competencies.

Table 5.19 shows the existence of triple helix network of firms covered in the sample. Triple helix linkage in this study retrieved from firm's activities that engage with university, industry and government. According to the results, overall firms connected with three parties is at 61.9% and firms that have connections with only one or two of the parties is at 38.1%.

Interestingly, investigation by firm size shows the major difference by which there are SMEs that engage in triple helix network with university, industry and government only around 41.2% and over 58.8% do not engage in a triple helix network. On the contrary, large firms results indicate that 79.2% of firms in the sample connected with all three parties and only 20.8% have not link with triple helix network. This could imply that large firms may have a better connection with university or government agencies than SMEs. In addition, a Chi-square test for independence indicates that there is a statistically significant association between firm size and triple helix linkage. In sum, large firms seem to achieve more networking ability while SMEs may lack opportunities to access to university/research institution or government agency.

The Triple Helix network unfolds as a dynamic ecosystem fostering collaboration among universities, industries, and government agencies. While this model encourages resource complementarity and knowledge synergies, firm size emerges as a pivotal factor. Large firms appear to harness the network more effectively, enjoying stronger connections with universities and government agencies. On the other hand, SMEs might encounter challenges in accessing these vital stakeholders. The statistically significant correlation between firm size and triple helix linkage substantiates the varying networking capacities of SMEs and large firms.

Table 5.19 Surveyed Firm's Triple helix Linkage

Triple Helix Linkage	**SME**		**Large Firms**		**Total Firms**		**Chi-Square test**
	Responses		Responses		Responses		X2 = 6.190
	No.of answers	Percentage	No.of answers	Percentage	No.of answers	Percentage	Df =1
Link with 3 parties	7	41.2%	19	79.2%	26	61.9%	Sig = 0.013
Link with 1 or 2 parties	10	58.8%	5	20.8%	16	38.1%	(p < 0.05)
	17	100	24	100	41	100	

* Total responding firms = 41

** p < 0.05 (significance at 0.05 level)

5.5.6 Potential partners/network that firms would cooperate to develop EV

To look into the nature of existing knowledge networks for the development EVs, firms were asked to rank three of the potential partners they would cooperate with to develop EV projects. Table 5.20 shows that the most vital partners that firms would work with while developing EV-related technologies are their customers. This observation is consistent with the evidence noted earlier regarding the existing knowledge network of firms - that inter-firm networks seem to be the primary medium for knowledge transfer, and that customers play a major role in the network through feedback effects on the activities of firms.

Table 5.20 also shows suppliers and government agencies as, respectively, the second and third vital partners that large firms would engage with while working on EV-related projects. While competitors are ranked third for SMEs. Academic institutions do not appear to feature prominently in the knowledge network of firms, suggesting that the triple helix network is not yet firmly on the ground, at least in the automotive sector if not in the economy at large. However, it is apparent from the survey data that research institutions are catching the attention of both firm sizes as prospective partners to collaborate on EV projects. This observation lends support to the point drawn from Figure 19 about activities between research institutions and firms. Firms indicate that their research and development activities are more linked with research institutions than universities. Firms also associate, if to a limited degree, with the Thailand Automotive Institute (TAI), which is a government agency that supports the automotive and parts firms in developing technological capabilities.

Table 5.20 Potential partners that surveyed firms would cooperate with to develop EV related project

Potential Partners	**SMEs Ranking**	**Large Firms Ranking**	**Total Ranking**
Customer	1	1	1
Suppliers	2	2	2
Government Agency	4	3	3
Research Institutions	4	4	4
Thailand Automotive Institute	5	4	5
Technical Consultancy	6	5	6
University	5	6	7
Competitor	3	3	8
Industrial Association	6	N/A	9
Technical Institute	7	N/A	10

5.7 Government policy interventions to support firms in transitioning to EV

This section presents results of firm's survey on the demand for policy interventions that would leverage firms in adjusting to the EV transition. According to MLP framework, policy initiatives may provide window of opportunities to firms in developing niche innovations. Policies listed in the survey consist of existing policy and potential new policy initiatives. Most of the policy in these categories are direct subsidy aim to support firms including R&D support, R&D funding, financial and tax subsidy, investment subsidy. In addition, demand policy to stimulate the adoption of EV is also included.

Table 5.21 shows that SMEs and large firms require the development of human resources with knowledge and technology to be consistent with EV as their highest priority. Followed by government support for R&D funding for EV relating projects. The next important policy for SMEs is still relating to human resources by requiring that government could provide researcher to work at their companies. Investment incentives from Board of Investment are similarly crucial for both SMEs and large firms by ranking at 2nd for SMEs and 3rd for large firms. Investing in EV also means new production investment, both SMEs and large firms expect financial incentive in funding for new production line. Other financial incentive is also important for SMEs such as low interest rate loan. R&D consortium aiming to stimulate collaboration between firms in exchanging new knowledge is appeared to be interested by SMEs than large firms. Various tax subsidy programs caught less interest for both firm sizes. The least interested policy for firms is government procurement to use EV policy.

In sum, human resources development to support potential EV projects is the most needed policy. Followed by R&D funding support, investment incentives and financial support for transitioning to EV.

Table 5.21 Rank of surveyed government policies intervention

Policy Initiatives	SMEs Ranking	Large firms Ranking	Total Ranking
Training of Human resources	1	1	1
Provision of researcher to firms	3	4	4
R&D funding for private sector	2	2	2
R&D Consortium	6	8	8
Funding Support to change product line	4	5	5
Low interest rate loan	5	7	7
Investment incentives (BOI)	2	3	3
Excise tax reduction	6	6	6
Battery Import duties reduction	9	12	12
R&D tax deduction	7	11	11

Policy Initiatives	SMEs Ranking	Large firms Ranking	Total Ranking
Supporting measures to build charging stations	10	13	13
Infrastructure for standard testing and calibration	8	10	10
Government Procurement for EV	11	13	14
Grant or tax subsidy for buyers	9	9	9

5.8 Test of association of factors contributing to technological learning of firms in the Thai automotive industry

This section discusses factors that would have an effect on a firm's learning processes or absorptive capacity. This study focuses on an external learning process of firms or absorptive capacity of firms which is the core factor of technological learning process. Absorptive capacity is an ability to explore, transform and apply new knowledge to a firm's advantage, particularly external knowledge which could lead to a firm's competitiveness and innovation development. Absorptive capacity is different between each firm; it is a factor that explains why some firms can recognize external knowledge and are able to assimilate, transform and use new external knowledge to achieve its purposes. This study explores influencing factors on technological learning of firms which in this study choose absorptive capacity model of Zahra and George (2002) as an indicator.

Besides internal efforts of firms, inter-organization cooperation is increasingly important; the rapid change in technology requires knowledge and capabilities beyond firm's internal resources. Previous studies suggested that collaborate with different partners broadly or deeply resulted in firm's innovative performance (Fosfuri & Tribó, 2008; Laursen & Salter, 2006). Absorptive capacity is considered a prerequisite to successful innovative performance, by recognizing the value of external knowledge and eventually internalizing and exploiting such knowledge. Thus, this present study explores the relationship between firm's knowledge searching approach and the development of a firm's absorptive capacity. Searching strategies involve how firms engage with external partners, whether firms involve broadly with several partners or collaborate deeply with selected partners. The intensity of relationship (depth) or a broad relationship (breadth) with various external agents may relate to a firm's learning processes.

Analysis of the effect of searching strategies is based on Ferreras-Méndez et al., (2016), studied the effect of external knowledge search with an emphasis on breadth and depth of the firm's strategy on the absorptive capacity of firms. Thus, the study argues that the external source of knowledge has an impact on an absorptive capacity process which comprise exploration learning, transformation learning exploitation learning. This paper argues that searching strategies that firms use with external partners may support the whole process of absorptive capacity. This research responds to the previous study by adopting the idea of Ferreras-Méndez et al. (2016) on the impact of searching strategies on absorptive capacity processes. The external search breadth refers to the diversification of organization that firms have knowledge relationship to induce innovation activities. And external search depth refers to an intensity that firms have with knowledge sources. This study extends the idea of external search depth into inter-firm depth and triple helix depth. Attempt to identify which different knowledge sources that firm draw deeply from has an impact on firm's absorptive capacity.

The exploration in terms of breadth was measured by the numbers of types of partners. The depth of inter-firm network and triple helix network are represented by number of projects that firms engage with each type of network.

This study also includes two control variables: firm size and turbulence. Firm size may have impact on firm's decision to invest in absorptive capacity. And turbulence which are events that could impact firm's decision to adapt its absorptive capacity such as technological and market change factors.

This study applies multiple regression model which are used to explore the relationship and influence between one dependent variable and two or more independent variables. The dependent variables consist of three variables that represent absorptive capacity and its subsets divided into three equations models. The independent variables are consisting of five variables representing the breadth and the depth of inter-firm linkage and triple helix linkage and control variables (see Table 5.23).

Table 5.22 Definition of regression variables

Model	Variable Name	Dependent variables (Y)
1	APC	Degree of absorptive capacity
2	PACAP	Degree of acquisition and assimilation capacity
3	RACAP	Degree of transformation and exploitation capacity
		Independent/explanatory variables (X)
	BREATH	Number of types of external partners
	THXD	Number of projects with triple helix partners
	INTFD	Number of projects with other firms
	SIZE	Firm size Large firm or SMEs
	TURBULENCE	Factors influencing firms to invest in EV
		Other variables
	β	Regression coefficients
	βo	Constant or intercept
	Ɛ	Error term

The regression model involved three equation with each of absorptive capacity proxy and subsets of absorptive capacity regressed on five independent variables. The regression model is presented as shown below.

$Y = \beta o + \beta X + \varepsilon$

Where : $Y = [\text{ APC PACAP RACAP }]^T$

$X = [\text{BREADTH THXD INFTD SIZE TURBULENCE}]^T$

$\beta = [\beta_{ij}]$, I =1,2,…,5 ; j = 1, 2, …, 5

$\beta o = [\beta_{o1}\ \beta_{o2}\ \ldots\ \beta_{o5}]^T$

$\varepsilon = [\varepsilon_1\ \varepsilon_2\ \ldots\ \varepsilon_5]^T$

Assumption test for multicollinearity check was conducted, Tolerance (TI) and the Variance Inflation Factor (VIF), to identify that a high degree of correlations between independent variables is not present. To confirm that the multicollinearity does not reduce the accuracy of the regression model, the VIF values should be less than 10 and the tolerance values is more than 0.1. According to Appendice H. (a-d), the five regression model, the result of variance inflation factors indicates that multicollinearity does not distort the results.

Multiple regression was employed using both standard and stepwise regression to yield the best predictors. The standard method enters all variables into the equation at a single time while stepwise method involves entering and removing of predictor variables if predictors are not contributing to a predictive power. This multiple regression approach has been adopted in other studies relating to external knowledge search strategies and their impact on absorptive capacity (Ferreras-Méndez et al., 2016, 2015).

According to Table 5.24 most of the models are statistically significant at 5% and 1% level which means these models can explain a significance amount of the variance.

In the APC model, the standard method explains 19.8% (Adj R^2 =0.198) of the variance and the stepwise approach explains slightly higher predictive power at 23% (Adj R^2= 0.230) of the variance. THXD showed statistically significant value at 5% level ($p<0.05$) and SIZE showed significant value at 10% level, both are positive using standard method and stepwise method. While in the stepwise method THXD and SIZE shows statistically significant at 5% level and 10% level respectively.

In the PACAP model, THXD and SIZE are statistically significant at 5% level in both standard method with the predictive power at 21.1% and stepwise method with the higher predictive power at 25.4%.

In the RACAP model, THXD is also positively significant at 5% level in the standard method and stepwise method with the predictive power at 15.5% and 16.7% respectively

Table 5.23 Regression analysis models for the effect of external knowledge search on absorptive capacity

Method	N	Constant	BREADTH	THXD	INTFD	SIZE	TURBULENCE	R^2	Adj R^2	Model Sig.
APC Model	40							0.301	0.198	0.027**
Standard		3.046	-0.163	0.048**	-0.003	0.366*	0.072			
Std. Coef.			(-0.143)	(0.505)	(-0.023)	(0.293)	(0.139)			
SE.		0.454	0.206	0.018	0.021	0.189	0.081			
T-value			-0.795	2.689	-0.137	1.940	0.880			
Sig.			0.432	0.011	0.892	0.061	0.385			

Method	N	Constant	BREADTH	THXD	INTFD	SIZE	TURBULENCE	R^2	Adj R^2	Model Sig.
Stepwise	40							0.270	0.230	0.003***
Standard		3.102		0.035**		0.352*				
Std. Coef.				(0.370)		(0.282)				
SE.		0.163		0.014		0.182				
T-value				2.541		1.939				
Sig.				0.015		0.060				
PACAP	40							0.312	0.211	0.021**

Method	N	Constant	BREADTH	THXD	INTFD	SIZE	TURBULENCE	R^2	Adj R^2	Model Sig.
Model										
Standard		3.232	-0.157	0.047**	-0.004	0.378**	0.038			
Std. Coef.			(-0.136)	(0.492)	(-0.029)	0.300	(0.073)			
SE.		0.454	.0206	0.018	0.021	0.189	0.081			
T-value			-0.764	2.638	-0.174	2.001	0.470			
Sig.			0.450	0.012	0.863	0.053	0.642			
Stepwise	40							0.292	0.254	0.002***

Method	N	Constant	BREADTH	THXD	INTFD	SIZE	TURBULENCE	R^2	Adj R^2	Model Sig.
Standard		3.154		0.036**		0.376**				
Std. Coef.				(0.380)		(0.298)				
SE.		0.146		0.014		0.181				
T-value				2.657		2.084				
Sig.				0.012		0.044				
RACAP Model	39									

Method	**N**	**Constant**	**BREADTH**	**THXD**	**INTFD**	**SIZE**	**TURBULENCE**	**R^2**	**Adj R^2**	**Model Sig.**
Standard		2.803	-0.169	0.048	-0.003	0.342	0.117	0.266	0.155	0.059**
Std. Coef.			(-0.144)	(0.497)	(-0.23)	(0.265)	(0.220)			
SE.		0.484	0.219	0.019	0.022	0.202	0.087			
T-value			-0.770	2.564	-0.132	1.691	1.347			
Sig.			0.447	0.015**	0.895	0.100*	0.187			
Stepwise	39							0.211	0.167	0.014**
Standard		3.250		0.033**		0.315				

Method	N	Constant	BREADTH	THXD	INTFD	SIZE	TURBULENCE	R^2	Adj R^2	Model Sig.
Std. Coef.				(0.334)		(0.244				
SE.		0.154		0.015		0.197				
T-value				2.191		1.599				
Sig.				0.035		0.119				

Significant at *p<0.1 level, ** p<0.05 level, *** p<0.01

Standardized coefficient (std. β) is in ( ) for comparison between variabl

5.8.1 Summary of Multiple Regression Analysis Results: Enhancing Absorptive Capacity through Triple Helix Networks

The results of the multiple regression analysis reveal insightful findings regarding the impact of firms' linkage with the triple helix network on absorptive capacity and its components. This network, involving collaboration between universities, research institutions, and government agencies, holds the potential to significantly influence a firm's capacity to acquire, assimilate, transform, and exploit external knowledge.

1) Impact of Triple Helix Linkage:

The study underscores that linkage with the triple helix network has a positive influence on absorptive capacity. Specifically, a strong and profound relationship with partners from academia and government institutions positively impacts both Potential Absorptive Capacity (PACAP) – the ability to identify and acquire external knowledge – and Realized Absorptive Capacity (RACAP) – the ability to effectively use such knowledge within the firm's operations.

In examining control variables, firm size emerges as a significant and positive factor within the context of PACAP and APC models. This suggests that larger firms tend to exhibit greater absorptive capacity across both potential and realized aspects. In contrast, the variable TURBULENCE does not demonstrate significant effects across any of the models.

2) Depth of Triple Helix Relationship:

The depth of relationships within the triple helix network emerges as pivotal. Establishing deep connections, particularly with academia and government, fosters the development of both potential and realized absorptive capacity. This echoes previous research by Ferreras-Méndez et al. (2015) which found similar trends between external knowledge search depth and absorptive capacity. Broad relationships, however, do not yield statistically significant results.

3) Strategic Insights and Knowledge Exchange:

The outcomes consistently highlight that the intensity of relationships, particularly in the context of the triple helix network, contributes to a firm's absorptive capacity development. Firms that engage deeply through innovative activities with partners such as universities, research institutions, and local government demonstrate enhanced absorptive capacity levels. This finding reinforces the notion that comprehensive interactions, fostering knowledge exchange, can catalyze a firm's ability to identify, assimilate, transform, and exploit external knowledge. Deep interactions facilitate effective translation of externally sourced information, nurturing innovation, and ultimately driving competitive advantage.

4) Conclusion

The results of the multiple regression analysis align with previous research (Ferreras-Méndez et al., 2016; Laursen & Salter, 2006), suggesting that open search strategies and intensive partnerships with triple helix network actors, especially universities, research institutions, and local government, strengthen a firm's absorptive capacity. Establishing deep relationships through innovative efforts elevates a firm's capacity to harness external knowledge effectively. The study underscores the significance of dynamic knowledge partnerships and their role in creating a competitive edge in today's ever-evolving business landscape.

5.7 Conclusion

The conclusion of the surveyed data in this chapter focuses on firm profiling, their response on the transition from internal combustion engine to electric vehicles, technological learning of firms, linkage with existing networks and analysis of factors affecting firm's technological learning. Regarding the impact on the advent of the EV technology on firm's operation, it is found that SMEs are inclined to be affected strongly by the transition to new technologies, while the impact on large firms is lower than SMEs. The impact relating to the continuity of current production, the result based on firm size indicates that both firm size are likely to adapt their products followed by discontinue some of the operation. To sum up, SMEs firms that predominantly in tier 2 and 3 categories tend to feel the most impact on the transition to EV. The transition also brings the recognition in adjusting their current operation; most of the surveyed firms respond that they would consider new opportunity, or they might convey their existing experiences into new sectors.

Regarding firm's technological learning, most of the surveyed firms learn by relying on their internal efforts following by external sources such as hiring or inter-firm networks. SMEs are interestingly connected with the network through horizontal network such as trade association and also connected with triple helix network actor such as universities as firm's sources of knowledge.

At the same time, large firms mostly associated with their parents' companies through a hierarchical structure of the automotive and parts industry.

Regarding firms' linkages, firms still maintain their inter-firm network as their priority following by government linkage and academic linkage. The inter-firm linkage concentrates mainly on business purposes than new knowledge creation activity. Mostly through the inter-firm vertical network which focuses on business relationship rather than a horizontal network which would focus on information sharing or the development of new products or processes.

While the survey results show that networking with academic institutions such as universities or research institutions is still rarely occurred among all firm sizes. The activities that firm mostly engage with universities are training services and testing services, while research services are the least activities firms engage with universities. Interestingly, research institutions seem to draw SMEs in collaborating in research activities more than with universities. Despite the small number of activities, the activities of firms with universities and research institutions show that SMEs engage in research activities such as joint research, contract research and R&D personnel exchange from university and R&D institutions more than large firms.

In terms of policy and incentives support from government agencies, it seems that all firm size mostly utilizes the training courses provided by government agencies. While large firms seem to have greater access to financial incentives provided by government agencies more than SMEs, particularly funding for collaborative projects. While small firms mostly utilize R&D-

related support for R&D personnel exchange run by government agencies. Remarkably, comparing between SMEs and large firms, these results suggests that large firms seem to develop a better relationship with triple helix actors significantly greater than SMEs. In addition, the finding of this study suggests that policies requirement for EV transition that firms need the most is the training of human resources support following by R&D funding for EV relating technologies. These results would seem to suggest that firms expect government to provide policy that support the human resources training of relevant knowledge and specific funding support for EV projects.

Regarding the development of network to support their future activities on EV, inter-firm partners are still crucial to firms by having customers and suppliers as the firm's priority partners. Interestingly, firms seem to be interested in government agencies and research institutions (ranked 3^{rd} and 4^{th}) as their prospective partners on their EV technological support. In conclusion, the triple helix network in the automotive sector is still not yet on the firm ground but firms seem to show some interest in networking with academic institutions and government agencies as part of their future partners.

The empirical findings of the factors affecting technological learning of firms which this study use an absorptive capacity as an indicator, indicates that the deep relationship with triple helix partners had a positive impact on firm's absorptive capacity. The intensity of the relationship or the deep relationship with triple helix partners was found to have a positive impact on overall absorptive capacity and also on the potential (PACAP) and realized (RACAP) absorptive capacity.

In summary, the results of this chapter show empirical evidence that answer objectives of the study, particularly on firm's responsiveness to the transition, firm's learning requirement, the development of knowledge network of firms, firm's technological learning process and factors that contributing to the learning processes.

Overall, the transition to EV would have an impact on the firm's current operation particularly on SMEs. The survey revealed that most firms are opt into the change by either readjust their goals or strategies towards EV or utilize existing capabilities towards other industries. The technological learning of firms is mostly based on the firm's internal effort following by acquisition from external sources through inter-firm network and slightly from triple helix network. Moreover, deep collaborations with triple helix networks are suggested to have a positive impact on firm's technological learning processes which allow firms to acquire and make use of new knowledge. While these findings provide valuable insights, it's prudent to interpret them within the context of a small sample size. The upcoming chapter will establish the research framework and methodology, providing a strong foundation for delving into the complicated aspects of how firms respond to the emergence of Electric Vehicles.

CHAPTER 6

Exploration of the role of governance and policy intervention in supporting the transition of the automotive and parts industry

The previous chapter explores empirical evidence from incumbent regime actors who are firms from the existing automotive and parts industry regarding their responsiveness to the EV transition and analysis of firms' technological learning to identify their potential in transitioning to develop EV technologies. Thus, this chapter focuses on exploring governance implications and policy intervention that encourage the transitioning of firms in the automotive and parts industry. Governance refers to mode of interventions which not restricted to merely government intervention or policy instruments but include non-state actors to coordinate towards common goal (Nilsson and Nykvist, 2016). Governance can occur across multi-socio-technical levels. This chapter has sought to explore from the policy makers, academic, research institution and also firms' perspective to identify policy interventions and programs which could lead to the technological learning support for firms in the conventional automotive and parts sector which eventually results in a regime transformation.

The data analysed in this chapter were gathered from a semi-structured interview with sixteen people: Ten were from government agencies, universities, and industry associations; six were from the industry. Government representatives are top executives or senior staff of government's policy agencies. Funding agency was selected from agency which determines direction of the research and development of next generation automotive industry. And professors from top universities who have been engaged in collaboration projects with firms. In addition, to support the results of the empirical analysis in the previous chapter which although useful but are not comprehensive due to the limitation of survey data. Thus, this chapter incorporates the view of selected firms in the automotive and parts industry relating to their responsiveness to the transition, linkage with government agencies and academic institution and the requirements for policy support.

6.1 Governance and policy intervention on the transition of firms to electric mobility

This section focuses primarily on exploring governance implications and policy intervention impacting the transition of an automotive and parts industry to electric mobility. The policy intervention and governance herein were examining from the MLP framework which allow the identification of governance implications for each socio-technical level i.e., landscape (macro), regime (meso) and niche level (micro). Multi-governance not only includes standard policies, interventions such as taxes, standards but also includes other measures such as an enabling network between actors that would enable the system change and to prevent a systemic failures of innovation process (Nilsson & Nykvist, 2016).

Policies at macro level or landscape level aim to support the uptake of EV, while policies at a meso level focus on enabling a regime change or to destabilize a regime “lock-in”. Policy at a micro level focuses on the development of knowledge network and technological capability of firms in the automotive and parts industry and EV industry to be able to join the global value chain. The building of technological learning capability of existing suppliers in conventional automotive and parts industry is essential to join the global value chain of EV industry.

The comprehensive overview of government policies relating to the development of EV in Thailand is located in Chapter 3: research context. The investigating of the interview data relating to policies in this chapter is to present the view of policy makers, academia, industry associations and firms on the sufficiency, efficiency and the coherence of the policies. This research synthesized and categorized the interview data regarding current and potential policies into three categories according to the MLP conceptual framework namely landscape level policy, regime level policy and niche level policy.

6.1.1 Landscape level policies

Landscape level policy refers to a wider policy framework that would exert pressure on the regime level or influence niche development (Frank W. Geels, 2018). In the transition to EV, contextual development that influence socio-technical regime such as environmental policy, fossil fuels availability, cost of EV technologies and purchasing capability of users (Nilsson and Nykvist, 2016).

The interview question asked to identify policy landscape by asking what the main goal is in supporting the EV development in Thailand. The answer to this question would help clarify the underlying reasons for the EV policy support at the national level and would indicate the policy framework imposes pressure on regime level and at the same time provide a clear direction for related actors in each socio-technical level.

6.1.1.1 Policy direction for the development of EV

This study tries to identify the principal reason of the country in supporting the development of EV which could lead to the identification of landscape level policy that would exert pressure at the regime level and stimulate development at niche level. At the international level, the zero-emission targets are put in place in various countries responding to the climate change problem. This constitutes a pressure to the automotive industry globally, however in Thailand the main source of pressure does not come from the global environmental concerns or quantitative target of zero emission.

At present, Thailand has an industry development plan towards electric vehicles. In 2017, Thailand announced the ten targeted industries, these are called "s-curve" industries which aim to be future industries of the country. One of the industries is the next generation automotive industry based on the strength of the current automotive and parts industry which has been the core industry of Thailand. Next generation automotive industry refers to four categories of vehicle 1) connected vehicles 2) autonomous vehicles 3) shared mobility and 4) electric vehicles. The interview revealed that, in terms of the development of industry, the country has initiated the investment policy to attract foreign direct investment to locate in Thailand.

The interview brought out an interesting perspective, with representatives from government agencies sharing the underlying reason based on their organization's responsibility. Government agencies that oversee the development of industry focus on the development of EV industry as a regional production hub and the protection of existing automotive and parts industry to transform to EV industry. However, the interview with non-governmental actors such as academic representatives or industry associations suggest that the country lacks any apparent justification or overarching goal for the development of EV. The overarching goal or long-term vision should aim at the current global and local environmental problem and the EV industry is merely parts of the puzzle to tackle the problem. The need for an overarching goal is to set the country's policy direction and formulating strategies and action plans according to the main goal.

According to the interview, Gov 6 who represents one of the government's policy offices relating to fiscal policy revealed that in order to align with global environmental trend, the Thai government has announced that Thailand would be the regional EV's hub in producing electric vehicles in Southeast Asian Region. Gov 3 who represents the agency that provide investment incentives and Gov 6 agreed that this EV policy development was developed based on global technology trend and the global demand and the EV industry promoting policy was based on the existing strength of the existing automotive industry.

Despite the aim being to be the production hub of EV in the Southeast Asia region, several interviewees (Uni1, Uni2, Ind2, Firm2) expressed a view that at the country level, there is a need for an overarching policy or long-term goal that would serve as a country's vision. For example, Singapore set out its country's initiative to be a smart nation and EV is one of the key initiatives (Uni 1, Ind 2). The lack of an overarching goal in shifting from internal combustion engine to EV does not indicate a clear purpose either for environmental purposes or for economic growth. Without the same goal, agencies develop their own plans and initiatives that might not align. According to Gov 3, the plan to develop EV industry is focused on the competitiveness of the country in order to escape from being the middle-income country to high-income country. While actors from industry association such as Electric Vehicle Industrial Association (EVAT) set the main objective of the association to adopt EV to solve environmental problem such as pollution problem (Ind 2).

The lack of a shared vision and integrated policies was similarly pointed out by Uni 2 and Ind 2. At present, many government agencies are actively involved in formulating plans relating to EV promotion, but the plans are formulated and being executed in a “silo” manner and are disconnected (Uni 2). A national vision could lead to a set of development strategies and actions that coincide with the nation’s priorities, while having different targets would lead to heterogenous actions.

Uni 2 pointed out that *“At present Thailand is still missing of person in charge to oversee a big picture, now each agency is working in a silo manner, Ministry of Science and Technology is in charge of of R&D, Ministry of Industry is working on promoting industry etc. There is no vision plan at a national level like other countries*.

If you set the goal to use EV to serve a quality-of-life purpose or you want to strengthen country’s competitiveness, the way to promote EV would be different. You need to pick the first vision.”

Ind 2 also shares the view that there are many responsible agencies, and each agency works according to their own mission. There is the need for an integrated policy framework which would require a top-down policy from the prime minister or deputy prime minister. According to Ind 2, EVAT is proposing its association's policy recommendation to the government to create a policy integration country-wide roadmap for EV development. Ind 2 also expressed concern regarding the lack of a common target or goal which could lead to an inconsistent execution of each agency.

Ind 2 states that *"we have to look back why we want to promote EV; in terms of policy perspective, it can be divided into two issue 1) the pollution issue such as pm 2.5 2) the country's industry is automotive industry. Is it possible to promote EV while promoting industry at the same time*? *Government duty is to facilitate and get rid of obstacle. But the first thing that the government should be doing is to set the common goal. Without the same vision, we would not go in the same direction. Government needs to be in charge of this not the private sector."*

Interestingly, two large supplier firms responded to the EV transition differently in terms of preparation for EV, while both agreed that the country needs to have a clear policy direction whether the country is moving towards EV. Firm 1 agrees that when there is no clear policy signal at a country level, this would result in foreign major car manufacturers deciding where to invest locally and this would affect local suppliers' decision on their investment as well. And Firm 2, a large company that has already started research on EV related technologies, believes that a key point that government should consider is to show strong policy ambition by setting a zero-emission target the same as other countries. Otherwise, stakeholders would not commit to an

EV scenario. The country's vision could stimulate incumbent actors to start adapting themselves.

"If we do not have a vision of when fossil fuel vehicles will be ceased their production in Thailand, it would be difficult for EV scenario to happen."

"If government has a firm standpoint, it will create an awareness for firms in the industry and firms will start to adapt and find new technology."

Firm 2 also emphasised there is the need for clear government policy, as clear policy will force related firms to start investing. Although the entrance of EV might have an impact on existing firms in the conventional automotive industry, new technologies also bring an opportunity in terms of creating new players and job creation.

Based on the interview, at the national level, Thailand is still lacking strong policy ambition, integrated public policy and quantitative goals such as zero-emission target that would provide pressure at regime level either on car producers to invest or consumers and encourage system change. The list of EV related government policies listed into phases were synthesized by researcher in CHAPTER 3.

6.1.2 Regime level policies

This study places focus on a firm's responsiveness to the EV transition and socio-technological regime shift. Thus, at the regime level, this study explored the policies that aim to support the reorientation of strategy of firms in conventional automotive and parts industry. Kemp et al., (1998) defined the socio-technological regime as an established practice of existing technologies in terms of "production practices and routines, consumption patterns, engineering and management belief systems and cultural values" so it can be summarised as an integrated system of technologies and social practice. Therefore, more stabilization of the regime implies greater barriers to system change.

The policy at this level encourages an optimum regime change but not radical change, due to the embedded practice of regime actors such as existing engineering practice, production facility or organizational routines. This section explored the response strategies provided by the government to the incumbent regime which can be categorized into two categories based on the interview data. 1) Policy that supports the development of EV industry and the transformation to the EV industry 2) Policy that supports the conventional suppliers into sectoral adaptation.

6.1.2.1 Policy that supports the development of EV industry

The following section explored policies intervention and governance that enable incumbent firms in regime adaptation to EV industry. According to the interview, key policies offered that would support car manufacturers and suppliers to realign their products to new technologies are 1) Industrial policy and 2) Research and innovation policy

6.1.2.1.1 Industrial Policy to promote EV industry

At present, the government is trying to create a favourable investment climate for the production of EV in Thailand. Industrial policy particularly a foreign direct investment (FDI) policy has been used to attract the development of EV industry to locate in Thailand. The investment policy packages offer an exemption of the capital income tax for investment activities relating to EV production and related supply chain namely electric cars (HEV, PHEV and EV), electric bike, electric bus and truck, electric tricycle, electric boats, charging station and local production of EV parts and components (See chapter 3). The current policies are based on the assumption that the transition of the production of EV would be executed mostly by key regime actors that are firms in an existing automotive and parts industry. Automotive companies that have applied for investment promotion from the Board of Investment (BOI) are mostly existing major automotive companies with a few newcomers outside the automotive industry.

Gov 3 explains that policy design was based on the concept that all-electric vehicles would receive the highest incentives, thus, BEV would receive the most incentives among other types of EV. However, Gov 3 pointed out that for BEV projects, firms that have their projects approved have not completely executed their submitted plan on BEV investment[3]. Firms claimed that due to a current small domestic market, high cost of BEV, limited charging infrastructure and insufficient demand side policy affected the firm's investment decision. The volume of all-electric vehicles to be produced are still relatively low and partly are semi-knocked down (SKD). This means there is not much production activities of all-electric vehicle in the country. Car producers that produce both internal combustion engine and EV would be reluctant to make new investment due to the committed investment on traditional cars for which the returns are not yet fully maximized.

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[3] The board of investment promotion conditions stated that "within 3 years after the date of promotion certificate issuance: manufacturer of electric vehicles must be started". See :https://www.boi.go.th/upload/content/New%20Investment%20Promotion%20Policies%20EN_6034b5448182b.pdf

Gov 3 believes that if the country would like to adopt fully electric vehicles sooner, it is necessary to have more intensive policy particularly demand side policy such as purchasing subsidy or public procurement policy. Gov 3 pointed out that although public procurement policy of EV has been approved by the cabinet, it is not yet substantial. This is due to the cost differential between ICE vehicle and EV, EV cost is largely expensive than conventional cars and would obstruct the public procurement decision.

Public procurement issue was also raised by Uni 2 suggests that government should support public procurement policy particularly in the public transportation sector. The use of EV in a more widespread area such as public bus or taxi could raise overall EV social awareness and support the change in belief and norm as stated below:

"Society also needs a learning curve in using electric vehicle to create a behavioral change, this could start with public transportation such as taxi or buses. When people trust and believe in technology, this would raise a demand for EV."

The use of EV in government fleet or the use of public electric bus could provide experience to potential users and stimulate market acceptance of EV and the demand for the technologies. The public procurement of an EV fleet is a government strategy for EV promotion to create market demand. This strategy was approved by the cabinet since 2017, BEV procurement ratio was set at twenty percent of all government new fleet. Some of the interviewees (Gov 2, Uni1, Research1) also mentioned government plans on public procurement to use EV for government fleets and the procurement of EV buses but the execution of this policy is still very limited.

Despite FDI policy to attract EV investment being initiated, interviewees criticized the EV investment policy regarding the lack of technology intensive activities and the lack of fostering local capability development. Gov 3 pointed out some of the weakness of current investment incentives that there is no minimum significant process and minimum investment requirement. Without a minimum significant process, it means investment firms can conduct the simple assembly process, without any advanced technological function or core technology development locally.

The lack of high-value activities or assembly-only processing has also been criticized. Uni 2 emphasized that due to the absence of a requirement for a core production process; the investment of battery technology only required a packing of battery or the assembly of a battery module. This policy will still maintain Thailand as a production hub, but it will not move Thailand higher up the technology ladder, plus the activity required has low value added.

This policy is being criticized by other government officials in that it would only attract FDI flows but not promote the learning and local capability development. Gov 5 believes that the scheme is not strong enough to draw benefit to the country in terms of the transfer of core knowledge but only to attract the capital investment.

Gov 4 also revealed that the technology transfer requirement determining that investment firms must transfer technology to suppliers does not have a concrete indicator. It is worth mentioned that Gov 6 who represents a government agency that co-designed technology transfer conditions with the board of investment also pointed out that there are technology transfer strategies to build domestic capabilities of local suppliers, but this has not yet been systemized. It is due to a lack of responsible institutions to learn and absorb technologies and transfer to firms.

In addition, interviewees from academia and industry indicate interesting point relating to promoting Thailand as an EV production hub that being only a production hub rather than start developing its own knowledge and technology, would risk the country in losing competitive advantage. Uni 2 suggested that the plan to become an EV production hub may not be the right position and the country should aim higher towards more research and development value proposition since the country is now in a premature deindustrialization stage. Uni2 explained that the stage of premature deindustrialization occurred because Thailand has been industrialized by having manufacturing activities locating in the country and productivity has been increased, including labour cost. However, during the industrialization stage, Thailand has not achieved technology deepening and been able to create its own proprietary technologies to move from being only a production hub. And the country status is now a production hub with a high labour cost. Thus, foreign firms could relocate their investment to a cheaper labour cost country and therefore cause an occurrence of premature deindustrialization.

Firm 1 also pointed out that the lesson from the past is that Thailand is not the technology owner in the case of the automotive and parts industry, when government tried to attract the foreign direct investment, country only benefit from the capital investment and a hiring of labour force. "*If the country still uses the same policy for the transition to EV, and maintain position as* a *"hitman (a production base) what would be a long-term benefit* *for the country? And if the government would like to support R&D, the promotion policy has to be coherence."*

In summary, government policy to support the establishment of EV industry is present. However, government officials and firms see the need of intervention for knowledge and technological development of local firms which is still lacking.

6.1.2.1.2 Research and Innovation policy to support EV technology development

This section explored government R&D programs on electric vehicles from the experience of a funding agency, research institution and policy maker. This section also includes some requirements of incumbent firms regarding R&D support. The interviews show that funding agency and research institution started providing some funding and undertook research projects relating to EV development. However, the scope of EV development projects covers other types of EV beyond passenger cars which attracts new players in new segments rather than existing firms such as electric modified bus, light weight material, boat and motorcycle.

Gov 2 who is an executive of major science and innovation funding agency for science and innovation revealed that projects relating to EV, include policy and technology funding. Policy funding relating to formulating a technology roadmap for the country's ten targeted industry which includes the next generation automotive industry. For technology development funding, most of the funding projects relating to EV are in other segments beyond passenger cars such as electric bus, push back tractor to use in airports or electric shuttle bus. However, the main funding is still mostly a matching grant for traditional existing automotive industry which accounted for approximately two million USD per annum covered productivity improvement and cost-reduction projects. According to this interview, large firms and SMEs in the traditional automotive industry engaged in different funding activities. Firms that have been funded for EV projects are mostly large firms from the conventional automotive and parts industry and also some newcomers from other industry. While SMEs firms who are suppliers in a conventional automotive and parts industry would still focus on funding support for productivity improvement and a cost reduction in their production line without engagement in EV development.

The increase of productivity projects for SMEs would focus mostly on using automation or the development of engineering design. Research and development projects were conducted in collaboration between research institutions or universities and industry. Some of the projects are designed to have large firms working with SMEs by providing know how on automation to SMEs. These projects also have academic institutions involved closely in the plants by having a professor and a team of undergraduate students take lesson learned from the automation system installed and transformed it into a technical report for firm's future use. The working process was designed to increase the firm's technological capability and at the same time prepare potential human resources for the automotive and parts industry.

The electric bus projects were funded for four companies, consisting of two large firms and two SMEs. Despite the support in terms of funding from the government, SME firms tend to withdraw from the projects due to the high cost to develop electric buses and the possibility to sell electric buses is relatively low. The firm that continues on this project previously produced raw materials and see the opportunity to produce parts made from carbon fiber or lightweight material which could apply to many electric mobility parts. Additional comment from the interviewee regarding the electric bus was concerning the stimulation of market demand which has not been achieved through government procurement of electric buses. Thus, the provision of supply side policy such as funding support or investment policy could not be achieved solely without demand side policy to stimulate the market.

Gov 2 confirmed the need to first develop other segments than passenger cars because local firms cannot yet compete with international brands.

Research 1 is a project manager under a major research institute in Thailand. Research 1 explained that projects have been conducted with a collaboration with government agencies and firms. Current EV projects include electric bus, electric motorcycle, electric boat and electric vehicle conversion. These collaborative projects are mostly funded by government agencies and firms are responsible for conducting most of the research and development tasks with some technical guidance from research institutions. In a development project lead by firms, it is expected that when projects are finished firms would have a technological capability to continue their research and development or even produce EV related parts. It is noteworthy to mentioned that these collaborative projects between industry and research institution led by firms in Thailand are different from previous studies which were mostly led by research institution (Plaeksakul, 2010) .

The electric bus project was funded by the Electricity Generating Authority of Thailand (EGAT) and Bangkok Mass Transit Authority (BMTA) and four local bus assembly to convert minibuses into electric buses. The aim of the project is to create knowledge for local bus producers since bus production is a local industry. However, the local bus industry does not have knowledge relating to electric mobility, thus this project could support an emergence of a new supply chain for the electric bus industry. The conversion was conducted mostly by incumbent firms with some technical advice from a research institution. Research 1 pointed out that firms should conduct most of the development by themselves because, the goal is to create a local supply chain for electric buses and this project should create a firm's technological learning and thereafter technological capability to produce local electric buses.

Another interesting project is the development of electric boats in which local boat production firms collaborate with research institutions. The development can be categorized into, 1) the development of system integration by acquiring parts in the market and integrate into electric boats and 2) the development of local components for an electric boat. The firm in this project is a subsidiary of a large firm in a conventional automotive and parts industry. The subsidiary firm focuses on the development of modern transportation.

The third project regarding the EV conversion is to convert internal combustion engine cars into EV. This project aims to transfer technical knowledge of EV conversion to firms, with some of the firm's business relating to after sale of the internal combustion engine. Thus, these incumbent firms are looking to adjust themselves to the new regime. The fourth project is a collaboration between a research institution and a newcomer firm in research and development parts used in motorcycle. This project was initiated by firm that produces electric motorcycles. The firm plans to sell their products in Europe where EU regulations require anti-lock brake system (ABS). However, the firm could not find any suppliers in Thailand, so approached research institution to help with engineering design. The research institution then matched another potential firm that could produce ABS. Research 1 pointed out that all these projects are expected to prepare for the firm's readiness in the transition to EV.

Testing and standards are considered of importance for new technology development for both incumbent manufacturers and newcomers. Thailand Automotive Institute (TAI) set up testing centers for components used in the automobile sector, such as a tire testing center and a recent battery testing center which cooperated with a foreign partner to set up the testing center and transfer battery testing knowledge. However, from a company perspective, Firm 1 believes that the number of testing centers and the variety is still insufficient, there should be more centers and they should cover more auto parts testing. The establishment of a testing center would be the place that supports the firm's R&D activities for future technologies. Firm1 gave an example of Taiwan that has several testing centers while producing fewer cars than Thailand i.e., approximately 800,000 cars annually while Thailand produces approximately two million cars per year. Firm 1 emphasised that having a testing center is very important in supporting firms particularly to adhere to international standards.

Government agencies also act as an intermediary in providing opportunities for firms to link with foreign experts or technology owners by setting up a technology field trip. Gov 1 who represents the agency responsible for research and innovation plans revealed that the agency and other responsible agencies were acting as an intermediary and set up a technology field trip for firms that have an interest to join the EV industry. Gov 1 revealed that firms that joined the trip are both incumbent firms and newcomers that are looking for new opportunities. These trips facilitated firms meeting with selected research institutions or foreign firms in South Korea and Taiwan that have specific knowledge relating to EV technologies which could save time for firms in browsing for experts.

Indus 1 who represents firms in the automotive and parts industry shares the need for technology matching with other partners. Indus 1 pointed out that the association has already considered EV technologies that firms could develop such as lightweight body, battery management system (BMS) etc. However, Indus 1 considers that Thailand does not have technological strength in these technologies, thus technology matching with foreign partners could shorten the time of development.

One of the support programs required by firms to support the reformation of the automotive and parts industry is the acquisition of foreign technologies to shorten the time of R&D by means of attracting world-class R&D firms or set up a joint venture with leading technology owners.

Firm 1 suggested that to be able to follow the trend quickly, the short cut to tap global technological knowledge by collaboration or setting up a joint venture with technology holders would benefit firms that would like to join the EV value chain. Firm 1 also suggested that since R&D is a long-term process it could take more than ten or twenty years to achieve. Thus, if government could develop an eco-system that would attract a world-class R&D firm to locate in the country and start a collaboration project with local firms, the R&D process would be quicker.

While Firm 2 already took an action by collaborating with several foreign partners from Asia and Europe. Firm 2 explained that the collaboration to learn new EV technologies is a preparation for its customers. According to the interview Firm 2 explained that only five to ten percent of the firm's product would be disrupted by EV, and the firm would not experience much impact due to the preparation of highly relevant EV products. The reason that Firm 2 has started collaboration projects is because the firm sees a positive view in the emergence of EV and if the future markets are dominated by EV, the company will already have a stock of knowledge to draw from.

Firm 2 pointed out that the firm has been prepared for approximately five or six years by benchmarking with other global firms to identify products and technologies to be developed. The company conducted a preliminary study of various car producer's technology and identified partners to develop technologies.

In summary, government agencies and research institutions have started R&D programs to support the development of EV technologies. Firms that joined these R&D projects are both incumbents and newcomer which could imply that incumbent firms are responding to the government support and show some willingness towards the regime change. However, most of the firms that joined EV projects tend to be large firms more than SMEs. The analysis of the survey data suggested that both firm sizes required R&D funding support as their second rank for government support. On the other hand, the information from the interview data shows that SMEs has not yet largely involved in government funded R&D projects. But what is shown is that SMEs focus mostly on funding support for incremental innovation or productivity improvement of the existing production line. According to the interview data, this cannot be claimed conclusive that SMEs are not interested in R&D activities relating to EV since the arrival of EV in Thailand is still in the early stage and the demand for EV is still limited as suggested in the interview. Rather this called for policy design to support R&D for SMEs who interested in transitioning to EV. The new initiative such as local bus conversion project that can draw incumbent actors from conventional automotive industry and aiming to develop local value chain should be considered its results, to continue and expand into other EV products.

In addition, some of the points in the interviews are not presented in the quantitative results but should be considered such as further policy requirements from firms in supporting the acquisition of foreign technologies to shorten the time of R&D process. Representatives of large firms agree that collaboration with foreign partners would allow firms to quickly acquire needed knowledge.

6.1.2.2 Policy that support the conventional suppliers into sectoral adaptation

EV technology can be considered a radical change particularly for existing suppliers in the automotive and parts industry, since it requires new investment and new knowledge. Thus, to support existing suppliers who would resist change, this policy aims at reformulating a firm's existing experience or products to serve new markets. According to the interview, many government interviewees and academia mentioned sectoral diversification policy as an option for existing suppliers to diversify their experience to enter new markets or industries. This policy would support suppliers to diversify a firm's existing capability into other industry sectors, such as a diversification of products to use in other industries. The expected industries are aviation industry, rail industry or medical equipment industry.

Ind 1 who represents firms in the automotive parts industry mentioned that the entry of electric mobility could impact internal combustion components from over twenty-thousand components to approximately twelve thousand components. The association explored two options for impacted firms which are 1) the replacement market (spare parts) and 2) alternative market or product diversification. The replacement market could support firms in the transition period since the cumulative counts of vehicles globally is approximately 1.6 billion cars. This could imply that the replacement market or the aftermarket of internal combustion engine vehicles would still remain for some times. Another option is to find new market opportunities by seeking to diversify a firm's portfolio for other sectors.

"We are now discussed among components suppliers to diverse to aviation industry or rail industry or even medical equipment."

Ind 1 pointed out that the decreased number of components of fully electric vehicles would impact many firms and only some firms could join the EV value chain. The most impacted firms would be SMEs since only 10% of all suppliers might have the capacity to join the EV value chain. However, most of the firms in the industry are SMEs that could not adapt immediately to the new market. Therefore, the association is trying to support SMEs in upskill or reskill and investment in new production system to prepare for the upcoming change.

"If SMEs have an increased skill, they can adjust themselves more easily particularly to be able to incorporate AI or robotics in their production system. We cannot tell them exactly what they should do, but we can help them develop their skills."

The requirement of sector diversification has been responded by TAI. Gov 5 revealed that agency has been conducting networking projects to create linkage between the automotive/parts industry and the aviation industry. The collaboration between two sectors is to realize the possibility of modifying or upgrading existing production lines to serve another industry. This project would allow incumbent players to diversify their experience and to alter their products to enter new markets or industries. At present TAI projects have only begin to create networking opportunities between the automotive/parts sector and the aviation sector. The other sector that was mentioned by Ind 1 such as the rail industry or medical devices has not been matched with automotive and parts industry.

However, Uni 1 also pointed out that if firms continue based on existing experience, firms need to improve their production system in terms of process and precision.

At the regime level, there has been government policy that supports the network creation between supplier firms or SMEs in the automotive industry in upgrading their production system, particularly using automation in the production line. The requirement is from firms in the second or third tier that need to boost their productivity to meet higher tier expectation. This program is a collaboration between universities, industry and government agencies. Former National Research Fund (NRF) a funding agency oversee this funding program by providing funding for SMEs to hire other firms in setting up and transferring knowledge regarding automation systems. While professor and university students would join the process of technological learning and analyse the lesson learned from the project and create a technical report for SMEs.

Gov 5 revealed that there are still some demands from incumbent players in the automotive and parts industry that since this is still a transition time, thus firms still require government policy to support their skills, either to upskill or reskill, for the continuous development of the internal combustion engine which would still occupy the market at the moment or new alternative vehicle that partly contain ICE such as hybrid vehicles. Interestingly, to destabilize the regime, at the policy level government is starting to restrain the budget allowance for programs involving internal combustion engines. Gov 5 revealed that "*When formulating budget proposal, if indicate that target group is for internal combustion engine, this project could be declined".*

In sum, there is some government policy offers to support incumbent firms in exploiting their existing expertise by offering product diversification or market diversification programs. The elicited interview data of policy aspect is aligned with the requirements of firms in the quantitative analysis of the survey data in Chapter 5. The survey data showed that both SMEs and large firms are interested in diversifying their experience to other sectors or investment in new production capacity. However, according to the results in Chapter 5, firms are mostly interested in robotics and automation, rail industry and then aviation industry. Thus, the existing programs offered by government has not yet covered firm's requirement.

6.1.2.3 Barriers to the technological regime transition

This section explored barriers that impede socio-technological regime transition. These barriers inhibit incumbent firms from altering their position to electric mobility. According to the interview, some of the barriers to the technological regime shift from the supply side are similar to the study of Kemp et al., (1998) such as production factors and demand factor.

6.1.2.3.1 The sunk cost of conventional cars production line

One of the barriers to entry to new technologies mentioned by firms is the sunk cost and existing investment in production lines of ICE. The sunk cost of production equipment could be a barrier for suppliers to entry to the new market. According to Kemp et al., (1998), one of the barriers of supply side to the regime shift is production factors. This is when the market demand for new products is still uncertain and there is no legislation to force the industry to produce such products. There is a risk to invest in new technologies while the sunk cost of existing investment has not been recovered.

Firm 1 pointed out that investment cycle for automobile industry is around eight to twelve years to reach the breakeven point. During this period, they expected that there would not be a major change in their operation. Gov 5 who represents an organization that work closely with the automotive industry also mentioned that it might be difficult to accelerate the transition since suppliers are dependent on key players and it has to reach the breakeven point before starting the new investment.

6.1.2.3.2 The lack of demand side policy to stimulate mass adoption hence the increase of EV production investment

Despite the emphasis on production firms and suppliers, the core concept of MLP in technological transition is the interaction between heterogenous elements. The distinction of MLP from system of innovation is the emphasis on users or demand side. One of the most important barriers for car producers and suppliers to invest in new technologies is market demand. Prospective customers are reluctant to buy EV, since it might not serve their specific needs in terms of performance or price. Thus, manufacturers are also reluctant to produce products that do not have a clear demand (Kemp et al., 1998) The lack of market demand is one of the issues mentioned by government officials, academia and firms during the interview since without market demand, firms would be reluctant to invest in EV. The findings also suggested a lack of demand side policy to create market demand.

Uni 2 pointed out the importance of demand side policy and the promotion of EV industry as a chicken and egg situation. This means that while the government is moving towards the promotion of being a future EV production hub, there is no articulated demand from customers, so this could be an obstacle for the promotion of EV industry.

"At the policy level, to promote the adoption of EV and to build an EV industry is different. Now it seems that we want to build an EV industry domestically, but it is the problem of chicken and egg what comes first. If the price is too expensive, consumers will still not buy EV and then it is difficult to promote EV industry. Now the policy does not cover the whole process such as demand side policy."

According to the interview, policy to stimulate market demand that was mentioned was relating to price incentives such as low excise tax for EV or monetary subsidy for users. Excise tax is a consumption tax charged on selected goods or products which area considered “luxury” including vehicles such as automobiles. The idea of taxing unsustainable technologies and reducing tax for sustainable ones was mentioned.

Firm 2 believed that although the country has been stimulating the EV investment by providing incentives to draw in the EV investment, without articulated market demand there would not be a real investment relating to EV. Firm 2 suggested that the excise tax should be lower for EV produced domestically. Simultaneously the tax should be raised for internal combustion engine vehicles based on the CO_2 emission to exert pressure on socio-technical regimes.

Uni 1 believed that without market demand, it is difficult to build an EV industry in the country. This view is confirmed by Gov 6 who works for a government agency that provide investment incentives. Gov 6 revealed that firms submitted applications before the deadline for EV production in Thailand only to secure the spot of investment privileges. However, firms did not have a solid action plan in producing PHEV or EV, providing reasons that at present the market is relatively small and the infrastructure for EV is insufficient.

Ind 2 revealed that the industrial association has proposed to the government to provide demand side policy both monetary and non-monetary policy to promote mass EV adoption. The proposed policy includes purchase subsidies or tax rebates for EV users, government procurement, the installment of public chargers etc.

Firm 4 also agreed with direct subsidies for users, since there are many limitations of EV compared to conventional cars in terms of driving range or price gap. Thus, direct purchase incentives could make EV more favourable and affordable and increase acceptability for consumers.

6.1.2.3.3 The dependence of suppliers on foreign car producers

The automotive industry is characterized by a strong supplier-buyer relationship between firms in a production network. Leading firms who are major transnational companies have a strong control over supply chain firms through their purchasing power. Thus, this leaves little room for suppliers to change the company's position (Schwabe, 2020).

The supplier-buyer relationship became one of the obstacles for supplier firms to develop new EV technologies. Despite various government policies in supporting the transition to EV, the dependence of firms in the automotive industry value chain remains an obstacle.

The issue of how regime players would respond to the EV trend being due to the direction of major car producers was mentioned by government agencies and firms. First, the automotive industry has been dominated by multinational companies, these companies own proprietary technologies for internal combustion engines. Thailand is a production hub, so local suppliers would follow the direction of major car producers (Gov 5). Gov 5 implied the difficulty for local suppliers in deciding what to invest in without direction of their customers by stating that:

"Thailand is a difficult case; we have a long history of the automotive and parts industry rooted in Thailand over 50-60 years, dominated by multi-national companies particularly Japanese companies. We have local Thai suppliers, but we do not hold the proprietary technologies of the industry particularly for passenger cars, we do have capacity for the pick-up truck but still it means we need to follow the decision of the key players. Local parts suppliers cannot just shift to EV."

Uni 1 also pointed out the need to follow direction of higher tier groups as follows:

"Many firms need to follow the direction of OEM (car producers), when they identify that you need to produce a certain component you have to do it, you cannot just produce new parts. The situation would be more difficult for lower tiers that produce non-functional parts and focus on the volume more than value."

This issue is confirmed by Firm 1 which is a joint venture with Japanese car company that:

"Since our partner is Japanese company, now the direction of Japanese group is towards how to enhance internal combustion technology to be more environmentally friendly and consumer friendly. There is an underlying reason in terms of economics for this chosen technology. Thailand mostly will rely on Japanese company direction. This could generate some gap during the transition of what direction Thailand will choose."

All previous statements illustrate that for some suppliers, due to the control of lead firms, they cannot embark on developing EV technologies without the direction of foreign car producers. According to Schwabe (2020), the dependence of suppliers is also a result of high cost in switching to other markets while the current markets guarantee a high volume of orders from buyers. Thus, suppliers seem to be reluctant in altering their market position.

6.1.2.4 Firms' attitudes towards regime change

The attitude towards the entry of EV is also different among firms. This led to a different positioning of firms towards an EV transition. In general, the entry to EV is relevant to all interviewed firms and firm representatives.

Firm 1, 2 and 3 shared that only part of the revenue would be disrupted by the electric mobility, approximately five to ten percent of the total production. While Firm 4, the car producer, has been prepared to launch many new models of EV by 2023. Firm 1, Firm 2 and Ind 1 all expected that the ICE market would remain stable and continue for at least a decade. While Firm 3, the SME firm, surprisingly expressed a different concern from other firms and expected EV to entry the market in two years.

Firm 1 that mostly produces suspension components conducted an organization assessment and identified that in the short-term 90% of parts produced would not be impacted, only approximately two percent of the total sales, which were exhaust manifolds, would be impacted. However, in the long-term over ten years, EV technologies could have a high impact on the firm's operation. However, Firm 1 explained that the future vehicle market would go beyond electric vehicles, and will include connected vehicles, autonomous vehicles and shared vehicles (CASE). Firm 1 saw CASE as a window of opportunity to create new businesses and would add value to the automotive and parts industry. However, Thailand do not have expertise in technologies relating to CASE, thus require a partnership to start these new technologies.

In terms of the view on EV adoption and production, Firm 1 pointed out that the choice of technology for green vehicles needed to be appropriate for each country. In Thailand the source of fuel could come from biodiesel and might be more cost effective than using battery technology which require rare elements. The use of biodiesel could support a local industry more than choosing a direction towards full EV in which over 90% of a car value is based on its batteries and depends on foreign technologies.

Firm 1 pointed out that government policy should not overly interfere with market mechanisms, since it might have an adverse impact on conventional parts suppliers if EV entry is too early. There is a concern over a zero percent import duty of EV from China, as a result of the China-Thailand Free Trade Agreement, which could have an impact on a local EV industry.

Firm 1 was started in an after-market or replacement market before it started to develop its reputation with an OEM. Firm 1 established itself as a reputable first tier supplier and developed technology capability through the support of foreign technical assistant (TA) and through establishment of a joint venture. The firms hired a retired engineer from Japan who used to be the firm's technical assistant to support design capability. The government policy that Firm 1 believed helps promote its technological capability is a local content policy. When there were new component firms and the local content policy was still imposed, the local production process gave an opportunity for firms to absorb the know-how from foreign firms particularly Japanese firms. However, the local content policy was revoked due to the

World Trade Organization (WTO) rules, so the country can no longer use this policy to support local suppliers.

Still, Firm 1 emphasised the importance of partnering with foreign TA, which the government could support by building an eco-system that would attract world-class firms to invest in future technologies locally. Firm 1 also agreed with a proposed knowledge network to develop an EV open platform which could be an incubator for firms that are interested in EV technology development.

Firm 2 is quite similar to Firm 1 in that it has a low dependency on ICE parts. The firm partly produces components relating to exhaust systems but this accounts for only 5-10% of total production. Firm 2 has several plants abroad such as in United States or China. Firm 2 pointed out that it has not yet seen significant EV transition in Thailand, and it might take around twenty years for the transition to occur. In contrast the firm's plant in United States might need a whole reinvestment within ten years. The reason that Firm 2 believes that it would take longer for Thailand to adopt EV is because of the lack of a government zero emission initiative.

Firm 2 also believed that the entry of EV would have an impact on the conventional auto industry, particularly for lower tiers. EV technologies are associated with high cost, the investment in EV technologies is high and the components are less than for conventional cars. Thus, SMEs or lower tiers that used to supply many small parts to higher tiers would be at risk.

Firm 2 also owns a diversified production plant such as wiring that could integrate into EV industry. Despite the firm's perspective on the entry of EV that might take almost twenty years, it has been starting its research and development on EV technologies such as lightweight materials or hot stamping. Firm 2 shared that it is uncertain which exact technologies would be used in EV for each of the car producers. Thus, to prepare for different technologies that could be adopted in EV, it chose to collaborate with various foreign technology partners from different countries. There is no collaboration with a domestic research institute or university since the firm believes that the technology advancement of the firm is greater than at any domestic university. The diversification of technologies could support the different needs of its customers since each car producer may be interested in different technologies, so the firm has been preparing a technology catalogue for its customers. The preparation for EV technologies has been conducted for approximately five years.

The acquisition of up-to-date information was gathered from customers or the firm's network or from trade exhibitions. The information helps the firm's positioning towards development of EV technologies.

The interviewer asked Firm 2 if Thailand can remain its position as the "Detroit of Asia". Firm 2 believed that Thailand may maintain position as the "Detroit of Asia" for an internal combustion engine. However, local supply chains could face a serious competition from other countries such as India, Indonesia, Vietnam since the technologies used are static. The unchanging technologies means other countries can catch up and might offer the same parts at a cheaper price. Thus, it became a price war instead of technology competition. Therefore, Thailand needs to focus on the technology change and upgrade its technology capability so government could provide support for the technology development.

Firm 3 is a SMEs firm that provide parts to several Japanese car producers. It was supported by a major car company in its production system and it was chosen to be a model plant for the supplier's network to visit and learn from. Firm 3 pointed out that there is no impact on the firm's operation due to the entry of EV, since the current products relating to wiring and harness can be used in EV.

Firm 3 has had regular monthly meetings with its customer in which information shared during the meeting would cover production trends, including other car producer's technology trends. Firm 3 has been given an early requirement from its customer during supplier's meetings to be prepared in case of the abrupt change in EV technology and shift to other system which might not need wiring products and depends on electronic systems. The customer's requirement was given two year earlier to Firm 3 before this interview was conduct in 2019. Firm 3 assessed that when customer gave a requirement, this could be an implication for change as follows:

"If they (customer) change, we need to change. When they told us their requirements, this means they are considering, otherwise there would not be any question or request." At first, we plan that the change would come in five years, but learning from the past experiences, technology change very fast, so we think it could change in 2 years."

Firm 3 has considered whether to adjust its production or to acquire parts from other companies and conduct an assembly process to serve its customer's expectation.

Generally, Firm 3 indicates that it received technological knowledge from suppliers through machine buying and received after sale training. Customers usually indicate requirements, and the firms would find suppliers that could meet the needs of customers.

Firm 3 has also been working with a university to create an effective work system. Firm 3 received funding from the Industrial Technology Assistance Program (ITAP) which operates under National Science and Technology Development Agency (NSTDA).

The need for support from government is to supply manpower, particularly in the field of information technology (IT) to support the development of software and automation systems in the plant. Due to the lack of workforce and to increase plant's productivity and precision, another requirement is a support to improve automation. Firm 3 also emphasized that what SMEs need is to be adaptable to be able to compete. SMEs require knowledge particularly in automation and cost reduction.

According to the interview, it can be concluded that Firm 3 has developed a knowledge network with other institutions i.e., a government agency, university and research institutions and network of firms in preparation for an upcoming transition.

Firm 4 is a European car manufacturer. It has been selling imported plug-in hybrid cars in Thailand since 2014. The assembly line of plug-in hybrids was operated in 2017 for four models. The company foresees that by 2025 the internal combustion engine vehicle will reach its market saturation point and be declining. During the first phase, hybrid and plug-in hybrids would replace internal combustion engine vehicle and thereafter pure electric vehicles. However, the parent company has announced a new timeline for the entry of electrified vehicles, which would arrive two years sooner or in 2023. In 2023, the company expect that there will be enough market demand and it could launch twenty-five electrified car models. Firm 4 pointed out that one of the reasons that major car producers would launch more electric vehicle is because of the CO_2 emission regulation standards for passenger cars particularly in the EU, US and China. This regulation would expedite the EV transition. This might not directly impact the Thai auto industry but parent companies who are multi-national companies will ultimately bring in the technology.

Firm 4 has established their assembly plants in Thailand since 2000. The assembly lines include five car models and seven motorcycle models. Firm 4 recently received an investment incentive from the Board of Investment (BOI) to assemble PHEV. According to BOI's condition on having core components developed locally, the firm also announced the opening of a battery packing plant in Thailand which is operated by the firm's supplier. However, Firm 4 indicated that there is a bottleneck in producing battery packs because it needs to import battery cells from abroad and later assemble to battery modules. Firm 4 explained the reason that the firm buys battery from suppliers instead of developing and producing by itself is because of the rapid change in technology trend and capacity. Thus, buying from experts in the field tends to save firm's time from research and development in case there is a sudden change in technology.

Firm 4 also commented on investment incentives particularly on limiting the volume of import vehicles for market testing. The investment condition granted a three-year grace period for EV investment firms before starting their assembly activities. Meanwhile during the three-year grace period, firms may import EV to start market testing. However, the government set a limit on the volume of imports at 7.5% of the total volume of EV to be produced in the first year. This volume is relatively small in the view of interviewee, and impractical to conduct market testing with this number of vehicles. Firm 4 shared a concern that there are many restrictions for investment firms while the importation, particularly from China, seems to have less restrictions. Thus, this could impede the promotion of EV production in Thailand.

Firm 4 has collaborated with a government agency since 2012 i.e., Office of the vocational commission in developing the workforce to serve the automotive industry. This program occurs because of a limited workforce in the industry.

In summary, this section addressed firms' perspectives towards regime transition and how firms respond to the transition. The impact on supplier firms is not obvious since the dependency on ICE parts is low. However, it seems that despite the low impact on firms, all firms from the interview generally recognize the changing trends. Some of the firms already prepare to adjust their business corresponding to EV trend and one firm showed an important concern and resistance towards the transition.

According to the firms interviewed, it is noteworthy to mention that firm's decision to invest in new technology is primarily a result of their customer's requirements which is corroborated with the survey result on EV potential partners. Knowledge acquisition sources to support the transition are different among the interviewed firms namely hiring of foreign experts, internal R&D, collaboration with foreign partners, collaboration with suppliers and collaboration with universities and research institutions.

A firm's requirements for government support also varies based on the firm's perspective on the transition. Firms with resistance prefer the government not to interfere with market mechanisms, while firms that believe the EV entrance will occur in the near future and is inevitable require government policy interventions to create market demand. The requirements of government support relating to technological support includes the supply of manpower which identified by SMEs and large firm and the acquisition of foreign technologies. The requirements for government support relating to the provision of human resources are also implicit in the results of quantitative analysis.

6.1.3 Niche level policies

In contrast to regime level, niche level provides a protective space or an incubator where seeds of new technologies could be developed (add reference). Niche development processes can also occur parallelly against the background of the existing regime, so regime actors could also partake in a niche development process. Public policy could support a niche formation process.

According to Kemp et al., (1998), there are three strategies that public policy makers can use to generate the change from an existing regime to a new regime. The first is the change of incentives, particularly tax incentives, to favour sustainable technologies, while giving tax negative to unsustainable technologies. Second is to build a total new socio-technological regime which is difficult to achieve. The third is the strategic niche management process which aims to create a space for experimentation within the on-going socio-technical change and provide a pressure to steer the transformation in a sustainable direction. The so called "protective space" is a place to foster certain new technologies or technological niches and allow them to develop and grow without interference or pressure from the regime level. The learning processes are a central idea of strategic niche management in order to learn the development of new technology and also the diffusion of technologies to market. The strategic niche management may include various actors either from governments or private sectors and either of them could be the manager of niche development project. The findings from the interview shows that there are attempts from government agencies and academia to create a protective space, to develop niche technologies, e.g. non-passenger cars vehicles.

6.1.3.1 Proposed knowledge network creation to support niche technological learning

Generally, in the automotive and parts industry, established practice at a regime level, particularly the technological learning processes of firms, has been conducted mainly through a firm's network e.g., their customers or their suppliers. Based on the result of chapter 5, firms learn mostly through their internal efforts and external sources from inter-firm network or hiring. The survey results also shows that the networking to support a firm's technological learning with governments or academic institutions are insignificant.

However, based on the interview data, interviewees from all sectors i.e., industry, government and academic institutions were all agreed with a potential niche policy intervention in establishing a triple helix network to work on the development of potential EV technologies.

Many interviewees both policy makers and firms mentioned the potential establishment of a network among government, academia and firms, both incumbents and new entrants, to collaborate on developing non-passenger cars EV. The co-development projects of local EV or non-passenger cars includes electric buses, electric tricycles, electric low speed vehicles etc. (Gov 1, Gov 4, Gov 5, Uni1, Indus 2, Firm 1).

The underlying reason for developing electric non-passenger cars mentioned by interviewees is because it would not have to compete with products of major car producers which is undeniably difficult. Also, suppliers need to follow the direction of foreign car producers. Thus, development projects in other segments are considered a window of opportunity for firms, both incumbent firms and newcomers, that are interested in developing EV technologies.

Uni1 revealed that the proposed idea of an EV open platform is to develop a central platform for non-passenger cars such as minibuses particularly the suspension system as a basis. This project aims to support firms that would like to develop electric mobility but do not have the technological capability to start. Afterwards, firms can further develop electric vehicles based on the co-developed central platform for their own business purposes.

The targeted stakeholder in this collaboration project includes both incumbent actors and newcomers such as suppliers in a lower tier of the automotive and parts industry that are interested in developing electric mobility. Uni1 explained the project could be an incubator for firms to engage in EV development i.e., for non-passenger cars. While government agencies or universities could support firms in terms of cost reduction by providing an EV central platform or testing lab. This could provide a level playing field for firms to easily enter the EV industry, by having an opportunity to engage in a non-competitive market and be able to develop technological capability. The collaboration project could act as a steppingstone and lead to an opportunity for firms to further develop more complicated EV products.

This is corroborated by the strategy and action plan of the office of SME promotion that the researcher had seen by joining a workshop on 4th April 2019.This proposed project is based on a concept of an EV open platform. The idea is to develop an EV platform which uses the same parts and components, such as suspension system, chassis, to reduce production costs. This collaboration project around non-passenger cars aims to develop local technological capability, which would allow firms that are interested in developing EV technologies to join the EV platform development. This initiative of establishing EV knowledge network for the development of EV platform was initiated by a government agency. Firms agree with the idea of an EV open platform since it could increase the capabilities of local suppliers and prepare firms to join the EV global value chain as illustrated by the comments below.

Firm 1 agreed with the open platform strategy that the open platform could be a showcase for global players to observe the technological capability of local suppliers and draw them to the global value chain.

"I see an open platform as a good opportunity for existing firms to join and develop new business regarding electric vehicle particularly this will not yet interfere with the conventional automotive and parts industry but at the same time can prepare the readiness for firms in case EV entrance came sooner."

However, the project is still a proposed dialogue between government agencies and academia, so it has not yet been operated.

In summary, niche level government intervention is still only a proposal and a dialogue between government agencies, academia and industry. The proposed concept will cover technologies learning aspect by selecting which technology to be developed.

Thus, there are some government policy interventions to support technological learning relating to EV technologies by means of R&D funding for incumbent and new entrants as mentioned in section 6.1.2.1.2 Research and Innovation policy to support EV technology development. This is considered as a form of niche development that has been undertaken by both incumbents and new players. Still, it seems that at present there are not many firms partake in the government R&D programs or knowledge network creation for niche innovation. Suppliers who are SMEs are interested in incremental R&D relating to productivity development to serve the existing automotive industry. In addition, the technology roadmap of EV developed by Thailand Science Research and Innovation (Gov2) which will identify scope of funding and technologies to be developed has not yet been implemented. The identification of technologies would support supplier firms during the transition in planning which technologies to invest, and human resources firms need to recruit. Taken together, these results suggest that there may be a gap in government policy intervention that support technological learning of new technologies in particular to support SMEs interested to adjust their strategy and join EV value chain.

6.2 Summary of empirical results

Issues	Results
1.Role of policy interventions: an overarching policy framework at the landscape level, with the aim of exerting influence on the transformative change within the existing regime.	The study reveals that an overarching policy is absent in Thailand, indicating a deficiency in robust policy ambition, integrated public policy, and the establishment of quantitative goals, such as a zero-emission target. This lack of comprehensive policy framework fails to exert the necessary pressure at the regime level, thereby impeding investment from car producers or suppliers and discouraging consumer engagement, consequently hindering the facilitation of system-level change.
2.Policy supports the reorientation of strategy of firms in the conventional automotive industry towards sustainability transition	The main findings suggested that Thailand has made significant strides in supporting the conventional automotive industry's transition towards electric vehicles (EVs) through various policies, including investment incentives, R&D funding, and market diversification initiatives. However, there are areas where these policies could be further improved, particularly in adequately assisting local suppliers in their transition to EV production.

Issues	Results
	While the investment policy aims to position Thailand as a regional EV hub, there is a need to balance the focus on building local capabilities alongside establishing the country as a prominent EV center. At present, the policy lacks effective mechanisms for facilitating local technological diffusion, hindering the promotion of high-value activities within the country and concrete technology transfer. The current R&D funding program primarily attracts large firms, leaving smaller local suppliers, especially those from traditional automotive backgrounds, still focused on increasing productivity rather than fully embracing the opportunities in the EV value chain. To foster a more inclusive transition, the R&D funding initiatives should be designed to specifically support SMEs interested in joining the EV industry. To promote sectoral diversification, government agencies have initiated programs to encourage existing suppliers to explore other markets, such as the aviation industry. However, the efforts are currently limited to linking suppliers with the aviation sector alone. A broader approach is necessary, considering potential industries that could benefit from existing supply chain

Issues	Results
	capabilities. Moreover, standard testing is crucial to ensure seamless integration into these new industries. In conclusion, while Thailand's policies have laid a foundation for the advancement of the EV industry, there is still room for improvement. The investment policy should strive for a balanced focus on local capabilities and establishing Thailand as an EV hub. R&D funding programs should be tailored to support interested SMEs, and sectoral diversification should encompass a broader range of industries while ensuring compatibility through standardized testing. By addressing these areas, Thailand can better support its existing suppliers and further boost its position in the rapidly evolving automotive landscape.
3.The emphasis on users or demand side policy which could constitute firms to start investing in EV technologies.	The MLP framework places significant emphasis on the transformative potential that emerges from the user side. While this study does not directly focus on users, the collective view of interviewees, including representatives from academic institutions, government agencies, and industry stakeholders, highlights the crucial role of demand-side policies in stimulating users' needs and facilitating suppliers' rapid adaptation to EV development.

Issues	Results
	Demand-side policies, such as providing direct financial support to EV buyers or offering tax incentives for buyers, play a pivotal role in driving the adoption of electric vehicles. These policies create a favorable environment that encourages consumers to embrace EV technology, leading to increased demand for EV in the market. By implementing the demand-side policies, governments can effectively influence consumer behavior and preferences, accelerating the transition to electric vehicles. Additionally, the increased demand for EVs encourages suppliers to adapt swiftly to meet the growing market requirements, thereby fostering a robust and responsive EV industry. And promoting the timely adaptation of suppliers to the evolving EV landscape.
4.Firm's attitude towards regime change to EV	According to the qualitative findings, most firms and industry representatives anticipate a transition period of approximately 10 years before the full-scale entrance of electric vehicles (EVs). This aligns with the research context and literature review in Chapter 3, which suggests that Thailand may experience minor impacts during this decade-long period. The transition is expected to involve a shift from hybrid (HEV) and

Issues	Results
	plug-in hybrid electric vehicles (PHEV) to fully electric vehicles. Several factors contribute to the expected time gap, including the absence of an integrated vision or plan, car producers' decisions to invest in EV technology, customer demand dynamics, and the availability of EV infrastructure, particularly charging stations. Despite the perceived time gap, some proactive firms have already begun preparing for the advent of EVs in response to customer inquiries. These firms are taking various measures, such as collaborating with foreign partners and suppliers, to position themselves for the EV market. Industrial associations are also partnering with government agencies and seeking knowledge-sharing opportunities from international sources. It's noteworthy that the firms' opinions on government intervention in market demand are mixed. Some firms, particularly those resistant to external interference, prefer the government not to intervene in market mechanisms. On the other hand, firms that anticipate the entrance of EVs advocate for government policies to create market demand and support the EV ecosystem.

Issues	Results
	In conclusion, all firms acknowledge the shifting trend towards EVs, but their preparation strategies vary based on their type and size. Larger firms may opt to collaborate with foreign experts or parent companies, while local firms choose to work closely with suppliers, universities, and research institutions to prepare for the new regime.
5. Government policy to support niche technological learning	Based on interviews with stakeholders from the industry, government, and academic institutions, there was unanimous agreement on the potential benefits of niche policy intervention to foster the development of EV technologies through a triple helix network. Given Thailand's current status as an automotive production hub with several major car producers, the competition for new passenger car models is expected to be challenging. To address this, representatives from universities and government agencies proposed the concept of an EV open platform. The primary aim of this platform is to encourage the development of non-passenger cars, such as minibuses and low-speed vehicles, in the electric mobility sector. By focusing on these segments, incumbent firms or newcomers can participate in EV technology development without

Issues	Results
	directly competing with dominant players in the passenger car market. The proposed EV open platform sees the government agency acting as an intermediary, facilitating the establishment of a knowledge network among relevant stakeholders. This would involve coordinating collaboration between universities/research institutions, which can provide valuable knowledge resources and access to R&D infrastructure. The industry representatives expressed support for the idea of the EV open platform, recognizing that it could enhance the capabilities of local suppliers and spur technological advancements in the electric mobility sector. As of now, the proposed EV open platform is still in the discussion phase, and policymakers are encouraged to explore and refine the concept further. Through ongoing dialogue and collaboration, the potential for creating a triple helix network to drive the development of EV technologies can be fully realized, leading to a more sustainable and competitive automotive industry in Thailand.

6.3 Conclusion

This chapter addresses the role of government agencies and policy intervention as an enabler to support the transition of supplier firms to engage in EV technologies. Exploring from the perspective of a MLP framework, government policy is the crucial factor in supporting niche activities to arise. It will also enable a regime change by supporting reorientation of goal or strategy of incumbent actors to transform to the niche.

At the landscape level, the evidence from this study suggests that besides pressure from global initiatives on zero carbon emission, at the national level, there is still a lack of a predominant policy that would exert pressure to destabilize regime level or stimulate niche formation. According to the interview data, representatives from government and industry also mentioned the lack of market demand which led to firms' resistance to EV investment despite an investment promotion policy. Thus, the reduction of cost differentiation could provide market incentives for users and create a mass market demand. These results would seem to suggest that demand side policy could stimulate incumbent firms to invest in EV and reduce barriers for both firms and users in moving towards electric mobility.

At the regime level, the results suggest that government has provided policies to support the reforming of the automotive and parts industry towards the EV industry i.e., investment policy and R&D support policy. However, it is believed that there are still some shortfalls in the investment policies particularly the lack of concrete mechanisms to support technological learning of local suppliers. In addition, to support companies that face difficulties in the transition, government provides a support program on sector diversification, to allow firms to use existing production line and deliver products to new industry. This policy is aligned with the interest of incumbent firms. However, only one of the participants mentioned this program and in its initial stage, caution must be applied when interpreting the viability of the program and require further study of this program operation.

Regarding barriers to the regime transition, it has commonly been suggested that the barrier is the lack of demand side policy to create market demand. The decreased gap in price differentiation between ICE and EV could lead to mass adoption which would stimulate firms to be more inclined towards EV investment. The results from the interview suggested that most of the interviewed firms shared similar attitudes that in the long term the expected entry of EV could impact the company's operation. Despite, the interviewed firms are mostly independent from ICE, it seems that some of the firms are prepared for the entrance of EV by conducting preliminary study according to their customer future's requirements. In addition, firms and industrial representatives expressed requirements for policy supports concerning the acquisition of knowledge and the development of the workforce to support the transition to EV.

At niche level, there has been an effort to develop a governance to create a knowledge network among government, academia, and industry. The proposed knowledge network aims to develop an EV open platform as a project that draw both incumbent firms and new firms to collaborate in developing EV technologies. However, the program is not yet concrete and still a proposed dialogue.

Thus, regarding government policy intervention in supporting firms for network creation and technological learning, initial observation suggests that there are some programs available for both incumbent firms and new entrants. The programs consist of R&D programs to develop electric non-passenger cars, conversion of ICE vehicles to EV and EV related technologies such as lightweight materials. The knowledge network created is between firms and research institution or university. However, the evidence from this study suggests that firms that involved in EV development program mostly are large firms more than SMEs. While SMEs are still focus on productivity improvement and cost-reduction which relating to their current business operation.

CHAPTER 7
Discussion and Conclusion

This chapter discusses the main results and summarizes the key findings from the quantitative and qualitative analyses according to the aim and objectives of the study. This chapter is organized into five parts. The first part features the discussion of the results from chapter 5 and chapter 6. In the second part, the study's findings provide policy implications for public policymakers in supporting the building of a firm's technological learning and technological capability. Policy implications suggest policies that support a broader context of the transition to electric mobility based on the MLP framework. The third part discusses the limitations of the study, which could be improved for future research. The fourth section proposes recommendations for future research. And the fifth part provides the final conclusion of the thesis.

7.1 Discussion of findings of the study

The results discussed in this section are to answer the research question, aim, and objectives of the study. The MLP transition theory is applied to explore firms' possible transition, particularly SMEs in the automotive and part industry, towards technological change to EV. Thus, the survey was conducted and targeted on incumbent regime actors; the survey was based on 42 firms specifically in the automotive and parts industry. A firm's survey was conducted to explore a possible transition of incumbent firms through the firm's responsiveness to the change and investigate the extent and direction of the firm's technological learning, including an engagement in the network that supports the firm's technological learning.

The transition is multi-dimensional and requires interactions between actors from all socio-technical levels such as government, consumer, society. Although this study focuses on an incumbent firm's transition to EV, the interview was also conducted with other relevant actors that have dynamic interaction with firms and involved in the transition process i.e., trading associations, government agencies, universities, and research institutions to assess how public policy and governance can bring about a change and support the firm's transition.

7.1.1 Responsiveness of SMEs on the transition from internal combustion engine vehicles to electric vehicles (Objective 1)

The technological paradigm shift of internal combustion engines to electric mobility has implications for the traditional automotive and parts industry. The change in landscape development particularly global environmental problem exert large amount of pressure to the automotive and parts industry because the existing internal combustion engine technology could not meet the new environmental requirement and standard. The shift implies both threats and opportunities to the existing automobile regime. The environmental trend and global support of green technologies will eventually impact on internal combustion engine vehicles to lessen and in due course, be phased out. However, this also means new market opportunities for some firms. Part of this study aims to understand the firm's position in responding to the shift in technology and market. The following are findings from literature review, quantitative and qualitative analysis.

Literature review findings:

Literature review was conducted to explore industry context of the Thai automotive industry and the global challenge on conventional automotive industry supply chain. It was found that in the Thailand context, most of the SMEs are suppliers to the MNCs and their direction would depend on their lead firms and how much dependency of lead firms on ICE. At the global level, it is found that EV would clearly disrupt the existing supply chain. Large firms that are highly dependent on ICE would experience radical change while SMEs would also face significant change. The radical change and significant change require development of new products or modification of existing production line and adding new production lines. However, the common perspective of firms for the responsiveness to the adjustment is to adjust its internal capabilities. The Thai automotive SMEs suppliers are in the medium to low impacted group, but it accounts for a large number of employments. In Thailand context, the transition period to EV would last approximately ten years. While the transition to EV would require new technological knowledge, it is found that technology capability of SMEs and Thai local firms are still limited to mostly basic and some intermediate capabilities.

Quantitative Findings:

A survey was administered to 42 firms. The survey included the branching questions related to the interest in joining EV or diversifying to other industries. The survey found that most firms (78%) are interested in exploring new opportunities on EV. This shows responsiveness in joining new opportunities. Which in descriptive statistic, large firms (83%) tend to show slightly more interest in joining EV value chain more than SMEs (71%). However, upon conducting Fisher's exact test to determine the significance of the difference between Large firms and SMEs, the results did not reach statistical significance. Thus, the difference cannot confidently conclude and generalize the entire population of firms. The interpretation is cautious and encourages further research for a more definitive understanding between interest in EV of large firms and SMEs.

In addition, regarding firms' technology capabilities, the quantitative findings show that both firm sizes are capable of basic and intermediate capabilities. And the requirement for government intervention revealed that both firm sizes need support in capability training and R&D supports.

Qualitative Findings:

The findings obtained from the interview conducted with the industrial association representing supplier firms indicate a significant impact on small and medium-sized enterprises (SMEs). It is evident that only a small proportion, specifically ten percent, of SMEs firms possess the capability to participate in the electric vehicle (EV) value chain. In order for SMEs to successfully adapt to this new paradigm, considerable investments are required in terms of enhancing their capacity and implementing a new production system.

Firm2, as exemplified in the interview, represents an SME that has effectively adjusted to the new requirements. However, this success may be attributed to the firm's status as a tier 1 supplier, which allows it to maintain a close network with car producers.

The findings relating to the joining of SMEs in conducting R&D with respect to EV technologies are also limited which mostly conducted by large firms.

Triangulation of findings:

Results from the literature review, quantitative analysis and qualitative interviews corroborate the understanding of the responsiveness of SMEs in the transition to EV. The quantitative finding shows responsiveness of SMEs firms in the Thai automotive industry towards EV. The literature review aligns with the qualitative insights that SMEs would be mostly disrupted by the advent of EV while the literature review and quantitative finding confirms that their technology capabilities are still very much limited which could limit their response. The qualitative finding also implies the limited involvement of SMEs in EV research and development programs. While the quantitative results show the requirement of firms that government should provide policy intervention to support SMEs with new knowledge and resources required.

Implications:

Despite the responsiveness to the transition, from integrated findings show limited technological capabilities of SMEs and the limited involvement in R&D particularly relating to EV technologies. Thus, the integrated findings highlight the importance of government policy interventions in supporting SMEs to equip them with new skill and knowledge which is aligned with their interest and could support the responsiveness of firms in joining EV value chain.

7.1.2 Extent of learning requirements that would equip SMEs with the knowledge and technology set that is consistent with the policy objective of reducing carbon emissions (Objective 2)

In order for companies to align their technological advancement with the shift towards electric vehicles (EVs), it's essential to pinpoint the gaps in skills and knowledge. This identification process is crucial for firms to formulate effective learning strategies. Furthermore, policymakers can utilize this information to create an environment that supports and meets the needs of these companies.

Literature review findings:

Prior studies that explore firms' technological capability in the Thai automotive and parts industry indicates the limited technological capabilities of local suppliers to basic and intermediate level (Sadoi, 2010; Gerdsri, Teekasap and Virasa, 2012; Intarakumnerd and Techakanont, 2016). Considering the long-term foreign direct investment in the automotive industry for over sixty years, the accumulation of technology from foreign firms through FDI is still limited. The Thai automotive industry has not yet succeeded in building its own indigenous technological and innovative capabilities. Shvetsova (2020) studied technology capabilities comparing South Korea and Thailand; both countries started the automotive industry approximately the same period during 1960 and found that Thailand and South Korea have developed their technological capabilities impressively. However, Thailand is still unable to reach advanced technology capabilities such as research and development capability as South Korea can. There was a shift towards more advanced activities during the 2000, mainly to underpin the increase of pick-up truck and multipurpose vehicle production, requiring a higher technological capability (Sadoi, 2010). However, the firm has not reached the stage of advising customer of its product's improvement. Study by Gerdsri et al., (2012) suggests that most firms employ a strong quality control ability and are able to produce products according to customer's specification which is considered a basic technological capability.

Multinational corporations (MNCs) operating within emerging economies have traditionally been recognized as significant drivers of technology transfer practices. They disseminate high-level technological insights, expertise, and managerial proficiencies to local firms in the host countries. This is often achieved through involving these domestic firms within their supply chain networks (Battat, Frank and Shen, 1996; Mariotti, Nicolini and Piscitello, 2013). The advancement of skills in Thailand's automotive and parts sector has been heavily intertwined with foreign enterprises. This interconnectedness was evident through collaborative efforts like joint ventures, licensing agreements, and guidance from foreign technical experts (TAs). An inquiry conducted by. A study by the College of Management Mahidol University in 2006 as cited by Intarakumnerd et al. (2012) explored technological capabilities of groups of firms in the industry. The results showed that firms that produce parts that depend on proprietary knowledge from MNCs such as engines, electronics parts tend to have lower technological capability than firms that produce less sophisticated parts such as interiors and exteriors or suspension and brakes. This implies that the dependence on technological learning solely through foreign firms has some shortcomings compared with firms seeking to develop technological capabilities by themselves. As a result, fostering indigenous capabilities becomes imperative.

Quantitative Findings:

The survey asked firms to identify their skill gaps to support firm's ability to be able to participate in EV projects in the future. The results show that for both firm sizes, R&D capability and design ability are the main requirement. Which is aligned with the government policy requirement question that firms stated that they would like R&D support in terms of finance and human resources. In terms of EV technologies that firms interest in exploring are related to EV powertrain, lightweight materials, advanced materials for EV components, motors, battery technologies and intelligence transport system.

Qualitative Findings :

The findings obtained from the interview, particularly from industry representatives, indicate that technologies that firms could develop includes lightweight body, battery management system. However, the learning of these technologies through R&D could take a considerable amount of time. Thus, the firm representatives indicate the acquisition of foreign technologies through technology matching or joint venture as a means to shorten the time.

The findings also indicates that Thailand position itself as an EV production hub. The investment policy is aligned with the country's objective by providing incentives for EV firms to invest in Thailand. However, the policy objective of being only production hub constitutes an interesting argument from interviewees (academia, firms and government agencies). Because interviewees saw that this objective would not promote the development of local knowledge or technology. The production hub objective would reinvent the similar position that Thailand has been for over sixty years for conventional automotive and part industry. And the result of technology capabilities at the low and medium capabilities is obvious in this study either from literature review findings or quantitative findings. This implies a challenge for the Thai automotive and parts industry to sustain its competitive advantage, particularly in transitioning to the EV context, since the investment in the auto industry is also spread around other ASEAN countries such as Malaysia, Indonesia, or Vietnam. The concern was also enunciated by the interviewees both from academic institutions and firms that if firms are unable to upgrade the firm’s technological capability and move to the R&D stage, this could lead to losing the country’s competitive advantage to neighbouring countries.

Triangulation of findings:

1) The quantitative results indicate that firms are interested in exploring EV powertrain, lightweight materials, advanced materials for EV components, motors, battery technologies, and intelligent transport systems. This finding is consistent with the qualitative data, where industry representatives mention technologies such as lightweight body and battery management systems as potential areas for development.

2) The qualitative findings reveal that firms acknowledge that learning and developing certain EV technologies through R&D could take a considerable amount of time. To overcome this challenge, they express interest in acquiring foreign technologies through technology matching or joint ventures. This qualitative insight supports the quantitative findings regarding the interest in exploring advanced materials and battery technologies, which may require expertise beyond the firms' current capabilities.

3) Technology Capabilities: The findings from the literature review, quantitative data, and qualitative insights all point to the importance of enhancing technology capabilities in the EV sector. The triangulation of these findings strengthens the argument that investing in R&D, developing local knowledge, and fostering technology transfer are critical for the long-term growth and competitiveness of the EV industry in Thailand.

Implications:

The implications drawn from the quantitative and qualitative findings, as well as the triangulation of data, suggest several key actions that could be taken to support the development of the electric vehicle (EV) industry in Thailand:

R&D Support: The survey results indicate that R&D capability and design ability are the main skill gaps identified by firms. To address this, the government should focus on providing R&D support in terms of finance and human resources. Investing in research and development will enable firms to develop advanced technologies such as EV powertrain, lightweight materials, advanced materials for EV components, motors, battery technologies, and intelligent transport systems.

Technology Transfer: Since developing certain EV technologies through R&D could take a significant amount of time, firms are interested in acquiring foreign technologies through technology matching or joint ventures. The government can facilitate technology transfer by encouraging collaborations between local and foreign companies, promoting knowledge exchange, and offering incentives for technology partnerships. In addition, As a way forward, it is noteworthy for public policymakers to consider how to promote the development of the EV industry while parallelly developing domestic capabilities more effectively than the conventional auto industry. Thailand had surpassed a competition on cheap labour due to high-skill workers and competitive investment packages that could attract foreign direct investment.

However, to remain competitive, particularly in transitioning to the EV industry that requires new skills and knowledge. There is a need for firms that are interested in the new industry to improve their technological learning to acquire new knowledge. This study clearly suggests that supporting a firm's ability to learn requires linking with external sources of knowledge, particularly triple helix actors.

Skilled Workforce: To support the development of the EV industry, there should be a focus on building a skilled workforce with expertise in EV-related technologies and manufacturing processes. This could be achieved through vocational training, educational programs, and initiatives to attract talent into the sector.

Overall, the triangulated implications emphasize the need for a holistic and forward-looking approach to support the EV industry in Thailand. By fostering a collaborative and innovation-driven ecosystem, investing in local R&D capabilities, and promoting a skilled workforce, Thailand can position itself as a leading player in the global EV market and unlock long-term economic and environmental benefits.

7.1.3 Technological learning of firms in the automotive industry (Objective 3-5)

Technological learning is an important process and a basis of technological and innovation capability development (Edquist, 1997; Linton & Walsh, 2013). The technological learning of firms occurs when firms acquire, absorb and adopt such knowledge (Phelps, Heidl, & Wadhwa, 2012). The learning process in this study includes various sources of knowledge that can occur internally or externally (Bell & Figueiredo, 2012; Malerba, 1992). This section presents the key findings of firm’s main technological learning processes, factors affecting firm’s absorptive capacity and firm’s knowledge network. Identifying a firm's technological learning processes and exploring how firms learn is important for the government to support the firm's technological learning of the automotive and parts industry for the transition to EV.

7.1.3.1 Technological learning processes of SMEs in automotive industry

Literature review Findings :

The literature review in Chapter 3 reveals that absorptive capacity is the central learning ability necessary for achieving technological capability development. Absorptive capacity refers to a firm's ability to acquire external knowledge and effectively internalize it for its own use. However, prior internal knowledge also plays a critical role as a foundation before acquiring new external knowledge. To enhance their existing knowledge, firms need to establish networks and engage in collaborations, either through inter-firm relationships or partnerships with research institutions and universities. Previous studies suggest that collaboration with research institutions or universities positively impacts a firm's innovation performance.

In the global automotive industry, the primary modes of learning are through inter-firm relationships and customer-supplier relationships. This pattern is also observed in the case of the Thai automotive industry, particularly between car producers and their first-tier suppliers. Local firms in the Thai context largely function as contractors or subcontractors for car producers. The core knowledge of the industry is concentrated among car producers and their first-tier suppliers, most of which are subsidiaries. On the other hand, second and third-tier suppliers consist mainly of local companies that serve as subcontractors to the first-tier suppliers. Knowledge transfer between the first and lower tiers occurs through technical support training or codified knowledge dissemination, such as manuals. It is worth noting that internal efforts within firms are also fundamental to learning in the Thai automotive industry, as emphasized by Techakanont and Terdudomtham (2004).

The study also highlights a notable issue: second and third-tier firms tend to possess lower absorptive capacity, which hinders effective knowledge transfer. To achieve technological capabilities, firms must identify their capability gaps and then seek external sources of knowledge to complement their internal knowledge. Comparing the relationships between firms and research institutions/universities, it is evident that universities primarily provide basic education rather than actively collaborating in research and development (R&D). However, cooperation with research institutions proves to be more result-oriented for local SMEs, and in some cases, it has been shown to increase a firm's absorptive capacity.

Quantitative Findings :

The key findings from the survey show that both firm sizes acquire knowledge from internal and external sources. The first source of knowledge for both firm sizes is through its own in-house effort. But the second source of knowledge that is significantly different between SMEs and large firms is that large firms learn through their parent company while SMEs hire human capital to acquire knowledge. And academia and research institution which deemed as new research-based knowledge are third priority of both.

In terms of firm’s absorptive capacity which is a crucial part of learning process which indicates the ability to learn new knowledge. The results show that there are statistically significant differences between SMEs and large firms which SMEs have lower absorptive capacity. Large firms identified themselves as having strong absorptive capacity in all constructs except for application of knowledge. While SMEs identify themselves as having average absorptive capacity in all constructs while having strong acquisition capability.

This results imply that SMEs might face more challenge in adjusting to the new regime than large firms.

Qualitative Findings :

The qualitative interviews shed light on the learning strategies employed by large firms and SMEs in the context of the global automotive industry. Large firms, particularly those serving as first-tier suppliers, emphasize learning through hiring foreign technical assistance or consultants and establishing joint ventures. Collaboration with universities primarily revolves around workforce development programs for these large firms. In contrast, SMEs adopt a diverse approach to learning, relying on multiple channels such as inter-firm relationships and triple helix relationships (involving collaboration between academia, industry, and government).

Triangulation of findings:

The triangulation of literature review, quantitative, and qualitative findings reveals several consistent patterns and insights:

1) Absorptive Capacity and Firm Size: The literature review highlights the importance of absorptive capacity as a core learning ability for achieving technological capability development. This aligns with the quantitative findings, where large firms perceive themselves as having stronger absorptive capacity compared to SMEs. Triangulating these results suggests that larger firms tend to have better resources and capabilities to acquire, assimilate, and apply external knowledge effectively, giving them an advantage in technological learning than SMEs.

2) Impact of Collaboration with Research Institutions/Universities: The literature review highlights the positive impact of collaboration with research institutions or universities on firm's innovation performance. The survey results corroborate this by showing academia and research institutions as the third

priority for knowledge acquisition by both firm sizes. The qualitative results also show the positive impact particularly for SMEs engaging in triple helix network.

This triangulation suggests that fostering stronger ties between industry and academia can contribute to enhancing technological learning and innovation in the automotive sector.

Implications:

1. Policymakers should focus on initiatives aimed at enhancing absorptive capacity for SMEs, as they perceive themselves to have lower absorptive capacity compared to large firms. This can involve providing support for training programs, fostering collaborations with research institutions, and promoting knowledge-sharing platforms to facilitate knowledge acquisition and utilization.

2. Policymakers should tailor support mechanisms to help SMEs navigate diverse learning strategies effectively. Providing access to resources, knowledge-sharing platforms, and training opportunities can empower SMEs to adapt and thrive in the changing technological landscape.

3. Continuous Learning and Adaptation: The triangulated results highlight the dynamic nature of technological learning in the automotive industry. Firms should prioritize continuous learning, adaptation, and knowledge-seeking behaviors to remain competitive in a rapidly evolving technological landscape. Encouraging a culture of innovation and openness to new ideas can help firms stay at the forefront of technological advancements.

7.1.3.2 Factors contributing to technological learning of SMEs in the Thai

As previously mentioned, a firm can learn from either internal or external sources to the firm. However, to overcome the limited resources of a firm, the firm needs to develop a network with external organizations to access new knowledge. Firms that learn from external networks are more likely to be resilient and innovative than poorly networked firms (Brink & Madsen, 2016; Jeffrey H Dyer & Nobeoka, 2000; W. W. Powell, Koput, & Smith-Doerr, 1996) Moreover, the absorptive capacity indicates the effectiveness of how a firm can absorb and apply external knowledge to its products or processes ipso facto leading to a firm's competitive advantage. Thus, this study employed absorptive capacity as a measurement to identify a firm's learning ability (L. Kim, 1997). Absorptive capacity is considered a core factor of a firm’s technological learning processes. Zahra & George (2002) define absorptive capacity as a "dynamic organizational capability" that allows firms to create or sustain a firm's competitive advantage. (Zahra & George (2002). The dynamic capability refers collectively to the ability to recognize, assimilate, transform and apply external new knowledge. It is of important in allowing firms to realize and exploit new knowledge and keep pace with technological change. The dynamic capability implies a managerial operation, which could be adjusted and address the firm's development path.

Literature Review Findings:

The literature review highlights several key factors that contribute to technological learning among SMEs in the Thai automotive industry:

1) Government Policy: Government policies, such as local content requirements (LCRs), have historically influenced firms' technological

learning by promoting the establishment of local suppliers and encouraging production capability development. Past government policy interventions have had a notable impact on firms' technological learning.

2) Inter-Firm Relationships: In the context of the automotive industry, knowledge transfer typically occurs between tier groups, starting from car producers to first-tier suppliers and then cascading down to lower-tier suppliers. SMEs mostly operate in the second or third tiers, leading to limited opportunities to learn directly from foreign companies (car producers) that possess core technology knowledge. Instead, SMEs rely on bilateral inter-firm relationships with first-tier firms, engaging in activities like training, seminars, or technical visits. While these interactions can affect SMEs' capabilities, they may primarily result in basic or intermediate levels of learning.

3) Internal Effort: SMEs also leverage their own internal efforts, such as acquiring new machinery, providing training, and hiring experienced employees. These internal efforts are essential as a prerequisite for building prior knowledge before seeking external knowledge.

4) Ownership Structure: The ownership structure of firms can influence their access to technical support. Foreign-owned or joint-venture firms may have better opportunities to receive intensive technical assistance from foreign parent companies or partners. Conversely, pure Thai-firms or local firms may face the pressure to adapt and perform required tasks independently.

5) Triple Helix Relationship: Government agencies, research institutions, and universities play a significant role in enhancing firms' technological capabilities, primarily through education and training.

Research institutions serve as valuable sources of knowledge for R&D, particularly for SMEs.

6) Antecedent to absorptive capacity: Generally, antecedents of absorptive capacity include prior knowledge and experience. The experience includes the firm's experience with external knowledge sources such as inter-firm relationships and R&D cooperation with other institutions (Fosfuri and Tribo, 2008). Several studies explored how a firm's openness to external networks leads to a firm's innovative performance (Laursen and Salter, 2006; Fosfuri and Tribo, 2008; Rangus et al., 2017)A previous study (Laursen & Salter, 2006) focuses on a firm's relationship between search strategies for external knowledge and innovation performance. However, absorptive capacity plays a mediating role between knowledge search and innovation performance. Thus, this study focuses on a firm's external searching channels incorporating the concept of the breadth and depth of search strategies and their effect on a firm's absorptive capacity. The approach focuses on the search channels such as customers, suppliers, competitors, industrial associations, universities, etc. This study focuses on a number of partners or the "breadth" and the degree of the firm's interaction with these search channels or the "depth". Further, this study extends the previous study and develops the depth concept by specifically categorizing it into inter-firm depth which refers to firms that link deeply with other firms The depth also extends to cover triple helix linkage, which is represented by a number of projects or activities firms have with triple helix network.

Quantitative Findings:

The quantitative results shed light on the sources of knowledge that firms consider important when developing innovation: 1) In-house capability development is deemed the most important source of knowledge across all firms. 2) For SMEs, the second most important source of knowledge is hiring employees. 3) The third source of innovation is from university/research institutions, though SMEs generally engage less with these institutions compared to other external organizations.

The study also identified linkages with external organizations:

- Inter-firm interactions are the most frequent within sample firms, indicating their significance for technological learning.
- University/research institutions have the least engagement, but SMEs tend to collaborate with these organizations for R&D activities.

For future development of EV technologies, vital partners are identified as customers and suppliers respectively for both firm sizes.

The research further examined factors influencing firms' learning processes, focusing on absorptive capacity. The main findings found that establishing deep relationships, particularly with academia/research institutions and government entities, positively affects firms in developing their absorptive capacity. These deep relationships foster greater communication and knowledge exchange, facilitating the acquisition and translation of information from external sources.

Qualitative Findings:

The qualitative insights from interviews provided additional valuable perspectives:

1) Clear Policy Direction for EV: Firms acknowledged the importance of a shared country vision or target for EV, which influences their investment plans and stimulates efforts to adapt to the country's EV requirements. This

applies to SMEs as well, as they prepare and adjust to the evolving EV landscape.

2) Foreign Technical Assistance/Consultants: Sample firms highlighted the significance of foreign technical assistance/consultants in their technological learning processes. Such external expertise plays a crucial role in supporting firms' capabilities.

3) Customer's Requirement and Direction: Firms emphasized the importance of customer requirements and directions in motivating them to acquire new knowledge related to EV technologies.

4) Networking with University/Research Institutions and Government: Representative SMEs indicated that networking with university/research institutions and government entities can support firms during their transition, providing valuable support in the learning and adoption of new technologies.

Triangulation of findings:

The triangulation of the literature review, quantitative findings, and qualitative insights provides a comprehensive understanding of the factors influencing technological learning among SMEs in the Thai automotive industry and their implications for the development of EV technologies:

1) Government Policy Impact: The literature review highlights the historical influence of government policies, such as local content requirements (LCRs), on firms' technological learning. This finding aligns with the qualitative insight that government policy could play a crucial role in shaping firms' technological learning strategies and their response to technological transitions.

2) Triple Helix Relationship: The literature review underscores the role of government agencies, research institutions, and universities in enhancing

firms' technological capabilities through education and training. The qualitative finding that networking with these external partners can support firms during their transition to EV technologies aligns with the potential benefits of engaging with research institutions and academia for R&D activities.

3) Customer impact on firm’s technological learning: The qualitative findings emphasize the significance of customer requirements and directions in motivating firms to acquire new knowledge related to EV technologies. The qualitative findings aligned with the quantitative findings relating to customer as a potential partner that SMEs and large firms would collaborate with in developing EV technologies.

4) Foreign Consultant/Foreign knowledge acquisition: the importance of foreign technical assistance/consultants, as highlighted by sample firms, underscores the role of external expertise in supporting firms' technological learning. Tapping global knowledge could provide a shortcut for firms.

Implications:

1) Government Policy Support: Given the historical influence of government policies on firms' technological learning, policymakers should continue to play an active role in supporting the development of the EV industry. Policies that encourage provide incentives for R&D activities can further stimulate firms' technological learning and innovation efforts.

2) Strengthening Triple Helix Relationships: To enhance firms' technological capabilities, policymakers should foster strong collaborations between government agencies, research institutions, universities, and private firms. This can be achieved through joint research projects, knowledge

exchange programs, and targeted training initiatives that focus on EV technologies.

3) Leveraging Foreign Technical Assistance: The recognition of foreign technical assistance/consultants as valuable contributors to firms' technological learning suggests the potential benefits of international collaboration. Government could support firms in explore partnerships with foreign experts, research institutions, and companies to access global knowledge, expertise, and best practices in the EV industry.

4) Tailored Support for SMEs: As SMEs tend to engage less with university/research institutions, policymakers should design targeted programs to facilitate their collaboration with these institutions. Tailored support, such as funding opportunities, mentorship programs, and technology matchmaking, can help SMEs overcome barriers and leverage external knowledge resources effectively.

According to the multiple regression analysis in this study, "the depth of relationship with triple helix actors," namely university/research institution and government agencies, was found to be the critical factor in a firm's absorptive capacity. The main findings suggested that linkage intensively with actors from universities/research institutions and government tend to positively affect the firm's overall absorptive capacity and most of the constructs, namely acquisition, transformation, and application.

7.1.3.3 The development of knowledge networks of SMEs engaged in technological learning

A knowledge network plays a crucial role in developing technological capabilities by facilitating the exchange of information, expertise, and insights among various stakeholders, such as researchers, engineers, policymakers, and industry professionals. This network involves both formal and informal channels for sharing knowledge, collaborating on research, and disseminating technological advancements. This study explores the current and potential knowledge networks of automotive and parts companies for the adjustment of incumbent firms to sustainability transition.

Literature review findings:

The primary findings of the literature review highlight that the main knowledge network for SMEs in the Thai automotive industry is the inter-firm network, which is predominantly based on customer-supplier relationships. SMEs, mostly in the second and third tiers, receive technological training from first or second-tier firms. However, the technological capability of auto parts suppliers is diverse according to tier groups which second-tier and third-tier firms mostly concentrate on a basic and intermediate levels. Government agencies and university/research institution also play supporting roles in training of human resources.

Quantitative findings:

The main findings of quantitative results also aligned with qualitative result that inter-firm network is the primary knowledge network within Thai automotive industry. Following by networking with government agency and university/research institution.

Within inter-firm linkage which can be categorized into vertical and horizontal linkage. Vertical linkage refers to a business relationship or a contractual relationship, while horizontal linkages refer to relationship focusing on knowledge development. The main findings indicate that sample firms (both sizes) mostly have a vertical linkage or strictly business relationship.

The linkages with university and government institution are similar in terms of educational and training purposes. While for SMEs would resort to research institution when it comes to research activities.

The study analyzes the existence of a triple helix network involving collaboration among university-industry-government. This collaboration is expected to foster competitive knowledge creation and utilization. However, the quantitative findings reveal that SMEs face statistically significant limitations in accessing this network compared to larger firms. It suggests that SMEs have fewer opportunities to engage with university/research institutions and government agencies, potentially hindering their access to valuable knowledge resources.

In terms of potential network/partners, SMEs primarily consider the inter-firm network as their primary partners, including customers, suppliers, and competitors. This aligns with the qualitative findings, which indicate that SMEs mainly acquire technological knowledge through collaborations with suppliers based on customer specifications. Nevertheless, government agencies and research institutions are also attracting attention from SMEs as forth potential partners.

Qualitative Findings:

The qualitative interviews support the previous findings, indicating that the inter-firm network remains the main source of knowledge sharing. Larger firms, with better resources and opportunities, opt for foreign partners, while SMEs gain technological knowledge through working with suppliers based on customer specifications.

Furthermore, government agencies, research institutions, and universities attempt to contribute to the knowledge network. Government funding agencies offer R&D funding programs to support productivity improvements for SMEs in the conventional automotive industry, with some efforts directed toward EV development. However, it found that SMEs still mostly engage in productivity improvement relating to the conventional automotive industry rather than R&D program for EV development.

Additionally, some government agencies act as intermediaries, facilitating networking business trips abroad with automotive industrial associations to acquire knowledge from foreign institutions or companies.

Triangulation of findings:

Triangulating the findings from the literature review, quantitative results, and qualitative findings, we can synthesise the key insights regarding the knowledge network within the Thai automotive industry and its implications for SMEs:

1) Inter-Firm Network as Primary Knowledge Network: The literature review, quantitative findings, and qualitative interviews consistently emphasise that the inter-firm network, particularly based on customer-supplier relationships, is the primary knowledge-sharing mechanism for SMEs in the Thai automotive industry. While the inter-firm network is a valuable source of knowledge for SMEs, it does have its limitations. The capability development induced by this network is often constrained to a certain level. This means that while SMEs can gain valuable insights and skills from their interactions with higher-tier firms, they may not be exposed to cutting-edge technologies or advanced practices that are reserved for the top-tier players.

2) Triple Helix Network Challenges for SMEs: The study analyses the existence of a triple helix network involving collaboration among university-industry-government. However, the quantitative results indicate that SMEs face significant limitations in accessing this network compared to larger firms. This may hinder their opportunities to engage with university/research institutions and government agencies, potentially limiting their access to valuable knowledge resources.

Implications:

Based on the triangulated findings, several implications emerge regarding the knowledge network within the Thai automotive industry and its implications for SMEs:

1) Diversifying Knowledge Sources: Recognizing the limitations of the inter-firm network in inducing high-level capabilities, SMEs should explore diverse knowledge sources. Engaging with government agencies, research institutions, and universities can offer access to cutting-edge research, advanced technologies, and specialized expertise. Collaborating with these entities can help SMEs advance their innovation capabilities, increase their product offerings, and respond more effectively to market changes.
2) Addressing Triple Helix Network Challenges: Policymakers and industry stakeholders should address the challenges SMEs face in accessing the triple helix network, which involves collaboration among university-industry-government. Creating supportive frameworks, such as funding programs and knowledge-sharing platforms, can facilitate SMEs' involvement in research and development initiatives.

In conclusion, the implications derived from the triangulated findings suggest that while the inter-firm network remains vital, SMEs should explore additional knowledge sources to overcome capability limitations. Embracing a triple helix network and strengthening collaborative partnerships can enhance SMEs' innovation.

7.1.4 Role of governance and policy interventions in supporting technological learning and technological capability development (Objective 6)

Governance and policy interventions play a vital role in supporting technological learning and technological capability development within a country. Effective governance and well-designed policies create an enabling environment that encourages innovation, research, and the acquisition of knowledge and skills. This study explored existing and gaps of policy interventions at each socio-technical level based on MLP frameworks.

Literature review findings:

According to the research context of the Thai automotive industry, it is obvious that government policy intervention had impacted the development of technological capability of local firms. For example the local content requirements (LCR) which require the use of local components which resulted in the development of auto parts supply chain. However, this policy was ceased due to the accession to World Trade Organization (WTO).

Upon transition to the EV industry, Thailand had been taking several measures to attract electric vehicle (EV) companies to locate their operations in the country. The country offers various incentives and benefits to attract EV companies. These incentives include tax breaks, investment privileges, import duty exemptions on EV-related machinery and equipment.

In terms of policy that support knowledge creation, the focus is on developing human resources. This includes providing specialized training and education programs to equip the local workforce with the necessary skills for EV manufacturing and related industries.

Overall, policy development indicates the efforts of the Thai government to create a new EV industry in Thailand. The central policy tends to focus on subsidies, particularly investment incentives. However, The policy intervention that would strategically support knowledge development of firms to join EV industry is still scarce.

Quantitative Findings

The main findings relating to the requirement of firms suggested that firms need support on human resource development as their priority followed by R&D funding support. For SMEs in particular, the provision of researchers to work at firm's workplace is their priority.

Qualitative Findings:

1) At the socio-technical landscape level: A lack of overarching policy at the national level to create a landscape push to the regime level for the transition to Electric Vehicles, particularly BEV. The lack of a favourable wider policy framework or the long-term policy signals of promoting electric mobility resulted in uncertainty and the lack of solid commitment to invest in mew technologies i.e., the investment to produce EVs from car manufacturers and suppliers. Firms may hesitate to move into new territory, because they are skeptical about future possibilities. The government long-term policy and visible targets can support the direction of technological development for technology producers (Fagerberg, 2018; Trencher et al., 2021). This is augmented by the qualitative analysis that firms shared their major concern on the current circumstance of EV in Thailand, which is the lack of clear policy direction or plan supporting programs for the development of EVs.

This issue is aligned with previous study of Nilsson & Nykvist (2016) that a strong policy signal at the landscape level is required for the transition to EV predominantly specific technology roadmaps underpinning chosen technologies, integrated policy frameworks and the development of EV infrastructure.

2) At the socio-technical regime level: The government's policy intervention concerning the development of knowledge networks and technological learning can be classified into two key categories: investment policy and research development policy.

(1) The investigation exposes the insufficiencies within the investment policy aimed at attracting the electric vehicle (EV) industry to establish itself in Thailand. Specifically, this policy lacks provisions for fostering high-value activities that promote knowledge acquisition for local firms. Moreover, it fails to implement an effective mechanism for transferring technology to local suppliers, despite being mentioned in the policy guidelines. The focus on capital investment without balancing with the development of indigenous technological capabilities has been a weakness of the Thai automotive and parts industry.

Consequently, the absence of a well-defined mechanism poses significant challenges in establishing fruitful connections among network members, particularly between local suppliers, research institutions and EV related manufacturing firms.

(2) The Research Development Policy can be further classified into two distinct categories: 1. Productivity research programs and 2. EV-related technologies research programs. The insights acquired from the interviews reveal that the majority of SMEs primarily concentrate on enhancing productivity within their production lines through collaborative efforts with universities. However, when it comes to engaging in research and development activities for new EV

technologies, SMEs' involvement is relatively scarce due to the considerable cost associated with such endeavors.

3) At the niche level, government interventions to support the development of niche innovations are not yet on firm ground. There is an effort to promote the collaboration between industry, university, and academia as appears in the industry strategic plan of the Office of SMEs Promotion. There are dialogue among government agencies and university/research institution relating to establishment of an EV open platform of non-passenger cars. This platform could be a basis of technological learning for firms in developing EV parts. Moreover, from the interview results, government agencies would like to initiate the open innovation platform. However, this is still only a dialogue between stakeholders and still requires a concrete implementation. Thus, at the socio-technical niche level, obviously, there is very limited governance and policy intervention that could support the firm's technological learning on EV.

Therefore, with regards to government interventions aimed at fostering the establishment of networks and promoting knowledge exchange and technological advancement focusing on EV technology capability development remains inadequate.

In addition, The lack of actual execution on EV production after submitting the investment incentives application to BOI also suggested the lack of market incentives. The demand side policy to stimulate a mass market demand is one of the most significant concerns from both industry and experts and evidently the main barrier identified in this study. This is in line with the study of Kemp, Schot, & Hoogma, (1998) that firms would be disinclined to produce products that do not have an articulated demand. The proposed demand side policy relates to purchasing incentives for the user, which could stimulate EV adoption such as initial purchasing support schemes, tax exemption, etc. The reduced gap on cost differentiation between ICE and EV would create a broader demand and also influence and ensure the actors in the EV industry invest firmly in the industry. This is corroborated with the study by Nilsson & Nykvist, (2016) to achieve a breakthrough transition of BEV, which required a broad landscape development to influence the investment capacity of firms, including lower technology cost. The intervention of government policy on price incentives should be adaptable depending on the costs of EV and the learning curves rate of car users.

Triangulation of findings:

Policy Interventions for Knowledge Networks and Technological Learning: The literature review and qualitative findings seem to highlight a potential misalignment between the investment incentives offered by the Thai government and the mechanisms for knowledge transfer. While the literature review indicates that Thailand offers investment incentives such as tax breaks, investment privileges, and import duty exemptions to attract companies, particularly in the EV industry, the qualitative findings point out that there is a lack of a well-defined mechanism for transferring knowledge and technology to local suppliers and fostering knowledge acquisition for local firms. This mismatch can hinder the development of technological capabilities in the EV sector despite the presence of investment incentives. Additionally, the limited involvement of SMEs in research and development activities for new EV technologies due to high costs is a crucial concern.

Implications:

1) Focus on Knowledge Transfer Mechanisms: The lack of a well-defined mechanism for transferring technology and knowledge to local suppliers and firms is a significant concern. Policymakers should prioritise the development of effective knowledge transfer

mechanisms that facilitate collaboration between industry players, research institutions, and government agencies. This could involve setting up open innovation platforms or research centers dedicated to EV technologies.

2) Support for SMEs in R&D: SMEs play a crucial role in the Thai automotive industry, and their involvement in research and development activities for new EV technologies is essential for sector growth. Policymakers should address the cost barriers faced by SMEs in engaging in R&D efforts. This could include providing funding support, creating collaborative frameworks with universities/research institutions, and offering incentives for technology adoption and innovation.
3) Accelerate Implementation of Open Innovation Platform: The ongoing dialogue about establishing an EV open platform for non-passenger cars shows potential for technological learning opportunities. However, the concrete implementation of this platform is vital. Policymakers should expedite the implementation process and ensure active governance to create an effective platform for knowledge exchange and collaboration among stakeholders.
4) Long-Term Vision for EV Industry: While investment incentives are attractive for attracting initial capital, policymakers should develop a long-term vision for the EV industry's growth and sustainability. This vision should encompass policies focused on building local technological capabilities, nurturing a skilled workforce, and encouraging innovation to position Thailand as a leading player in the global EV market.

7.2 Policy Implications

The synthesis of findings through triangulation involving the literature review, quantitative analysis, and qualitative interviews illuminates a comprehensive picture of SMEs' responsiveness to the transition to electric vehicles (EVs) in the Thai automotive industry. This multifaceted approach has enabled a deeper understanding of the challenges and opportunities faced by SMEs, particularly concerning their technological capabilities, collaboration strategies, and the role of government policies in driving innovation and adaptation.

The quantitative findings provide quantitative evidence of SMEs' interest in EV-related technologies, while the alignment between the literature review and qualitative insights underscores the disruptive potential of EV adoption on these smaller firms. At the same time, the convergence of the literature review and quantitative data accentuates the technological limitations that could hinder SMEs from responding effectively to this transition. The qualitative findings show this sentiment by revealing a limited involvement of SMEs in EV research and development programs.

In light of these integrated findings, it becomes evident that government policy interventions play a critical role in supporting SMEs' capabilities and responsiveness to the EV transition.

According to the findings, there are three main options for firms in the conventional automotive and parts industry in the transition to EV context, namely 1) to deliver new products to EV market or 2) to deliver products to new market/sector diversification or 3) deliver products to the replacement/aftermarket. These three options require different government policy interventions. The third option does not require support regarding the firm's technological learning or to adjust any internal capabilities. However, it may require adjusting internal organization planning. Option one and option two would require support from government policies, particularly R&D supports and standards and testing. Option 1 will involve standards testing to enter new sectors. Government agencies could provide testing facilities and consultants to guide the industry into new sectors. In addition, based on the industry's requirement in this study, the government could provide support relating to the skill upgrading on robotics and automation, which is a prerequisite for firms either in the conventional automotive industry or diversified sector.

The policy to support technological learning of firms should include near-term strategies and long-term strategies. Because the national priority is to be the regional EV production hub, near-term efforts should focus on skills development to serve the EV industry entrance. In the long term, the development of domestic technological capabilities to an innovative level is critical. Otherwise, the country would only continue to be a production hub and could face serious competition from other countries and lose its competitiveness. The policy implications for the government to be considered are as follows.

1) R&D supporting policies: According to this study, the ability to perform research and development is identified as the significant skill gap and the priority requirement of firms for all firm sizes. Addressing the identified skill gaps in R&D capabilities and design proficiency is vital. The government's provision of financial resources and human capital support can empower SMEs to engage more effectively in the development of advanced EV technologies, such as powertrains, lightweight materials, and intelligent transport systems. At present, some programs provide researchers or technical assistants to assist firms in research and development or solve firm's problems at the firm's establishment, namely talent mobility program

and innovation and technology assistance program (ITAP). However, these existing programs could be designed to be more specific to serve the existing demand for incumbent firms that would be impacted by the entrance of EV. The R&D funding should be provided for the strategic EV technologies that the country has the potential to develop.

2) Triple Helix Collaboration: The connection of government agencies, research institutions, and private firms is a recurring theme in the findings. Policies that facilitate and incentivize collaboration among these stakeholders can strengthen technological learning, knowledge exchange, and innovation in the EV industry.

3) Global Collaboration: The insights into the significance of foreign technical assistance highlight the potential benefits of international collaboration. Encouraging SMEs to tap into global expertise can expedite their technological learning curve and provide novel solutions to the challenges posed by EV technology adoption. To shorten the time of research and development, the government could arrange a business matching, technical collaboration, or a provision of foreign experts between Thai firms and foreign entities that possess knowledge relating to EV. In addition, the tax reduction for the acquisition of intellectual property during the EV transition period could be considered.

4) Skills development: According to the findings, the primary requirement for government support is regarding human resources development. The emphasis should be on training programs, vocational education, and initiatives to attract talent to the EV sector. This approach would not only bridge the skills gap but also nurture a pool of experts capable of propelling the industry forward.

5) Based on the MLP framework, the transition may occur due to 1) exerting pressure from landscape level 2) destabilization of the regime, and 3) the emergence of niche innovations (Hoffmann, Weyer, & Longen, 2017).

Thus, in a broader context, transition to EV mobility requires several policy interventions at each socio-technical level to achieve the transition to EV and the transition of firms to join EV industry effectively. This corresponds with the concept of MLP by Geels (2011) that the transition is not a result of a "single cause or driver," but it is a wide range of processes and interactions among actors in each socio-technical level who interplay and reinforce each other. Various actors involved in the transition to EV include automobile manufacturers, supplier firms, car users, institutional actors such as government, policymakers, universities, research institutions, and infrastructure providers.

At the socio-technical landscape level, to constitute pressure to the regime and niche level, the government needs to impose a strong public policy signal by setting an achievable target to phase out ICE. In addition, overall market trends could also influence the shift in regime level; thus, policy required is relating to the demand side policy that would create a mass market demand for EV. Regarding the demand side policy, this study identified the lack of demand side policy as a major obstacle for firms in being willing to adapt themselves to the EV scenario because of the lack of mass market demand. Thus, the provision of demand side policy could constitute a mass market demand, increase users' learning curves, and increase both incumbent and new entrant firms' willingness to invest and firmly enter the EV market. The demand side policy to help stimulate a mass adoption of EV should include fiscal incentives, for example, a direct purchase incentive for car users to reduce the price differentiation between ICE and EV.

At the regime level, the government could initiate policies that support the reformation of the conventional automotive industry to create new regime and destabilize established practices. At present, the country provides investment incentives to attract the EV industry into the country. However, there is still a lack of many policy supports, particularly in the aspect of technological learning of EV technologies for firms interested in adapting their business to EV. Policies could relate to the support of technological learning of firms as mentioned earlier by focusing on R&D support in terms of researchers and R&D funding for collaboration between firms and triple helix actors, the acquisition of EV technologies, and skills development. In addition, based on the requirement of firms, to engage in global EV industry would require an external knowledge base. According to the findings, large firms found that local academia does not have enough advance knowledge on EV technologies. Thus, there is a necessity to draw on global knowledge from international sources. Another support could be to provide incentives in attracting research centers to locate in the country.

In addition, to destabilize the established practice such as user norms, the government could initiate policies that create the familiarization of EV to the society, such as public procurement of EV, demonstration of a test fleet of commercial vehicles such as e-bus, e-motorcycle, or e-boat. The provision of public charging infrastructure should also be in place, which could be provided by the government or support the funding for the private sector to invest.

The study revealed that over eighty percent of surveyed firms are willing to break out of the existing path dependency and explore new opportunities in EV markets. However, developing EV technologies could be a competitive challenge, particularly for SMEs who lack R&D capabilities and resources. Thus, at the niche level, the government could provide a protective space to nurture related EV technologies so that local actors have the potential to develop without external interference. Policy initiatives should include support for the establishment of a knowledge network comprising firms, government agencies, and academia. The government could provide funding to support the development of a knowledge network in developing niche innovation projects that, in the context of this study, are non-passenger cars and/or act as intermediaries in facilitating the relating of stakeholders. Firms should be the main actors in running the knowledge network with support from the government and academia. While academia, namely research institutions, and universities could help develop or assist firms in developing an EV open platform. The government could also bring in foreign experts to shorten the research and development time of the projects. The funding support should continue through the commercialization process, which includes prototyping, scale-up and standard testing.

In terms of actors, at the regime level or at the niche level these could potentially be the same actors, conducting different activities parallelly. At the regime level, actors continue their established practice to serve the current ICE market while at the niche level they participate in a network to learn and develop a new EV technology.

In developing new products, the government should also investigate into related regulations that are required to be updated. Technology trends that come with electric vehicles would include connected vehicles, autonomous vehicles, car-sharing services. Therefore, the regulations should be updated to support the upcoming technology trends and support the overall transition. The regulatory sandbox, which provides testing space for new technologies, should also be considered. The summary of policy implications according to MLP level is shown in Table 7.1

Table 7.1 Summarize of governance implications for each socio-technical level to support the transition to EV of suppliers in the automotive and parts industry

MLP Level	System changed needed for suppliers' transition	Key governance required	Actor	Influence
Landscape level	1.Strong public policy	1) Long-term vision that country is moving towards EV 2) Quantitative target such as zero-emission target 3) Integrated EV policies and roadmap from each ministry	National level/ Prime Minister and cabinet	Would set a strong direction and certainty for firms interested in joining EV industry and encourage more investment in EV and related infrastructure Would create a coherent policy framework and policy execution
	2.Wide user adoption of EV	4) Purchasing incentives including monetary or tax incentives	National level/ Prime Minister and cabinet	Increase user recognition of EV and create a mass market demand
Regime level	1.Reforming of automotive and parts industry	1) R&D support such as provision of researcher, an acquisition of knowledge from abroad i.e., purchasing of intellectual property, business matching, joint venture 2) Establishment of several testing centers for EV components	Ministry of higher education science research and innovation Ministry of Industry	Would support incumbent manufacturers and suppliers in the transition and mitigate a resistance of incumbent firms
		3) Investment incentives focused on more sophisticated activities and measurable technology	Ministry of Industry and Ministry of higher education	

MLP Level	System changed needed for suppliers' transition	Key governance required	Actor	Influence
		transfer mechanism to local suppliers 4) Incentives to attract world-class research centers to establish locally	science research and innovation	
	2.Alteration of user norms by creating social awareness and familiarization of EV	2) public procurement of EV	All Ministries	Programs on learning curve and recognition for EV potential user
		3) Test fleets in public transportation such as public bus/minibus in Bangkok area and other pilot provinces	Local government and private sector	Would create a pervasive user experience towards EV and lead to an increase of market demand
		4) Establishment of charging infrastructure	Local government and private sector	
Niche level	1.Provision of platform for niche management	1) Establishment of EV actors' network and R&D support for new technology platforms, EV related technologies Such as • Create EV open platform for non-passenger car • Incubator and testing for new technologies	National government, local government and private sector	Would create new business opportunities for both incumbent actors and newcomer
		2) Provide regulatory sandbox for testing new technologies beyond EV such	National government, local government	Would provide a place for experiment of niche products or

MLP Level	System changed needed for suppliers' transition	Key governance required	Actor	Influence
		as autonomous vehicle		new business model

Adapted from Nilsson & Nykvist (2016) by author

7.3 Limitation of the study

The main limitation in this study relates to the low response rate to the questionnaire survey (n=42), which might indicate as suggestive rather than conclusive nature of this study. The survey has sought to includes firms that would be impacted by the entrance of EV and sent out the survey via various media namely postal, email and web survey but many firms failed to respond. Due to the limited number of data, in the logistic regression model can only find the association between absorptive capacity and overall firms but cannot categorized by firm size. This has affected the analysis in comparing between SMEs and large firms, which cannot be conducted.

7.4 Recommendations for future research

As noted above, due to the limitation of low response rate, which affects the robustness of the data analysis, the conclusions based on the results of this study can only be suggestive and not conclusive. The future study could repeat with a larger sample size by employing alternate methods of questionnaire administration such as administer the survey by telephone to help clarify and guide firms through the questionnaire. However, the disadvantage of this method is it is time-consuming and may require extra personnel, which may be costly. The qualitative research method solely could also be adopted to gain a more in-depth analysis, particularly from the firm's perspective.

Second, this study focuses on the incumbent actors at the socio-technical regime level, specifically firms in the traditional automotive and parts industry in the transition to the EV industry. Future research should consider new actors who might be incumbents in other industries that are interested in joining the EV industry, such as firms in the electronics industry or the IT and software industry which conceivably could join the global value chain of the EV industry. Moreover, government interventions could support firms in other sectors to join the global EV value chain. This research explored roughly on decision of firm's diversification, further research could empirically explore the move from core business to other sectors, their diversification processes and contribution factors and policy implication on how firms can diversify to other sectors.

Third, the policy interventions framework at each socio-technical level developed in this thesis can be adopted to analyse government policy interventions in other automobile production hub countries in ASEAN such as Malaysia, Indonesia, or Vietnam. Preparing for the entrance of Electric Vehicles (EVs) is of importance for countries that serve as production hubs for the automotive industry, particularly middle-income countries like Thailand and other developing countries that might not possess the proprietary EV technology. Entrance of EV can offer both risks and opportunities. The shift to EVs may disrupt the traditional automotive industry, impacting existing supply chains as discussed in this study. The alterations in manufacturing processes, components sourcing, and distribution networks could potentially lead to substantial job losses and economic challenges for countries heavily reliant on the automotive sector. Countries that heavily rely on the traditional automobile sector might eventually experience a decline in economic output and face the critical task of retraining their workforce to adapt to the evolving landscape of automobile manufacturing. Furthermore, there is a need to transcend the notion of being solely an automotive production hub and instead evolve into a hub that generates high-value added activities. This can be achieved through strategic policies and initiatives that promote innovation, research, and development within the EV sector.

In conclusion, this study delves into the realm of government policy interventions aimed at assisting incumbent companies in adapting to the emerging paradigm. However, given that Thailand remains a significant production hub for internal combustion engine vehicles, the government has not yet formulated or imposed policies that would cause the radical shift of the EV scenario. As a direction for future research, exploring the private sector centered role in influencing the transition from the niche level by exploring the interplay among firms and how it could lead to electric mobility transition.

7.5 Conclusion

In conclusion, this study investigates into the complex landscape of the transition to electric mobility within the context of Thailand's automotive and parts industry. By adopting the vantage points of incumbent firms, particularly SMEs, and employing the Multi-Level Perspective (MLP) framework, this research offers an understanding of the challenges, opportunities, and government interventions that shape this critical change. The findings emphasize the crucial role of SMEs in this transformative journey, while highlighting the necessity of strategic policy actions to facilitate their technological learning and adaptation.

The empirical observations obtained from SMEs emphasize the impact of EV entry on their operations, with potential consequences varying from product discontinuation to adaptive strategies. During this industry shift, SMEs find themselves in a situation where challenges and possibilities coincide, urging them to investigate the unexplored aspects of the EV domain. To adapt to this changing landscape, SMEs are considering diversification, both within and beyond the automotive sector, emerges as a strategy to navigate the evolving territory and ensure business continuity.

Central to this process is the notion of technological learning, a critical predecessor to the development of technological capabilities. The study highlights that SMEs' technological capability largely derives from internal efforts enhanced by interactions with external entities. However, their average absorptive capacity implies that SMEs might encounter challenges in transitioning to EV due to their limited capacity to assimilate new external knowledge. Notably, strong interactions with the triple helix actors—industry, government, and academia—hold the potential to increase a firm's ability to learn and adapt.

The obstacles related to the existing socio-technical systems and the strong reliance on established relationships between users and suppliers highlight the intricate nature of the transition. Previous investments and established practices in the traditional automotive sector can slow down the changes needed. However, the real-world evidence shows that companies are taking an active approach by acknowledging the necessity for change and exploring opportunities in different sectors.

In response to these insights, the study emphasizes the essential role of government policy intervention. Making policy mechanisms that strengthen technological learning becomes crucial. The significance of R&D and manpower support echoes strongly, especially for SMEs tackling with resource constraints. Aligning with the triple helix framework, policies that nurture collaboration between industry, academia, and government can foster an environment conducive to learning and innovation.

Furthermore, recognizing the distinctive nature of the EV industry compared to the traditional automotive sector, this study underscores the need for tailored policy approaches. A shift from a "business as usual" mindset is advocated, with the call to develop indigenous innovative capabilities to meet the demands of the evolving landscape. Addressing barriers at multiple socio-technical levels, such as market norms and incumbent practices, can be achieved through strategic policy interventions.

While this study offers valuable insights within the context of Thailand's automotive industry, its implications extend beyond borders. Other countries with similar industrial landscapes may encounter similar challenges as they navigate the transition to electric mobility. The analytical framework of the MLP, coupled with government interventions across different socio-technical dimensions, provides a robust toolkit for analyzing and addressing similar transitions in other automobile production hubs.

In the wider context of promoting sustainability, this study emphasises the importance of governments taking proactive steps and fostering cooperation among various stakeholders to bring about significant changes. By using the knowledge gained from this research, policymakers, industries, and academia can work together to guide the shift towards electric mobility. This collaborative effort will promote innovation, boost economic growth, and ensure responsible environmental management.

REFERENCES

Argyris, C., & Schön, D. A. (1997). Organizational Learning: A Theory of Action Perspective. *Reis*, (77/78), 345. https://doi.org/10.2307/40183951

Bell, M., & Figueiredo, P. N. (2012, March). Innovation capability building and learning mechanisms in latecomer firms: Recent empirical contributions and implications for research. *Canadian Journal of Development Studies*. Routledge. https://doi.org/10.1080/02255189.2012.677168

Bell, M., & Pavitt, K. (1993). Technological Accumulation and Industrial Growth: Contrast between Developed and Developing Countries. *Technology, Globalisation and Economic Performance*, (May), 157–210.

Berggren, C., Magnusson, T., & Sushandoyo, D. (2015). Transition pathways revisited: Established firms as multi-level actors in the heavy vehicle industry. *Research Policy*, *44*(5), 1017–1028. Retrieved from http://dx.doi.org/10.1016/j.respol.2014.11.009

Berkeley, N., Bailey, D., Jones, A., & Jarvis, D. (2017). Assessing the transition towards Battery Electric Vehicles: A Multi-Level Perspective on drivers of, and barriers to, take up. *Transportation Research Part A: Policy and Practice*, *106*, 320–332. https://doi.org/10.1016/J.TRA.2017.10.004

Bierau, F., Perlo, P., Müller, B., Gomez, A., Coosemans, T., Meyer, G., … Gomez, A. A. (2016). Opportunities for European SMEs in Global Electric Vehicle Supply Chains in Europe and Beyond. *Lecture Notes in Mobility*, 223–235. https://doi.org/10.1007/978-3-319-20855-8_18

Bierly, P. E., & Chakrabarti, A. K. (1996). Technological learning, strategic flexibility, and new product development in the pharmaceutical industry.

IEEE Transactions on Engineering Management, *43*(4), 368–380. https://doi.org/10.1109/17.543979

Birky, A. K. (2008). *Socio-Technical Transition As A Co-Evolutionary Process: Innovation And The Role Of Niche Markets In The Transition To Motor Vehicles*. University of Maryland, College Park.

Braun, V., Clarke, V., Hayfield, N., & Terry, G. (2019). Thematic analysis. In *Handbook of Research Methods in Health Social Sciences* (pp. 843–860). Springer Singapore. https://doi.org/10.1007/978-981-10-5251-4_103

Brink, T. (2017). SME routes for innovation collaboration with larger enterprises. https://doi.org/10.1016/j.indmarman.2017.01.010

Brink, T., & Madsen, S. O. (2016). The triple helix frame for small- and medium-sized enterprises for innovation and development of offshore wind energy. *Triple Helix*, *3*(1), 4. https://doi.org/10.1186/s40604-016-0035-8

Camisón, C., & Forés, B. (2009). Knowledge absorptive capacity: New insights for its conceptualization and measurement ☆. *Journal of Business Research*, *63*, 707–715. https://doi.org/10.1016/j.jbusres.2009.04.022

Caniëls, M. C. J., & Romijn, H. A. (2008). Strategic niche management: Towards a policy tool for sustainable development. *Technology Analysis and Strategic Management*, *20*(2), 245–266. https://doi.org/10.1080/09537320701711264

Carrizo, A. (2009). Knowledge capability flows in buyer-supplier relationships Challenges for small domestic suppliers in international contexts. *Journal of Small Business and Enterprise Development*, *16*(1), 93–114. https://doi.org/10.1108/14626000910932908

Cecere, G., Corrocher, N., Gossart, C., & Ozman, M. (2014). Lock-in and path dependence: an evolutionary approach to eco-innovations. *Journal of*

Evolutionary Economics, *24*(5), 1037–1065. https://doi.org/10.1007/s00191-014-0381-5

Chesbrough, H. (2003). *Open Innovation The New Imperative for Creating and Profiting from Technology* . Boston, Massachusetts: Harvard Business School .

Christensen, A. (2011). Business Research , Development and Innovation in Denmark - policies and effects, (October).

Clifton, N., Keast, R., Pickernell, D., & Senior, M. (2010). *Network Structure, Knowledge Governance, and Firm Performance: Evidence from Innovation Networks and SMEs in the UK*. Retrieved from https://s3.amazonaws.com/academia.edu.documents/32114075/Network_Structure__Knowledge_Governance__and_Firm_Performance_Evidence_from_Innovation_Networks_and_SMEs_in_the_UK.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1539867304&Signature=sVpPeQ6lGo7nhq2fzm160z9Hsh8%3D&response-content-disposition=inline%3B filename%3DNetwork_Structure_Knowledge_Governance_a.pdf

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and Learning: The Two Faces of R&D. *The Economic Journal*, *99*(397), 569. https://doi.org/10.2307/2233763

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Source: Administrative Science Quarterly*, *35*(1), 128–152. Retrieved from http://www.jstor.org

Cope, J. (2003). Entrepreneurial Learning and Critical Reflection: Discontinuous Events as Triggers for “Higher-level” Learning. *Management Learning*, *34*(4), 429–450. https://doi.org/10.1177/1350507603039067

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and Conducting Mixed Methods Research*. Sage Publicatiions,INC.

Cunningham, P., & Ramlogan, R. (2012). The effects of innovation network policies. *Nesta Working Paper*, *12/04*(12). Retrieved from http://www.nesta.org.uk/publications/effects-innovation-network-policies

Dodgson, M. (1991). Technology Learning, Technology Strategy and Competitive Pressures. *British Journal of Management*, *2*(3), 133–149. https://doi.org/10.1111/J.1467-8551.1991.TB00022.X

Dyer, J. H., & Singh, H. (1998). The Relational View: Cooperative Strategy And Sources Of Interorganizational Competitive Advantage. *Academy of Management Review*, *23*(4), 660–679. https://doi.org/10.5465/AMR.1998.1255632

Dyer, Jeffrey H, & Nobeoka, K. (2000). *Creating and Managing a High-Performance Knowledge-Sharing Network: The Toyota Case*. *Source: Strategic Management Journal* (Vol. 21). Retrieved from https://about.jstor.org/terms

Edquist, C. (1997). *Systems of Innovation*. Routledge. https://doi.org/10.4324/9780203357620

El Bilali, H. (2019). The multi-level perspective in research on sustainability transitions in agriculture and food systems: A systematic review. *Agriculture (Switzerland)*, *9*(4). https://doi.org/10.3390/agriculture9040074

Ernst, D., & Kim, L. (2001). Global Production Networks, Knowledge Diffusion, And Local Capability Formation A Conceptual Framework. In *Nelson & Winter Conference*. Aalborg, Denmark.

Faems, D., Van Looy, B., & Debackere, K. (2005). Interorganizational collaboration and innovation: Toward a portfolio approach. *Journal of*

Product Innovation Management, *22*(3), 238–250. https://doi.org/10.1111/j.0737-6782.2005.00120.x

Ferreras-Méndez, J. L., Fernández-Mesa, A., & Alegre, J. (2016). The relationship between knowledge search strategies and absorptive capacity: A deeper look. *Technovation*, *54*, 48–61. https://doi.org/10.1016/j.technovation.2016.03.001

Ferreras-Méndez, J. L., Newell, S., Fernández-Mesa, A., & Alegre, J. (2015). Depth and breadth of external knowledge search and performance: The mediating role of absorptive capacity. *Industrial Marketing Management*. https://doi.org/10.1016/j.indmarman.2015.02.038

Fischer, M. M. (2006). *The Innovation Process and Networks Activities of Manufacturing Firms*. (Manfred M. Fischer, Ed.), *Innovation, Networks, and Knowledge Spillovers*. Berlin, Heidelberg: Springer. https://doi.org/10.1007/3-540-35981-8_6

Flatten, T. C., Engelen, A., Zahra, S. A., & Brettel, M. (2011). A measure of absorptive capacity: Scale development and validation. *European Management Journal*, *29*(2), 98–116. https://doi.org/10.1016/j.emj.2010.11.002

Forés, B., & Camisón, C. (2016). Does incremental and radical innovation performance depend on different types of knowledge accumulation capabilities and organizational size? *Journal of Business Research*, *69*(2), 831–848. https://doi.org/10.1016/J.JBUSRES.2015.07.006

Fosfuri, A., & Tribo, J. A. (2008). Exploring the antecedents of potential absorptive capacity and its impact on innovation performance. *Omega*, *36*(2), 173–188. Retrieved from https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=03050483&v=2.1&it=r&id=GALE%7CA178454069&sid=googleScholar&linkaccess=fulltext

Fosfuri, A., & Tribó, J. A. (2008). Exploring the antecedents of potential absorptive capacity and its impact on innovation performance. *Omega*, *36*(2), 173–187. https://doi.org/10.1016/J.OMEGA.2006.06.012

Geels, F.W. (2019). Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. *Current Opinion in Environmental Sustainability*, *39*, 187–201. https://doi.org/10.1016/j.cosust.2019.06.009

Geels, Frank W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, Frank W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geels, Frank W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002

Geels, Frank W. (2014). Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society*, *31*(5), 21–40. https://doi.org/10.1177/0263276414531627

Geels, Frank W. (2018). Disruption and low-carbon system transformation: Progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. *Energy Research & Social Science*, *37*, 224–231. https://doi.org/10.1016/J.ERSS.2017.10.010

Geels, Frank W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, *36*(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

Geels, Frank W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017, November 15). The Socio-Technical Dynamics of Low-Carbon Transitions. *Joule*. Cell Press. https://doi.org/10.1016/j.joule.2017.09.018

Geels, Frank W. (2004). From sectoral systems of innovation to socio-technical systems Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*, 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geels, I. F. W. (2005). The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860-1930). *Technology Analysis and Strategic Management*, *17*(4), 445–476. https://doi.org/10.1080/09537320500357319

Gerdsri, N., Teekasap, P., & Virasa, T. (2012). Technological capability gap assessment: A study of automotive industry in Thailand. *2012 IEEE 6th International Conference on Management of Innovation and Technology, ICMIT 2012*, 29–34. https://doi.org/10.1109/ICMIT.2012.6225774

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal*, *17*(S2), 109–122. https://doi.org/10.1002/SMJ.4250171110

Grin, J., Jan, R., & Schot, J. (2010). *Transitions to sustainable development: new directions in the study of long term transformative change*. New York: Routledge.

Guest, G., MacQueen, M. K., & Namey, E. E. (2014). Introduction to Applied Thematic Analysis. In *SAGE Research Methods* (pp. 3–20). Thousand

Oaks: SAGE Publications, Inc. Retrieved from http://antle.iat.sfu.ca/wp-content/uploads/Guest_2012_AppliedThematicAnlaysis_Ch1.pdf

Guo, B., & Guo, J.-J. (2011). Patterns of technological learning within the knowledge systems of industrial clusters in emerging economies: Evidence from China. *Technovation*, *31*, 87–104. https://doi.org/10.1016/j.technovation.2010.10.006

Hall K., J., & Martin J.C., M. (2005). Disruptive technologies, stakeholders and the innovation value-added chain:...: EBSCOhost. *R&D Management*, *35*(3). Retrieved from http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=1&sid=6a471dd3-d8fe-479f-9701-66ba7d890ae1%40pdc-v-sessmgr05

Hewitt-Dundas, N. (2006). Resource and capability constraints to innovation in small and large plants. *Small Business Economics*, *26*(3), 257–277. https://doi.org/10.1007/S11187-005-2140-3

Hill, C. W. L., & Rothaermel, F. T. (2003). The Performance of Incumbent Firms in the Face of Radical Technological Innovation. *The Academy of Management Review*, *28*(2), 257–274. Retrieved from https://www.jstor.org/stable/pdf/30040712.pdf?casa_token=2eWNPBNBKeIAAAAA:cahyztJaIvlTkQgKRTzbO70LaoWpPXjKzedCsvS-TX2tjPO-Bb0_1hbmlNXMYDqjuxcJJzArDMeFOP4o17NmkueAdrc6m03bOAqaVEFKavSO9vFLuHY

Hoffmann, S., Weyer, J., & Longen, J. (2017). Discontinuation of the automobility regime? An integrated approach to multi-level governance. *Transportation Research Part A: Policy and Practice*, *103*, 391–408. https://doi.org/10.1016/j.tra.2017.06.016

Hoogma, R., Kemp, R., Schot, J., & Truffer, B. (2005). Experimenting for

Sustainable Transport : The Approach of Strategic Niche Management. *Experimenting for Sustainable Transport: The Approach of Strategic Niche Management*, 1–212. https://doi.org/10.4324/9780203994061

Hörisch, J. (2015). The Role of Sustainable Entrepreneurship in Sustainability Transitions: A Conceptual Synthesis against the Background of the Multi-Level Perspective. *Administrative Sciences*, *5*(4), 286–300. https://doi.org/10.3390/admsci5040286

Intarakumnerd, P. (Ed.). (2011). *How to enhance innovation capability with internal and external sources*. Retrieved from https://www.eria.org/uploads/media/Research-Project-Report/RPR-2010-9.pdf

Intarakumnerd, P., & Techakanont, K. (2016). Intra-industry trade, product fragmentation and technological capability development in Thai automotive industry. *Asia Pacific Business Review*, *22*(1), 65–85. https://doi.org/10.1080/13602381.2014.990214

Jansen, J. J. P., Van, F. A. J., Bosch, D., & Volberda, H. W. (2005). Managing Potential and Realized Absorptive Capacity: How Do Organizational Antecedents Matter? *Source: The Academy of Management Journal*, *48*(6), 999–1015. Retrieved from https://about.jstor.org/terms

Kanger, L., Sovacool, B. K., & Noorkõiv, M. (2020). Six policy intervention points for sustainability transitions: A conceptual framework and a systematic literature review. *Research Policy*, *49*(7). https://doi.org/10.1016/J.RESPOL.2020.104072

Kemp, R. (1994). Technology and the transition to environmental sustainability:The Problem of technological regime shifts. *Futures*, *26*(10), 1023–1046. Retrieved from https://s3.amazonaws.com/academia.edu.documents/33040429/Kemp_-

_problem_of_technological_regime_shifts.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1556719157&Signature=A%252Fab5R06Xr4x4NWsBSy5bNGR23M%253D&response-content-disposition=inline%253B%2520f

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis and Strategic Management*, *10*(2), 175–198. https://doi.org/10.1080/09537329808524310

Kester, J., Noel, L., Zarazua de Rubens, G., & Sovacool, B. K. (2018). Policy mechanisms to accelerate electric vehicle adoption: A qualitative review from the Nordic region. *Renewable and Sustainable Energy Reviews*, *94*, 719–731. https://doi.org/10.1016/j.rser.2018.05.067

Kim, D. H. (1993). *The Link between Individual and Organizational Learning*. Retrieved from https://pdfs.semanticscholar.org/5919/9dd1bb06d51f2c0580fc85bfebd97d684dbb.pdf

Kim, L. (1997). *Imitation to Innovation The Dynamics of Korea's Technological Learning*. Boston,Massachusetts: Harvard Business School Press.

Kim, L., & Nelson, R. R. (2000). *Technology,Learning and Innovation : Experiences of Newly Industrializing Economies*. Cambridge University Press.

Kinn, M. C. (2016). *An Analysis Of The Sociotechnical Transition Process From The Existing Centralised Alternating Current Voltage Electrical System In The Uk To One Where Distributed Direct Current Voltage Is Used To Meet The Energy Needs Of The Built Environment*. Retrieved from http://usir.salford.ac.uk/id/eprint/40962/3/Moshe Kinn PhD thesis

10-12-2016.pdf

Klug, F. (2015). How electric car manufacturing transforms automotive supply chains. *Zalnet.De*, (July), 1–10. Retrieved from http://www.zalnet.de/electric car manufacturing.pdf

Kohpaiboon, A. (2007). Thai Automotive Industry : Multinational Enterprises and Global Integration Archanun Kohpaiboon. *Discussion Paper; Faculty of Economic Thammasat University*, (4). Retrieved from https://www.academia.edu/22220334/Thai_Automotive_Industry_Multinational_Enterprises_and_Global_Integration

Kongklaew, C., Phoungthong, K., Prabpayak, C., Chowdhury, M. S., Khan, I., Yuangyai, N., … Techato, K. (2021). Barriers to electric vehicle adoption in Thailand. *Sustainability (Switzerland)*, *13*(22). https://doi.org/10.3390/SU132212839

Kulkolkarn, K. (2019). *Impact of Transition to Electric Vehicles on Workers in Auto-Parts Manufacturing*.

Kwon, T. (2012). Strategic niche management of alternative fuel vehicles: A system dynamics model of the policy effect. *Technological Forecasting and Social Change*, *79*(9), 1672–1680. https://doi.org/10.1016/j.techfore.2012.05.015

Lall, S. (1992). Technological capabilities and industrialization. *World Development*, *20*(2), 165–186. https://doi.org/10.1016/0305-750X(92)90097-F

Lane, P. J., Koka, B. R., & Pathak, S. (2006). The Reification of Absorptive Capacity: A Critical Review and Rejuvenation of the Construct. *Source: The Academy of Management Review*, *31*(4), 833–863. Retrieved from https://www.jstor.org/stable/20159255

Laoonual, Y. (2015). *Assessment of Electric Vehicle Technology Development* *and Its Implication in Thailand*.

Laursen, K., & Salter, A. (2006). Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms. *Strategic Management Journal*, *27*(2), 131–150. https://doi.org/10.1002/smj.507

Lee, K., Qu, D., & Mao, Z. (2021). Global Value Chains, Industrial Policy, and Industrial Upgrading: Automotive Sectors in Malaysia, Thailand, and China in Comparison with Korea. *European Journal of Development Research*, *33*(2), 275–303. https://doi.org/10.1057/s41287-020-00354-0

Lee, K., Wong, C. Y., Intarakumnerd, P., & Limapornvanich, C. (2020). Is the Fourth Industrial Revolution a window of opportunity for upgrading or reinforcing the middle-income trap? Asian model of development in Southeast Asia. *Journal of Economic Policy Reform*, *23*(4), 408–425. https://doi.org/10.1080/17487870.2019.1565411

Lindström, M., & Heimer, T. (2017). *Electric Vehicles: Shifting Gear or Changing Direction?* Retrieved from https://trid.trb.org/view/1635377

Linton, J., & Walsh, S. (2013). The effect of technology on learning during the acquisition and development of competencies in technology-intensive small firms. *International Journal of Entrepreneurial Behavior & Research*, *19*(2), 165–186. https://doi.org/10.1108/13552551311310365

Liu, X., Sun, X., Zheng, H., & Huang, D. (2021). Do policy incentives drive electric vehicle adoption? Evidence from China. *Transportation Research Part A: Policy and Practice*, *150*, 49–62. https://doi.org/10.1016/J.TRA.2021.05.013

Malerba, F. (1992). Learning by Firms and Incremental Technical Change. *The Economic Journal*, *102*(413), 845–859. https://doi.org/10.2307/2234581

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, *41*(6), 955–967. https://doi.org/10.1016/j.respol.2012.02.013

Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy*, *37*(4), 596–615. https://doi.org/10.1016/J.RESPOL.2008.01.004

Mazur, C., Contestabile, M., Offer, G. J., & Brandon, N. P. (2015). Assessing and comparing German and UK transition policies for electric mobility. *Environmental Innovation and Societal Transitions*, *14*, 84–100. https://doi.org/10.1016/j.eist.2014.04.005

Moeini, E., & Zawdie, G. (1998). Import Substitution, Technological Learning and Innovation in Strategic Industries in Iran : A Survey of Evidence. *Science, Technology and Development*, *16*(1), 17–43.

Monjon, S., & Waelbroeck, P. (2003). Assessing spillovers from universities to firms: evidence from French firm-level data. *International Journal of Industrial Organization*, *21*(9), 1255–1270. https://doi.org/10.1016/S0167-7187(03)00082-1

Mowery, D., Oxley, J., & Silverman, B. (1996). Strategic Alliances and Interfirm Knowledge Transfer. *Strategic Management*, *17*(Winter,1996), 77–91.

Muscio, A. (2007). THE IMPACT OF ABSORPTIVE CAPACITY ON SMEs' COLLABORATION THE IMPACT OF ABSORPTIVE CAPACITY ON SMEs' COLLABORATION. *Economics of Innovation and New Technology*, *16*(8), 653–668. https://doi.org/10.1080/10438590600983994

Nakwa, K. (2013). *Innovation intermediaries and triple helix networks in developing countries with particular reference to the case of Thailand*. University of Strathclyde.

Nakwa, K., Zawdie, G., & Intarakumnerd, P. (2012). Role of intermediaries in accelerating the transformation of inter-firm networks into Triple Helix networks : A case study of SME-based industries in Thailand, *52*, 52–61. https://doi.org/10.1016/j.sbspro.2012.09.441

Nelson, Richard R., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Cambridge: The Belknap Press of Harvard University Press.

Nelson, R. R., & Winter, S. G. (1977). In search of useful theory of innovation. *Research Policy*, *6*(1), 36–76. https://doi.org/10.1016/0048-7333(77)90029-4

Nieto, M. J., & Santamaría, L. (2010). Technological collaboration: Bridging the innovation gap between small and large firms. *Journal of Small Business Management*, *48*(1), 44–69. https://doi.org/10.1111/j.1540-627X.2009.00286.x

Nilsson, M., Hillman, K., & Magnusson, T. (2012). How do we govern sustainable innovations? Mapping patterns of governance for biofuels and hybrid-electric vehicle technologies. *Environmental Innovation and Societal Transitions*, *3*, 50–66. https://doi.org/10.1016/J.EIST.2012.04.002

Nilsson, M., & Nykvist, B. (2016). Governing the electric vehicle transition – Near term interventions to support a green energy economy. *Applied Energy*, *179*, 1360–1371. https://doi.org/10.1016/j.apenergy.2016.03.056

Oyelaran-Oyeyinka, B., & Lal, K. (2006). Learning new technologies by small and medium enterprises in developing countries. *Technovation*, *26*(2), 220–231. https://doi.org/10.1016/j.technovation.2004.07.015

Panson, T., & Choojarukul, K. (2019). Behavioral Acceptance of Electric Vehicles in Bangkok. *Journal of Transportation and Logistics*, *1*(12), 68–90.

Peteraf, M. A., & Barney, J. B. (2003). Unraveling the resource-based tangle. *Managerial and Decision Economics*, *24*(4), 309–323. https://doi.org/10.1002/MDE.1126

Phelps, C., Heidl, R., & Wadhwa, A. (2012). *Knowledge, Networks, and Knowledge Networks: A Review and Research Agenda*. *Journal of Management* (Vol. 38). https://doi.org/10.1177/0149206311432640

Phelps, C., Heidl, R., Wadhwa, A., & Paris, H. (2012). Knowledge, Networks, and Knowledge Networks : A Review and Research Knowledge, Networks, and Knowledge Networks: A Review and Research Agenda. *Journal of Management*, *38*(4), 1115–1166. https://doi.org/10.1177/0149206311432640

Plaeksakul, A. (2010). Local innovation system and public-private research partnership : a case study of national research centres and a science park in Thailand. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ddu&AN=C3C218E2B9B7E1CA&site=ehost-live

Potinecke, T., & Rogowski, T. (2009). A View of SME Clusters and Networks in Europe. In *A Road Map to the Development of European SME Networks* (pp. 23–60). London: Springer London. https://doi.org/10.1007/978-1-84800-342-2_2

Powell, W., Koput, K., & Smith-Doerr, L. (1996). Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. *Administrative Science Quarterly*, *41*(1), 116. https://doi.org/10.2307/2393988

Powell, W. W., Koput, K. W., & Smith-Doerr, L. (1996). Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Locus of Innovation: Networks of Learning in Biotechnology. *Source:*

Administrative Science Quarterly, *41159244*(1), 116–145. Retrieved from http://www.jstor.org/stable/2393988

Punyasavatsut, C. (2008). *‘SMEs in the Thai Manufacturing Industry: Linking with MNES*. *ERIA Research Project Report*. Retrieved from http://www.eria.org/SMEs in The Thai Manufacturing Industry_Lin

Raven, R. P. J. M. (2006). Towards alternative trajectories? Reconfigurations in the Dutch electricity regime. *Research Policy*, *35*(4), 581–595. https://doi.org/10.1016/j.respol.2006.02.001

Rip, A., & Kemp, R. (1998). Technological change. *Human Choice and Climate Change*, *2*(2), 327–399.

Romme, A. G. L., Romme, A. G. L., & Witteloostuijn, A. Van. (n.d.). Circular organizing and triple loop learning Circular organizing and triple loop learning.

Rossini, M., Ciarapica, F. E., Matt, D. T., & Russo Spena, P. (2016). A Preliminary Study on the Changes in the Italian Automotive Supply Chain for the Introduction of Electric Vehicles. *Journal of Industrial Engineering and Management*, *9*(2), 450–486. https://doi.org/10.3926/jiem.1504

Rungsuriyawiboon, S., Opaspanyasarn, R., Wongcharoen, P., & Sirisoontorn, P. (2019). *Consumer Behaviour Analysis on Electric Vehicles Adoption*. Retrieved from https://www.econ.tu.ac.th/uploads/discussion_paper/file/20200805/ejqvwx013458.pdf

Sadoi, Y. (2010). Technological capability of automobile parts suppliers in Thailand. *Journal of the Asia Pacific Economy*, *15*(3), 320–334. https://doi.org/10.1080/13547860.2010.494912

Sadovnikova, A., Pujari, A., & Mikhailitchenko, A. (2016). Radical innovation in strategic partnerships: A framework for analysis. *Journal of Business*

Research, *69*(5), 1829–1833. https://doi.org/10.1016/J.JBUSRES.2015.10.064

Samarnbutr, C. (2012). *An Examination of Technological Capability Development in the Thailand Automotive Industry: The Role of Thai Government Policy from 1960-2009*. University of Portsmouth. Retrieved from https://researchportal.port.ac.uk/portal/files/6060776/Charuspong_Samarnbutr_Final_Thesis.pdf

Saunders, M. N. K., Gray, D. E., & Goregaokar, H. (2014). SME innovation and learning: the role of networks and crisis events. *European Journal of Training and Development*, *38*(1/2), 136–149. https://doi.org/10.1108/EJTD-07-2013-0073

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *Technology Analysis and Strategic Management*, *20*(5), 537–554. https://doi.org/10.1080/09537320802292651

Schot, J., Hoogma, R., & Elzen, B. (1994). *STRATEGIES FOR SHIFTING TECHNOLOGICAL SYSTEMS The case of the automobile system*. *futures* (Vol. 26). Pergamon. https://doi.org/10.1016/0016-3287(94)90073-6

Schwabe, J. (2020). Risk and counter-strategies: The impact of electric mobility on German automotive suppliers. *Geoforum*, *110*, 157–167. https://doi.org/10.1016/j.geoforum.2020.02.011

Scott-Kemmis, D., & Chitravas, C. (2007). Revisiting the learning and capability concepts –building learning systems in Thai auto component firms. *Asian Journal of Technology Innovation*, *15*(2), 67–100. https://doi.org/10.1080/19761597.2007.9668638

Shu, S. T., Wong, V., & Lee, N. (2007). The effects of external linkages on new product innovativeness : an examination of moderating and mediating influences The effects of external linkages on new product innovativeness : an examination of moderating and mediating influences, *4488*. https://doi.org/10.1080/09652540500171373

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. *Research Policy*, *41*(6), 1025–1036. https://doi.org/10.1016/j.respol.2011.12.012

Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research Policy*, *34*(10), 1491–1510. https://doi.org/10.1016/J.RESPOL.2005.07.005

Smith, A., Voß, J.-P., & Grin, J. (2010). Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research Policy*, *39*, 435–448. https://doi.org/10.1016/j.respol.2010.01.023

Späth, P., Rohracher, H., & Radecki, A. Von. (2016). Incumbent Actors as Niche Agents : The German Car Industry and the Taming of the " Stuttgart E-Mobility Region ." https://doi.org/10.3390/su8030252

Steen, M., & Weaver, T. (2017). Incumbents' diversification and cross-sectorial energy industry dynamics. *Research Policy*, *46*(6), 1071–1086. https://doi.org/10.1016/J.RESPOL.2017.04.001

Suwannapirom, S., & Lertputtarak, S. (2008). Across the boundary of advanced manufacturing technology transfer in auto-parts industry in thailand, *2*(2), 121–140.

Techakanont, K., & Terdudomtham, T. (2004). Evolution of Inter-firm Technology Transfer and Technological Capability Formation of Local Parts Firms in the Thai Automobile Industry. *Journal of Technology Innovation*, *12*(2). Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.126.9583&rep=rep1&type=pdf

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–591. Retrieved from https://onlinelibrary.wiley.com/doi/epdf/10.1002/%28SICI%291097-0266%28199708%2918%3A7%3C509%3A%3AAID-SMJ882%3E3.0.CO%3B2-Z

Terry, G., Hayfield, N., Clarke, V., & Braun, V. (2017). Thematic Analysis. In *The SAGE Handbook of Qualitative Research in Psychology* . Sage Publications Ltd. Retrieved from https://books.google.co.th/books?hl=en&lr=&id=AAniDgAAQBAJ&oi=fnd&pg=PA17&dq=thematic+analysis&ots=dom2jpHjMY&sig=Dbq_PT86S7bewuX-C_AbCFnnfdA&redir_esc=y#v=onepage&q=thematic analysis&f=false

Thananusak, T., Punnakitikashem, P., Tanthasith, S., & Kongarchapatara, B. (2021). The development of electric vehicle charging stations in Thailand: Policies, players, and key issues (2015–2020). *World Electric Vehicle Journal*, *12*(1), 1–30. https://doi.org/10.3390/WEVJ12010002

Thananusak, T., Rakthin, S., Tavewatanaphan, T., & Punnakitikashem, P. (2017). Factors affecting the intention to buy electric vehicles: Empirical evidence from Thailand. *International Journal of Electric and Hybrid Vehicles*, *9*(4), 361–381. https://doi.org/10.1504/IJEHV.2017.089875

Timilsina R., G., & Shrestha, A. (2009). Transport sector CO2 emissions growth in Asia: Underlying factors and policy options. *Energy Policy*, 4523–4539. Retrieved from https://ac.els-cdn.com/S0301421509004236/1-s2.0-S0301421509004236-main.pdf?_tid=599bc1fb-cff8-4065-8087-

83fe3af590a4&acdnat=1538570312_c59bd765e253c8dea8f8d0a15416cf0c

Trencher, G., Truong, N., Temocin, P., & Duygan, M. (2021). Top-down sustainability transitions in action: How do incumbent actors drive electric mobility diffusion in China, Japan, and California?, *79*. https://doi.org/10.1016/J.ERSS.2021.102184

Tsai, K. H. (2009). Collaborative networks and product innovation performance: Toward a contingency perspective. *Research Policy*, *38*(5), 765–778. https://doi.org/10.1016/j.respol.2008.12.012

Valentine-Urbschat, M., & Bernhart, W. (2009). *Powertrain 2020 – The Future Drives Electric. Roland Berger Strategy Consultants Report*. *Roland Berger Strategy Consultants* (Vol. 9).

Van Hemert, P., Nijkamp, P., Masurel, E., Van Hemert, P., Masurel, E., & Nijkamp, P. (2013). From innovation to commercialization through networks and agglomerations: analysis of sources of innovation, innovation capabilities and performance of Dutch SMEs. *Ann Reg Sci*, *50*, 425–452. https://doi.org/10.1007/s00168-012-0509-1

Wade, M., & Hulland, J. (2004). Review: The resource-based view and information systems research: Review, extension, and suggestions for future research. *MIS Quarterly: Management Information Systems*, *28*(1), 107–142. https://doi.org/10.2307/25148626

Wee, S., Coffman, M., & La Croix, S. (2018). Do electric vehicle incentives matter? Evidence from the 50 U.S. states. *Research Policy*, *47*(9), 1601–1610. https://doi.org/10.1016/J.RESPOL.2018.05.003

Wells, P., & Nieuwenhuis, P. (2012). Transition failure: Understanding continuity in the automotive industry. *Technological Forecasting and Social Change*, *79*(9), 1681–1692. Retrieved from https://www.sciencedirect.com/science/article/pii/S0040162512001552

Zahra, S. A., & George, G. (2002). Absorptive Capacity: A Review, Reconceptualization, and Extension. *The Academy of Management Review*, *27*(2), 185. https://doi.org/10.2307/4134351

Zeng, S. X., Xie, X. M., & Tam, C. M. (2010). Relationship between cooperation networks and innovation performance of SMEs. *Technovation*, *30*(3), 181–194. https://doi.org/10.1016/J.TECHNOVATION.2009.08.003

Zhang, M., Macpherson, A., & Jones, O. (2006). Conceptualizing the learning process in SMEs: Improving innovation through external orientation. *International Small Business Journal*, *24*(3), 299–323. https://doi.org/10.1177/0266242606063434

Appendices

A. Ethics application form

OFFICE USE ONLY
UECREF
Date
Paper

University of Strathclyde Glasgow

Ethics Application Form

Please answer all questions

1. Title of the investigation
Evolution of knowledge networks, technological learning and development of SMEs : A multi-level perspective of innovation and environmental trends in the automotive sector in Thailand
Please state the title on the PIS and Consent Form, if different:

2. Chief Investigator (must be at least a Grade 7 member of staff or equivalent)
Name: Dr.Girma Zawdie ☐ Professor ☐ Reader ☒ Senior Lecturer ☐ Lecturer ☐ Senior Teaching Fellow ☐ Teaching Fellow Department: Civil and Environmental Engineering Telephone: 0 141 548 4443 E-mail: g.zawdie@strath.ac.uk

3. Other Strathclyde investigator(s)
Name: Pattarawan Charumilin Status (e.g. lecturer, post-/undergraduate): post-graduate Department: Civil and Environmental Engineering Telephone: +44(0)75 490 57895 E-mail: pattarawan.charumilin@strath.ac.uk

4. Non-Strathclyde collaborating investigator(s) (where applicable)
Name: Status (e.g. lecturer, post-/undergraduate): Department/Institution: If student(s), name of supervisor: Telephone:

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E-mail:
Please provide details for all investigators involved in the study:

5. Overseas Supervisor(s) (where applicable)

Name(s):
Status:
Department/Institution:
Telephone:
Email:
I can confirm that the local supervisor has obtained a copy of the Code of Practice: Yes ☐ No ☐
Please provide details for all supervisors involved in the study:

6. Location of the investigation

At what place(s) will the investigation be conducted

Investigation by means of survey and interviews will be conducted at the following places

1. Thai auto-parts manufacturers association and their selected member firms

2. Auto Parts Industry Club, The Federation of Thai Industries

2. Thailand automotive institute

3. Electric Vehicle association of Thailand

4. National Science and Technology Development Agency (NSTDA)

5. Board of Investment Thailand

6. Thailand Science Research and Innovation

7. Office of the National Higher Education, Science, Research and Innovation Policy Council

8. King Mongkut's University of Technology Thonburi

If this is not on University of Strathclyde premises, how have you satisfied yourself that adequate Health and Safety arrangements are in place to prevent injury or harm?
No harmful activities will be carried out beyond usual day to day activities.

7. Duration of the investigation

Duration(years/months) : 18 months

Start date (expected): 9 / 07 / 2019 Completion date (expected): 31 / 12 / 2020

8. Sponsor
Please note that this is not the funder; refer to Section C and Annexes 1 and 3 of the Code of Practice for a definition and the key responsibilities of the sponsor.

Will the sponsor be the University of Strathclyde: Yes ☒ No ☐
If not, please specify who is the sponsor: No sponsor required

9. Funding body or proposed funding body (if applicable)

Name of funding body:
Status of proposal – if seeking funding (please click appropriate box):
☐ In preparation
☐ Submitted
☐ Accepted
Date of submission of proposal: / / Date of start of funding: / /

10. Ethical issues

Describe the main ethical issues and how you propose to address them:
Data to be collected regarding firm's identities and information about perception of firms on transition to electric vehicles (EVs), network of firms and perception of firms on rules and regulations supporting EVs rather than personal information. Participants and firms will be asked how they wish to be identified and their wishes will be followed. Methodology has been designed to minimise collecting personal matters.

11. Objectives of investigation (including the academic rationale and justification for the investigation) Please use plain English.

1. To explore how the auto parts suppliers (particularly small and medium enterprises) in the Thai automotive sector are responsive to the technological requirement of transition from internal combustion engine to electric vehicle.
2. To explore the development of knowledge network of auto parts suppliers in order to adjust to the change in automotive industry.
3. To investigate the policies impact on the development of technological learning of firms in the Thai automotive sector.

12. Participants

Please detail the nature of the participants:
1. Small and medium size firms who are auto parts suppliers which might be affected by the transition of production of electric vehicles in the Thai automotive industry (approximately 300 firms for questionnaire survey and 30 for interviews)

2. Large firms who are auto parts suppliers which might be affected by the transition of production of electric vehicles in the Thai automotive industry (10 for interviews)

3. Industrial associations relating to Thailand automotive industry

3. Research institutions, Universities which conducted research program on electric vehicle technology

4. Government agencies (policy bodies)
Summarise the number and age (range) of each group of participants:
Number: 25-50 Age (range): 18+
Please detail any inclusion/exclusion criteria and any further screening procedures to be used:

Inclusion criteria : 1.Firms in Thailand automotive and parts industry 2. Only firms that produces parts which might be affected by the transition of production from internal combustion engines to electric vehicles.

13. Nature of the participants Please note that investigations governed by the Code of Practice that involve any of the types of participants listed in B1(b) must be submitted to the University Ethics Committee (UEC) rather than DEC/SEC for approval.
Do any of the participants fall into a category listed in Section B1(b) (participant considerations) applicable in this investigation?: Yes ☐ No ☒ If yes, please detail which category (and submit this application to the UEC):

14. Method of recruitment
Describe the method of recruitment (see section B4 of the Code of Practice), providing information on any payments, expenses or other incentives. 1. The list of firms in automotive and part industry is obtained from Thai Autopart Manufacturer Association. Selected suppliers' firms from the list are firms that potentially impacted by the transition to production of electric vehicles. Postal surveys will be sent to selected firm with and explanation of research purpose and consent form signed prior to answering the questionnaires. 2. Interviewees which consists of Government policy agencies, Industrial Associations, Research Institutes and Universities will be inform of research purpose and consent form signed prior to conducting an interview.

15. Participant consent
Please state the groups from whom consent/assent will be sought (please refer to the Guidance Document). The PIS and Consent Form(s) to be used should be attached to this application form. 1. Selected suppliers firms in Thailand automotive and parts industry 2. Government policy agencies, Industrial Associations, Research Institutes (same list as question number 6)

16. Methodology Investigations governed by the Code of Practice which involve any of the types of projects listed in B1(a) must be submitted to the University Ethics Committee rather than DEC/SEC for approval.
Are any of the categories mentioned in the Code of Practice Section B1(a) (project considerations) applicable in this investigation? ☐ Yes ☒ No If 'yes' please detail:

Describe the research methodology and procedure, providing a timeline of activities where possible. Please use plain English. 1. Self-administrated questionnaires by means of online, in person, and/or postal survey during 9 July - 30 December 2019 2. Interviews will be conducted during 15 July -30 December 2019 Interviews and questionnaires will be translated into Thai and administered locally. Responses will be translated to English for use in the thesis and any publications coming from it.
What specific techniques will be employed and what exactly is asked of the participants? Please identify any non-validated scale or measure and include any scale and measures charts as an Appendix to this application. Please include questionnaires, interview schedules or any other non-standardised method of data collection as appendices to this application. 1. The questionnaire survey will seek to collect quantitative and qualitative data relating to the 1) responsiveness of firm to a transition from internal combustion engine to electric vehicle 2) technological learning of firms 3) development of knowledge networks to exploit resources necessary for technological transition and 4) the perception and the use of policy support. 2. Semi-structured interview which will conducting with key players representing policy, regime and niche actors - i.e. industry and industry associations, university and research institutions, government agencies relating to the following questions; 2.1) Organization's policies or project involving electric vehicle development and collaboration policy to promote technological capability of SMEs and its effectiveness. 2.2) Critical success factors affecting collaboration among government, university and industry. 2.3) Perspective on government policy support for technological learning of SMEs in the Thai automotive industry.
Where an independent reviewer is not used, then the UEC, DEC or SEC reserves the right to scrutinise the methodology. Has this methodology been subject to independent scrutiny? Yes ☐ No ☒ If yes, please provide the name and contact details of the independent reviewer:

17. Previous experience of the investigator(s) with the procedures involved. Experience should demonstrate an ability to carry out the proposed research in accordance with the written methodology.
I have been a policy researcher at National Science Technology and Innovation Policy Office in Thailand for 9 years prior to PhD study. My work has been related to conducting a policy research which involve processes of data collection from stakeholders including survey and interview. PI has many years' experience conducting qualitative research.

18. Data collection, storage and security
How and where are data handled? Please specify whether it will be fully anonymous (i.e. the identity unknown even to the researchers) or pseudo-anonymised (i.e. the raw data is anonymised and given a code name, with the key for code names being stored in a separate location from the raw data) - if neither please justify. Participants will be asked how they and their firms wish to be identified and these wishes will be followed. Ideally, participants will be pseudo-anonymous with a characteristic description as agreed between the researchers and participants. Participants can be fully anonymous if desired. Identifying details will be stored separately from interview transcripts. Codenames will link the two files.

Explain how and where it will be stored, who has access to it, how long it will be stored and whether it will be securely destroyed after use All collected information will be store electronically in secure environment through password protection. Once the research has been completed, the PhD thesis has been examined, and the papers generated by it have been published, all the original data files will be destroyed.
Will anyone other than the named investigators have access to the data? Yes ☐ No ☑ If 'yes' please explain:

19. Potential risks or hazards
Briefly describe the potential Occupational Health and Safety (OHS) hazards and risks associated with the investigation: Travel to and from investigation locations. On site hazards in office settings.
Please attach a completed OHS Risk Assessment (S20) for the research. Further Guidance on Risk Assessment and Form can be obtained on Occupational Health, Safety and Wellbeing's webpages

20. What method will you use to communicate the outcomes and any additional relevant details of the study to the participants?
It will be communicated through publications and conference presentations.

21. How will the outcomes of the study be disseminated (e.g. will you seek to publish the results and, if relevant, how will you protect the identities of your participants in said dissemination)?
It will be disseminated through publications, conference presentations and submitted as Ph.D. research to the Department of Civil and Environmental Engineering. Participants will not be named in any of these publications.

Checklist	**Enclosed**	**N/A**
Participant Information Sheet(s)	☑	☐
Consent Form(s)	☑	☐
Sample questionnaire(s)	☑	☐
Sample interview format(s)	☐	☐
Sample advertisement(s)	☐	☐
OHS Risk Assessment (S20)	☐	

Any other documents (please specify below)	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐

22. Chief Investigator and Head of Department Declaration
Please note that unsigned applications will not be accepted and both signatures are required

I have read the University's Code of Practice on Investigations involving Human Beings and have completed this application accordingly. By signing below, I acknowledge that I am aware of and accept my responsibilities as Chief Investigator under Clauses 3.11 – 3.13 of the Research Governance Framework and that this investigation cannot proceed before all approvals required have been obtained.

Signature of Chief Investigator [redacted]

Please also type name here: Girma Zawdie

I confirm I have read this application, I am happy that the study is consistent with departmental strategy, that the staff and/or students involved have the appropriate expertise to undertake the study and that adequate arrangements are in place to supervise any students that might be acting as investigators, that the study has access to the resources needed to conduct the proposed research successfully, and that there are no other departmental-specific issues relating to the study of which I am aware.

Signature of Head of Department [redacted]

Please also type name here Professor Zoe Shipton Zoe Shipton

Date: 31 / 07 / 2019

23. Only for University sponsored projects under the remit of the DEC/SEC, with no external funding and no NHS involvement

Head of Department statement on Sponsorship
This application requires the University to sponsor the investigation. This is done by the Head of Department for all DEC applications with exception of those that are externally funded and those which are connected to the NHS (those exceptions should be submitted to R&KES). I am aware of the implications of University sponsorship of the investigation and have assessed this investigation with respect to sponsorship and management risk. As this particular investigation is within the remit of the DEC and has no external funding and no NHS involvement, I agree on behalf of the University that the University is the appropriate sponsor of the investigation and there are no management risks posed by the investigation.

If not applicable, tick here ☐

Signature of Head of Department [redacted]

Please also type name here	Zoe Shipton
Date:	31 / 07 / 2019

For applications to the University Ethics Committee, the completed form should be sent to ethics@strath.ac.uk with the relevant electronic signatures.

24. Insurance
The questionnaire below must be completed and included in your submission to the UEC/DEC/SEC:

Is the proposed research an investigation or series of investigations conducted on any person for a Medicinal Purpose? Medicinal Purpose means: ▪ treating or preventing disease or diagnosing disease or ▪ ascertaining the existence degree of or extent of a physiological condition or ▪ assisting with or altering in any way the process of conception or ▪ investigating or participating in methods of contraception or ▪ inducing anaesthesia or ▪ otherwise preventing or interfering with the normal operation of a physiological function or ▪ altering the administration of prescribed medication.	Yes / No

If "**Yes**" please go to **Section A (Clinical Trials)** – all questions must be completed
If "**No**" please go to **Section B (Public Liability)** – all questions must be completed

Section A (Clinical Trials)

Does the proposed research involve subjects who are either: i. under the age of 5 years at the time of the trial; ii. known to be pregnant at the time of the trial	Yes / No

*If "**Yes**" the UEC should refer to Finance*

Is the proposed research limited to: iii. Questionnaires, interviews, psychological activity including CBT; iv. Venepuncture (withdrawal of blood); v. Muscle biopsy; vi. Measurements or monitoring of physiological processes including scanning; vii. Collections of body secretions by non-invasive methods; viii. Intake of foods or nutrients or variation of diet (excluding administration of drugs).	Yes / No

*If "**No**" the UEC should refer to Finance*

Will the proposed research take place within the UK?	Yes / No

*If "**No**" the UEC should refer to Finance*

Title of Research		
Chief Investigator		
Sponsoring Organisation	None	
Does the proposed research involve:		
a) investigating or participating in methods of contraception?		Yes / No
b) assisting with or altering the process of conception?		Yes / No
c) the use of drugs?		Yes / No
d) the use of surgery (other than biopsy)?		Yes / No
e) genetic engineering?		Yes / No
f) participants under 5 years of age(other than activities i-vi above)?		Yes / No
g) participants known to be pregnant (other than activities i-vi above)?		Yes / No
h) pharmaceutical product/appliance designed or manufactured by the institution?		Yes / No
i) work outside the United Kingdom?		Yes / No

If **"YES"** to **any** of the questions a-i please also complete the **Employee Activity Form** (attached).
If **"YES"** to **any** of the questions a-i, and this is a follow-on phase, please provide details of SUSARs on a separate sheet.
If "Yes" to any of the questions a-i then the UEC/DEC/SEC should refer to Finance (insurance-services@strath.ac.uk).

Section B (Public Liability)	
Does the proposed research involve :	
a) aircraft or any aerial device	Yes / No
b) hovercraft or any water borne craft	Yes / No
c) ionising radiation	Yes / No
d) asbestos	Yes / No
e) participants under 5 years of age	Yes / No
f) participants known to be pregnant	Yes / No
g) pharmaceutical product/appliance designed or manufactured by the institution?	Yes / No
h) work outside the United Kingdom?	Yes / No

*If **"YES"** to any of the questions the UEC/DEC/SEC should refer to Finance (insurance-services@strath.ac.uk).*

For NHS applications only - Employee Activity Form

Has NHS Indemnity been provided?	Yes / No
Are Medical Practitioners involved in the project?	Yes / No
If YES, will Medical Practitioners be covered by the MDU or other body?	Yes / No

This section aims to identify the staff involved, their employment contract and the extent of their involvement in the research (in some cases it may be more appropriate to refer to a group of persons rather than individuals).

Chief Investigator		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No
Others		
Name	**Employer**	**NHS Honorary Contract?**
		Yes / No
		Yes / No
		Yes / No
		Yes / No

Please provide any further relevant information here:

B. Participant Information Sheet and Consent Form

Participant Information Sheet for [please enter group]

Name of department: Civil and Environmental Engineering

Title of the study: Evolution of knowledge networks, technological learning and development of SMEs: A multi-level perspective of innovation and environmental trends in the automotive sector in Thailand

Introduction
This research is a part of Ph.D. study currently undertaken by Miss Pattarawan Charumilin (Ph.D. student) who is studying within the Department of Civil and Environmental Engineering, University of Strathclyde, Glasgow G1 1XQ, Scotland. English will be used in the Participant Information Sheet. Any further information can be contacted at Department of Civil and Environmental Engineering, James Weir Building Level 5, 75 Montrose Street Glasgow, G1 1XJ, +44 (0)141 548 3275, pattarawan.charumilin@strath.ac.uk

What is the purpose of this investigation?

The purpose of this survey is to

1) to explore how the auto parts suppliers (particularly small and medium enterprises) in the Thai automotive sector are responsive to the technological requirement of transition from internal combustion engine to electric vehicle.

2) to explore the development of knowledge network of auto parts suppliers in order to adjust to the change in automotive industry.

3) to investigate the policies impact on the development of technological learning of firms in the Thai automotive sector.

Do you have to take part?

You can choose to participate or not in this research. Additionally, there are no right or wrong answers the questionnaire purely looks for your views and opinions. Your consent for the questionnaire is assumed by participation; you are free to fill in or not as you wish. If you do not wish to take part in any aspect of this investigation, you do not have to take part. Participation is completely voluntary. As for the interview, you have the right to withdraw at any point throughout the interview.

What will you do in the project?

The research involves collecting quantitative and qualitative data from firms in the automotive and parts industry in Thailand and other agencies such as government policy agency, research institutions, universities and industrial associations. Methods include questionnaire survey and interview. Questionnaire aims to collect data relating to the 1) responsiveness of firm to a transition from internal combustion engine to electric vehicle 2) technological learning of firms 3) development of knowledge networks to exploit resources necessary for technological transition and 4) the perception and the use of policy support. Interview will collect data relating to organization's policies on electric vehicles development and their perspective on government policy support for technological learning of SMEs.

Why have you been invited to take part?
You have been asked to participate in this investigation of the research because you are firms in automotive and parts industry in Thailand, government organizations which issue policy support for EVs development, research institutions, universities having EVs development program and industrial associations in automotive and parts industry.

What are the potential risks to you in taking part?
There are no potential risks to you participating in this investigation.

What happens to the information in the project?

All information drawn from your input to our investigation will be anonymised and no participants will ever be identified in person in any findings. Information provided will be used to examine the Ph.D. research. All collected information will be stored electronically in secure. At a suitable time after the completion of the research, normally one year, all the data files will be destroyed. Access to data will only be available to researcher. The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998. Thank you for reading this information – please ask any questions if you are unsure about what is written here.

What happens next?

You will be asked to sign a consent form if you wish to fill in the questionnaire after you have agreed in this research. If you do not wish to contribute you need not fill this out. The information you provided will be used to investigate the development of knowledge network and technological learning of firms in the Thai automotive and parts industry. Research feedback and publication of the results will be available to you after the completion of the research.

Researcher contact details:

Pattarawan Charumilin from Department of Civil and Environmental Engineering, University of Strathclyde. Department of Civil and Environmental Engineering, James Weir Building Level 5, University of Strathclyde, 75 Montrose Street Glasgow, G1 1XJ, +44 (0)74 532 44223, pattarawan.charumilin@strath.ac.uk

Chief Investigator details:

Chief Investigators, Department of Civil and Environmental Engineering, James Weir Building

Level 5, University of Strathclyde, 75 Montrose Street Glasgow, G1 1XJ, +44 (0)141 548 3275,

contact-civeng@strath.ac.uk

This investigation was granted ethical approval by the University of Strathclyde Ethics Committee.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Secretary to the University Ethics Committee
Research & Knowledge Exchange Services
University of Strathclyde
Graham Hills Building
50 George Street
Glasgow
G1 1QE

Telephone: 0141 548 3707
Email: ethics@strath.ac.uk

Consent Form for [name of group]

Name of department: Civil and Environmental Engineering

Title of the study: The role of science park in promoting knowledge exchange and innovation with particular reference of the case of Thailand.

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. If I exercise my right to withdraw and I don't want my data to be used, any data which have been collected from me will be destroyed.
- I understand that I can withdraw from the study any personal data (i.e. data which identify me personally) at any time.
- I understand that anonymised data (i.e. .data which do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project
- I consent to being audio and/or video recorded as part of the project

Where human biological samples are taken e.g. blood samples or biopsy samples then the following wording should be included: I consent to the taking of biological samples from me, and understand that they will be the property of the University of Strathclyde.

Where it is proposed to carry out DNA analysis of material in any samples then the following statement should be included in the consent form: I consent to DNA in the samples being analysed.

For investigations where it has been decided that "no fault compensation" cover will be provided the following wording needs to be included: In agreeing to participate in this investigation I am aware that I may be entitled to compensation for accidental bodily injury, including death or disease, arising out of the investigation without the need to prove fault. However, such compensation is subject to acceptance of the Conditions of Compensation, a copy of which is available on request.

(PRINT NAME)	
Signature of Participant:	Date:

C. Questionnaire

แบบสอบถาม

การปรับตัวด้านการเรียนรู้เทคโนโลยีและการพัฒนาเครือข่ายความรู้ของผู้ประกอบการยานยนต์และชิ้นส่วนกรณีการเปลี่ยนผ่านสู่การพัฒนายานยนต์ไฟฟ้าของประเทศไทย

Automotive and Part's Suppliers Survey on the transition to electric mobility

จุดประสงค์ของแบบสอบถาม

การสำรวจข้อมูลนี้เพื่อสำรวจความพร้อม แนวทางการปรับตัว ระดับการเรียนรู้ทางเทคโนโลยีของผู้ผลิตชิ้นส่วนยานยนต์ ความต้องการทางด้านนโยบายสนับสนุนจากภาครัฐ โดยเฉพาะอย่างยิ่งผู้ประกอบการผู้ประกอบการขนาดกลางและขนาดย่อม ในกรณีที่มีการเปลี่ยนแปลงของอุตสาหกรรมยานยนต์และชิ้นส่วนจากการผลิตยานยนต์สันดาปภายในไปสู่การผลิตยานยนต์ไฟฟ้า โดยการศึกษานี้เป็นส่วนหนึ่งของการศึกษาในระดับปริญญาเอกของ นส.ภัทรวรรณ จารุมิลินท มหาวิทยาลัยสแตรธไคลด์ (University of Strathclyde) กลาสโกว์ สหราชอาณาจักร **ทั้งนี้ข้อมูลจากการตอบแบบสอบถามจะถูกเก็บรักษาไว้เป็นความลับอย่างเคร่งครัดซึ่งข้อมูลที่ได้จะถูกนำมาใช้ในงานวิจัยนี้เท่านั้น**

Contact person: ถ้าท่านมีคำถามที่เกี่ยวข้องกับการตอบแบบสอบถามกรุณาติดต่อ นส.ภัทรวรรณ จารุมิลินท email : pattarawan.charumilin@strath.ac.uk หรือ pattarawan@sti.or.th phone : 0897990981

ยานยนต์ไฟฟ้าในที่นี้ หมายถึง 1) ยานยนต์ไฟฟ้าไฮบริด (Hybrid Electric Vehicle, HEV) 2) ยานยนต์ไฟฟ้าไฮบริดปลั๊กอิน (Plug-in Hybrid Electric Vehicle, PHEV) 3) ยานยนต์ไฟฟ้าแบตเตอรี่ (Battery Electric Vehicle, BEV) 4) ยานยนต์ไฟฟ้าเซลล์เชื้อเพลิง (Fuel Cell Electric Vehicle, FCEV)

The aim of the study for which information and data are sought is to investigate the extent of SME participation in the transition of the automotive sector from internal combustion engine vehicles to the production of vehicles driven by renewable energy technology systems, and particularly the extent to which they are prepared to adjust to the requirements of the new technology regime.

Vehicle driven by renewable energy includes the following vehicles; 1) Hybrid Electric Vehicle (HEV), 2) Plug-in Hybrid Electric Vehicle (PHEV), 3) Battery Electric Vehicle (BEV), 4) Fuel Cell Electric Vehicle (FCEV)

Confidentiality

The information you provide will be held in the strictest confidence. All the data and information to be elicited through this questionnaire will be used exclusively for the purpose of statistical analysis which will form the part of the PhD thesis, the student will submit to the University of Strathclyde in Glasgow, UK.

Contact Person : If there are any questions raise regarding the survey please contact Miss Pattarawan Charumilin" email : pattarawan.charumilin@strath.ac.uk or pattarawan@sti.or.th phone : 0897990981

ภาพรวมการพัฒนายานยนต์ไฟฟ้าในประเทศไทย

เมื่อวันที่ 28 มีนาคม 2560 คณะรัฐมนตรีอนุมัติมาตรการส่งเสริมการพัฒนาการผลิตยานยนต์ไฟฟ้าในประเทศไทยได้แก่ มาตรการส่งเสริมการลงทุนของ BOI ส่งเสริมการผลิตรถยนต์ไฟฟ้าและชิ้นส่วน รวมถึงสถานีอัดประจุไฟฟ้า, การจัดเก็บภาษีพิเศษของกรมสรรพสามิตลดจากอัตราปกติ, มาตรการจัดซื้อจัดจ้างภาครัฐโดยให้ส่วนราชการและรัฐวิสาหกิจสามารถซื้อยานยนต์ไฟฟ้าแบบแบตเตอรี่ได้, การเตรียมความพร้อมของโครงสร้างพื้นฐาน ได้แก่ การติดตั้งสถานีอัดประจุไฟฟ้า การจัดตั้งศูนย์ทดสอบยานยนต์และยางล้อแห่งชาติรวมถึงการรองรับการทดสอบยานยนต์ไฟฟ้าต่อไป, การจัดทำมาตรฐานยานยนต์ไฟฟ้า, การบริหารจัดการแบตเตอรี่ใช้แล้ว และมาตรการอื่น ๆ เช่นการพัฒนาบุคลากรเพื่อรองรับอุตสาหกรรมยานยนต์แห่งอนาคต

ในด้านภาษีสรรพาสามิตได้มีการลดอัตราภาษีลงสำหรับ PHEV, HEV และ BEV เหลือในอัตรา 10%, 5% และ 0% สำหรับรถไฟฟ้าแบตเตอรี่

ในด้านการลงทุน บริษัทรถยนต์เริ่มมีการลงทุนยานยนต์ไฟฟ้าในประเทศไทย โดยเช่น บริษัทโตโยต้ามีแผนการลงทุนผลิตรถยนต์ไฮบริด 770,000 คัน/ปี และผลิตแบตเตอรี่ 70,000 ชิ้น/ปี หรือบริษัทมาสด้าซึ่งได้รับมาตรการส่งเสริมการลงทุนสำหรับรถไฮบริดเช่นกัน บริษัทรถค่ายยุโรปเช่น BMW เริ่มสายการผลิตสำหรับไฮบริดปลั๊กอิน และ Mercedes Benz เริ่มการผลิตยานยนต์ไฟฟ้าแบตเตอรี่ สำหรับด้านโครงสร้างพื้นฐานปัจจุบันมีสถานีอัดประจุไฟฟ้ามากกว่า 200 จุดในเขตกรุงเทพ และสำนักงานคณะกรรมการส่งเสริมการลงทุนได้อนุมัติโครงการติดตั้งสถานีอัดประจุไฟฟ้า 3,000 จุดทั่วประเทศ

นอกจากนี้บริษัทรถยนต์ เช่น นิสสัน มาสด้า เมอร์เซเดส เบนซ์ บีเอ็มดับเบิลยู เอ็มจี มิตซูบิชิ และ Fomm ได้แสดงความสนใจที่จะลงทุนเพื่อตั้งสายการผลิตรถไฟฟ้าแบตเตอรี่ในประเทศไทย

Overview of EV development in Thailand

On 28th March 2017, the Thai Government approved a set of measures to promote EV production. The measures included promotional privileges administered by the Board of Investment; excise tax reduction; government procurement of EVs; and development of testing infrastructure. These measures were aimed at stimulating the demand for and supply of electric and battery driven vehicles.

The major car producers in Thailand are gearing their investments in next generation vehicle. Toyota plans to produce 7,000 hybrid EVs/year and 70,000 batteries for EVs. Mazda has been granted investment privileges for manufacturing hybrid electric and has submitted application to BOI to produce full EV. BMW operates assembly line for Plug-in Hybrid Electric Vehicles (PHEVs). Mercedes Benz has begun their production of the four EV models noted above. There are approximately 200 charging stations in Bangkok. At present excise tax for EVs have been reduced to 10%, 5% and 0% for PHEV, HEV and BEV respectively.

The BOI also approved a new investment plan for setting up over 3,000 charging stations nationwide. Currently there are 8 multi-national companies that plan to set up production of EVs in Thailand. These are: Toyota, Honda, Nissan, Mazda, Mercedes-Benz, BMW, MG, Mitsubishi and Fomm.

ชื่อผู้ตอบแบบสอบถาม Name of

Respondent...

ตำแหน่งผู้ตอบแบบสอบถาม Position of

respondent:...

ชื่อบริษัท Company name:

....

ที่อยู่

Address:..

............โทรศัพท์... แฟกซ์......................................

อีเมลล์...

Phone Fax Email

แบบสอบถามประกอบด้วย 4 ส่วน รวม 36 คำถาม

This survey consists of 4 parts, 36 Questions ;

ส่วนที่ 1 : ข้อมูลทั่วไป

Part 1 : General Information

หัวข้อที่สำรวจ : โครงสร้างของกิจการ บุคลากร และกิจกรรมทางธุรกิจ

Data on: Business Structure, employment and business activities

ส่วนที่ 2 : คำถามเกี่ยวข้องกับการเปลี่ยนแปลงไปสู่ยานยนต์ไฟฟ้า

Part 2: Questions about firms transitioning to EVs

หัวข้อที่สำรวจ : ความตระหนัก การรับมือกับความเปลี่ยนแปลง และช่องว่างขององค์ความรู้

Data on : awareness, responsiveness to the change, skill gap of firms

ส่วนที่ 3 : การเรียนรู้ทางเทคโนโลยีของบริษัทและการเชื่อมโยงเครือข่าย

Part 3: Technological learning of firms and networks

หัวข้อที่สำรวจ : ที่มาขององค์ความรู้ การเชื่อมโยงกับเครือข่ายความรู้ ความสามารถในการดูดซับความรู้

Data on: source of knowledge, linkages to knowledge networks, absorptive capacity

ส่วนที่ 4 : นโยบายและมาตรการสนับสนุนการผลิตยานยนต์ไฟฟ้า

Part 4: Supporting policies for EV production

หัวข้อที่สำรวจ การใช้มาตรการสนับสนุนด้านและ EV ข้อเสนอแนะด้านมาตรการสนับสนุน EV

Data on : utilization of EV policies and recommendation on EV supporting policies

ส่วนที่ 1 : ข้อมูลทั่วไป

Part 1 : General Information

กรุณาทำเครื่องหมาย ✓ ในช่อง □ หรือเติมข้อความในช่องว่างให้สมบูรณ์

Please check □ in the box □ or fill in the blank

1.ปีที่ก่อตั้งบริษัท Year of establishment
…………………………………………………………………………………..

2. จำนวนพนักงาน Number of employees : ………...………
3. จำนวนพนักงานที่ใช้ในการพัฒนาเทคโนโลยี เช่นปรับปรุงกระบวนการ/ผลิตภัณฑ์ วิจัยและพัฒนาเป็นต้น

   Number of employees for technology and innovation development คน

4. สินทรัพย์ถาวร Fixed assets

□ น้อยกว่า 50 ล้านบาท less than 50 million baht □ ตั้งแต่ 50-200 ล้านบาท from 50-200 million baht

□ มากกว่า 200 ล้านบาท more than 200 million baht

5. เปอร์เซ็นต์การถือครองหุ้น Ownership structure of your enterprise

□ ถือหุ้นโดยคนไทยทั้งหมด Wholly-owned by Thai

□ ถือหุ้นโดยคนไทยมากกว่า 51% >51% owned by Thai

□ ถือหุ้นโดยคนไทยน้อยกว่า 50% 1-50% owned by Thais

□ ถือหุ้นโดยต่างชาติทั้งหมด Wholly-owned by foreigners

6. กรุณาระบุสถานะของบริษัทในซัพพลายเชน Please indicate tier of your supply chain

□ บริษัทผู้ผลิตยานยนต์ car producer

□ Tier 1 □ Tier 2 □ Tier 3

□ อื่นๆ โปรดระบุ Others, please specify…………………….

□ ไม่ทราบ Not known

7. ผลิตภัณฑ์หลักของบริษัท What are your company's main products?
   1) ……………………………………
   2) ……………………………………
   3) ……………………………………
8. เทคโนโลยีในการทำผลิตภัณฑ์

Product technology type

☐ การลอกแบบหรือใช้เทคโนโลยีของผู้อื่น Simple fabrication and primarily using borrowed technology

☐ ผลิตสินค้าอะไหล่ทดแทน Replacement Equipment manufacturer (REM)

☐ รับจ้างผลิตสินค้าตามแบบที่ลูกค้ากำหนด Original Equipment Manufacturer (OEM)

☐ ผลิตสินค้าโดยพัฒนาดีไซน์และรูปแบบเอง Original Designed Manufacture (ODM)

☐ ผลิตแบรนด์สินค้าของตนเอง Own Brand Manufacturer (OBM)

☐ อื่นๆ โปรดระบุ……………………………………..Other, please specify

Other, please specify

9. บริษัทท่านมีขีดความสามารถทางเทคโนโลยีอยู่ในระดับใด Which level of technology capability do you have?

☐ ซ่อมบำรุง maintenance ☐ แก้ปัญหาทางเทคนิค trouble shooting ☐ ควบคุมคุณภาพ quality control

☐ แก้ปัญหาทางเทคโนโลยี solving technology problem ☐ ปรับปรุงกระบวนการ product improvement

☐ ปรับปรุงผลิตภัณฑ์ modification of products

☐ พัฒนาผลิตภัณฑ์ใหม่developing new products ☐ พัฒนากระบวนการใหม่ developing new processes

10. งบประมาณสำหรับการพัฒนาเทคโนโลยีและนวัตกรรมคิดเป็นสัดส่วนของยอดขาย ร้อยละ ………………..

Budget for innovation and development as a percentage of sales ....percent

11. ท่านได้รับสัญญาการผลิตจากบริษัทอื่นหรือไม่ Have you obtained contract to manufacture/supply for other firms?

☐ ไม่ No

☐ ใช่ โปรดระบุบริษัทและระยะเวลาของการเป็นซัพพลายเออร์ Yes, please identify names and year of being supplier

ชื่อบริษัท	บริษัทของท่านเป็นซัพพลายเออร์ให้กับบริษัทข้างต้นมาเป็นระยะเวลาเท่าใด

ส่วนที่ 2 : คำถามเกี่ยวข้องกับการเปลี่ยนแปลงไปสู่ยานยนต์ไฟฟ้า

Part 2: Questions about firms transitioning to EVs

12. รัฐบาลไทยวางแผนที่จะให้ประเทศไทยเป็นผู้นำของภูมิภาคในการผลิตยานยนต์ไฟฟ้า ในมุมมองของท่านจากสถานการณ์การส่งเสริมในปัจจุบัน (โปรดพิจารณาจากข้อมูลภาพรวมการพัฒนายานยนต์ไฟฟ้าในประเทศไทยข้างต้น) ท่านเห็นด้วยหรือไม่ว่าเป็นข้อเสนอที่เป็นไปได้ โปรดกาเครื่องหมาย P ในช่องที่ท่านเห็นว่าเหมาะสม (1 ไม่เห็นด้วยอย่างยิ่ง 5 เห็นด้วยอย่างยิ่ง)

The Thai Government has a plan to make Thailand leader in the production of BEV. In view of current circumstances the Government's promotion of EVs (please see overview of EVs development in Thailand), would you agree this to be a viable and relevant proposition? Please check ☐ in the box to your level of agreement (1 strongly disagree, 5 strongly agree)

ระดับความเห็นด้วย Degree of Agreement				
1	2	3	4	5
☐	☐	☐	☐	☐

13. การเปลี่ยนแปลงทางเทคโนโลยีจากเครื่องยนต์สันดาปภายในไปสู่ยานยนต์ไฟฟ้าหมายความว่าชิ้นส่วนจะต้องมีการหายไปหรือมีการปรับเปลี่ยนให้เข้ากับยานยนต์ไฟฟ้า การเปลี่ยนแปลงดังกล่าวจะกระทบกับการดำเนินงานของบริษัทท่านมากน้อยเพียงใด (1 กระทบน้อยที่สุด 5 กระทบมากที่สุด)

A change in technology from internal combustion engine to renewable energy vehicle, electrification will mean that some components will have to be adapted. How much would this shift affect your operation? On the scale of 0-5 (1 least relevant, 5 most relevant)

ระดับความเกี่ยวข้อง Degree of relevancy					
1	2	3	4	5	ไม่กระทบ
☐	☐	☐	☐	☐	☐

14. ในกรณีที่การเปลี่ยนแปลงไปสู่เทคโนโลยียานยนต์ไฟฟ้ากระทบต่อการดำเนินงานของบริษัท การเปลี่ยนแปลงนี้จะกระทบกับผลิตภัณฑ์ของบริษัทอย่างไร If the change to EVs will affect your operation, how would the shift to new technology affect your existing products?

☐ ผลิตภัณฑ์จะถูกยกเลิกการผลิต

Products will be discontinued

☐ ยังคงดำเนินการผลิตต่อ

Products continue to be produced

☐ ผลิตภัณฑ์ต้องมีการปรับเปลี่ยน

Products will have to be adapted

☐ อื่น ๆ โปรดระบุ ……………………………………….

Others, please specify

15. บริษัทท่านมีความสนใจที่จะพัฒนาผลิตภัณฑ์ใหม่ที่จะสามารถเป็นส่วนหนึ่งของห่วงโซ่อุปทานของการผลิตยานยนต์ไฟฟ้าหรือไม่

Do you have any interest in the development of new products in your company that would add to the supply chain for the production of electric vehicles?

☐ ไม่สนใจ No ☐ สนใจ Yes โปรดระบุสาขาเทคโนโลยีที่สนใจ โดยเลือกได้มากกว่า 1 สาขา

If yes, please indicate your area of interest, you can choose more than one

☐ เทคโนโลยีแบตเตอรี่ (ลิเธียมไอออน โพลิเมอร์ ตะกั่วกรด)

Battery technology (Li-ion/Polymer/Lead-acid)

☐ อุปกรณ์เสริมแบตเตอรี่

Battery accessories and fabrication method

☐ ระบบประจุไฟฟ้าในยานยนต์ไฟฟ้า

Charging system

□ วัสดุยางสำหรับยานยนต์ไฟฟ้า

Rubber material for EVs

□ ระบบขับเคลื่อนอัจฉริยะ

Intelligence transport system

□ อื่นๆ โปรดระบุ...................................

Other

16. ถ้าบริษัทไม่สนใจในการลงทุนที่เกี่ยวข้องกับผลิตภัณฑ์ยานยนต์ไฟฟ้า ท่านสนใจที่จะนำประสบการณ์ความเชี่ยวชาญการผลิตของท่านไปใช้ในสาขาอุตสาหกรรมอื่นหรือไม่ If you are not interested in investing in EV related products, would you rather divert your expertise and experience to areas other than where you are currently engaged ?

□ ไม่สนใจ No

□ สนใจ โปรดระบุสาขาที่ท่านสนใจ เลือกได้มากกว่า 1 สาขา

Yes, (please specify the areas where you would consider migrating to

□ เครื่องมือทางการแพทย์ Medical device

□ การบิน Aviation

□ หุ่นยนต์ Robot

□ ระบบราง

□ อื่นๆ โปรดระบุ ……………………………………

Other, please specify

17. โปรดระบุสาขาองค์ความรู้ 3 ลำดับ ที่บริษัทท่านยังขาด และเป็นอุปสรรคต่อการที่บริษัทจะดำเนินการวางแผนผลิตชิ้นส่วนเพื่อรองรับอุตสาหกรรมยานยนต์ไฟฟ้า Please rank 3 areas of knowledges and skill gaps that would constrain your company to actively participating in the production of parts for the manufacture of EVs.

□ การออกแบบและการควบคุมสายการผลิต Design and Operation of Production Lines

□ การออกแบบทางวิศวกรรม Engineering design

□ การวิจัยและพัฒนา R&D

□ การออกแบบผลิตภัณฑ์ Product design

□ ทักษะด้าน Marketing

□ Electronics & IT

□ Networking

□ Others, please specify…………………………………………

18. โปรดระบุปัจจัยที่เกี่ยวข้องที่สนับสนุนให้บริษัทท่านตัดสินใจลงทุนในเทคโนโลยียานยนต์ไฟฟ้า (1 น้อยที่สุด 5 มากที่สุด) (Please rate factors that support your enterprise's decision to enter the EV markets.(1 least relevant, 5 most relevant)

ปัจจัย Factors	ระดับความเกี่ยวข้อง Degree of Relevancy					
	1	2	3	4	5	ไม่เกี่ยวข้อง
ลูกค้ามีโครงการผลิตยานยนต์ไฟฟ้า Your customers EVs development project	□	□	□	□	□	□
แนวโน้มการขยายตัวของตลาด EVs Increase market prospect of EVs	□	□	□	□	□	□
จำนวนคู่แข่งที่พัฒนาสินค้า EVs เพิ่มขึ้น Increase number of launching competitors	□	□	□	□	□	□
ความเป็นมิตรต่อสิ่งแวดล้อมของ EVs Environmental contribution of EVs	□	□	□	□	□	□
เป็นโอกาสในการเปิดตลาดใหม่ Opportunity to open a new market	□	□	□	□	□	□
การเพิ่มขึ้นของสถานีอัดประจุไฟฟ้า Availability of charging Infrastructure	□	□	□	□	□	□
การกำหนดมาตรฐานของผลิตภัณฑ์และโครงสร้างพื้นฐานที่เกี่ยวข้องกับยานยนต์ไฟฟ้าStandardization of products and infrastructure	□	□	□	□	□	□
มาตรการสนับสนุนที่เกี่ยวข้องกับการพัฒนายานยนต์ไฟฟ้า โปรดระบุ………………………………………………….. Government support & policies ,please specify	□	□	□	□	□	□
อื่นๆ โปรดระบุ …………………………………………………. Others (Please specify)………………………	□	□	□	□	□	□

19. กฎหมายกฎระเบียบต่อไปนี้มีผลกระทบต่อการตัดสินใจในการลงทุนในเทคโนโลยียานยนต์ไฟฟ้ามากน้อยเพียงใด (1 น้อยที่สุด 5 มากที่สุด) How significant are the following rules and regulations for your decision to invest into EVs technologies?

(1 least relevant, 5 most relevant)

Rules and regulations	1	2	3	4	5
แผนอนุรักษ์พลังงาน 20 ปี พ.ศ. 2558-2579 กำหนดเป้าหมายระยะ 20 ปีในการลดความเข้มในการใช้พลังงาน Energy efficiency plan 2015 which sets a target for energy intensity reduction of 30% by 2036 with specific measure on energy consumption in the transportation sector.					
การจดทะเบียนยานยนต์ครอบคลุมยานยนต์ไฟฟ้าทุกรุ่น Type of EVs that can be registered					
การกำหนดมาตรฐานสำหรับผลิตภัณฑ์ที่เกี่ยวข้องกับยานยนต์ไฟฟ้า Industrial Standards for EVs related products					
อัตราภาษีสรรพสามิต Excise tax rate					
การบังคับใช้มาตรฐานยูโร 5 และ ยูโร 6 Compliance to Euro 5 and Euro 6 standard					
อื่นๆ โปรดระบุ Others, please specify………………………………					

20. กรุณาระบุระดับความเห็นเกี่ยวกับยานยนต์ไฟฟ้าจากมุมมองของบริษัทท่าน (1 ไม่เห็นด้วยอย่างยิ่ง 5 เห็นด้วยอย่างยิ่ง)

Please indicate your level of agreement with the following statements (1 strongly disagree, 5 strongly agree)

	1	2	3	4	5
1. ยานยนต์ไฟฟ้าเป็นอุตสาหกรรมใหม่ในระดับโลก EVs are the new global industry					
2. ประเทศไทยมีโอกาสได้รับการถ่ายทอดเทคโนโลยียานยนต์ไฟฟ้าจากบริษัทผู้ผลิตรถยนต์ต่างชาติเพราะประเทศไทยเป็นฐานการผลิตรถยนต์ที่สำคัญ Thailand has an opportunity for technology transfer from MNCs car producers since Thailand is the important automobile production base					
3. คลัสเตอร์ยานยนต์ที่มีความเข้มแข็ง Strong existing automotive cluster network					
4. ไทยมีความน่าเชื่อถือในฐานะเป็นผู้ส่งออกระดับต้นๆของโลก Reliability as top tier exporter					
5. รัฐบาลริเริ่มนโยบายและมาตรการต่าง ๆ เพื่อพัฒนายานยนต์ไฟฟ้า โดยเริ่มจากยานยนต์สาธารณะ Government initiatives on supporting the development of public EVs					
6. อุตสาหกรรมยานยนต์มีแรงงานฝีมือระดับสูง Availability of high skill labour in automotive industry					
7. นโยบายส่งเสริมการลงทุนสร้างแรงจูงใจให้เกิดกิจกรรมการผลิตยานยนต์ไฟฟ้าขึ้นในประเทศ -Investment privilege that incentivize EVs production activities					
8. การผลิตแบตเตอรี่ยังมีราคาสูง High production cost of batteries					
9. สถานีอัดประจุไฟฟ้ายังขาดแคลน The lack of charging infrastructure					
10. กลุ่มผู้เล่นใหม่หรือบริษัทใหม่ๆ จะเพิ่มเข้ามาเป็น value chain ใหม่ของอุตสาหกรรมยานยนต์ 11. New actors will be introduced into automotive value chain					
12. รัฐบาลยังขาดนโยบายและแนวทางที่ชัดเจนในการสนับสนุนโครงการพัฒนายานยนต์ไฟฟ้า Government is still lack clear direction or plan on supporting program for new EVs development					
13. จำนวนผู้ใช้ยานยนต์ไฟฟ้ายังมีจำนวนน้อย Limited number of users of EVs					

ส่วนที่ 3 : การเรียนรู้ทางเทคโนโลยีของบริษัทและการเชื่อมโยงเครือข่าย

Part 3: Technological learning of firms and networks

21. บริษัทของท่านเสาะหาองค์ความรู้จากแหล่งใดบ้าง เลือกได้มากกว่า 1 แหล่งที่มาและโปรดระบุความสำคัญของแหล่งที่มา (1 น้อยที่สุด 5 มากที่สุด)

    For each of the following lists how did your firm acquire technological knowledge, please indicate the significance? (1 least important, 5 most important)

แหล่งที่มา Source	1	2	3	4	5
บริษัทแม่ Parent companies					
การฝึกอบรมโดยลูกค้า Training by key customers					
การฝึกอบรมโดยสมาคมการค้า (เช่น สมาคมผู้ประกอบการต่างๆ) Training by trade bodies					
การพัฒนาความรู้ภายในองค์กรด้วยตนเอง In-house capability development					
การพัฒนาองค์ความรู้ร่วมกับมหาวิทยาลัยหรือสถาบันวิจัย Collaborative development with university/research institution					
การพัฒนาองค์ความรู้ร่วมกับบริษัทอื่น Collaborative development with firms					
การจ้างบุคลากร Hiring					
การเลียนแบบ/วิศวกรรมย้อนรอย Imitation/reverse engineering					
การส่งบุคลากรไปอบรมในต่างประเทศ Overseas training					
ผู้เชี่ยวชาญต่างประเทศ Foreign expert assistance					
ซื้อหรือทำสัญญาใช้องค์ความรู้ เช่น สิทธบัตร หรืออนุญาตให้ใช้สิทธิ์ Purchase of codified knowledge (e.g.patent, licensing)					
การประชุมวิชาการ Conference and meetings					

อื่นๆ โปรดระบุ……………………………………Others, please specify					

22. บริษัทของท่านมีความเชื่อมโยงกับบริษัทอื่นๆ หรือไม่ Do you have linkages with other firms

☐ ไม่มี No ☐ มี โปรดระบุหน่วยงานและรูปแบบความสัมพันธ์ลงในตารางด้านล่าง (เลือกได้มากกว่า 1ข้อ)

Yes If yes please specify partners and type of linkages according to the following list in the table below.

หน่วยงาน	รูปแบบความสัมพันธ์ Type of linkages
ลูกค้า Customers	☐ ความสัมพันธ์ทางการค้า (Trading relationship) ☐ ร่วมกันพัฒนาผลิตภัณฑ์หรือกระบวนการใหม่ (Developing new product and process) ☐ พัฒนาระบบการแลกเปลี่ยนข้อมูล (Developing information sharing platform) ☐ การใช้บริการให้คำปรึกษาเพื่อแก้ปัญหาทางเทคนิค (Provision of consultancy services to solve technical problems) ☐ การฝึกอบรมTraining courses ☐ อื่นๆ โปรดระบุกิจกรรม ……………………………………………………………(Others, please specify)
ซัพพลายเออร์ Suppliers	☐ ความสัมพันธ์ทางการค้า(Trading relationship) ☐ ร่วมกันพัฒนาผลิตภัณฑ์หรือกระบวนการใหม่ (Developing new product and process) ☐ พัฒนาระบบการแลกเปลี่ยนข้อมูล (Developing information sharing platform) ☐ การใช้บริการให้คำปรึกษาเพื่อแก้ปัญหาทางเทคนิค (Provision of consultancy services to solve technical problems) ☐ การฝึกอบรมTraining courses ☐ อื่นๆ โปรดระบุกิจกรรม ……………………………………………………(Others, please specify)
คู่แข่งทางการค้า Competitors	☐ ความสัมพันธ์ทางการค้า(Trading relationship) ☐ ร่วมกันพัฒนาผลิตภัณฑ์หรือกระบวนการใหม่ (Developing new product and process) ☐ พัฒนาระบบการแลกเปลี่ยนข้อมูล (Developing information sharing platform) ☐ การใช้บริการให้คำปรึกษาเพื่อแก้ปัญหาทางเทคนิค (Provision of consultancy services to solve technical problems) ☐ การฝึกอบรมTraining courses ☐ อื่นๆ โปรดระบุกิจกรรม …………………………………………………………(Others, please specify)
สมาคมการค้า เช่น TAPMA	☐ ความสัมพันธ์ทางการค้า(Trading relationship) ☐ ร่วมกันพัฒนาผลิตภัณฑ์หรือกระบวนการใหม่ (Developing new product and process) ☐ พัฒนาระบบการแลกเปลี่ยนข้อมูล (Developing information sharing platform) ☐ การใช้บริการให้คำปรึกษาเพื่อแก้ปัญหาทางเทคนิค (Provision of consultancy services to solve technical problems)

Industrial Associations	☐ การฝึกอบรมTraining courses ☐ อื่นๆ โปรดระบุกิจกรรม ……………………………………………………………(Others, please specify)
บริษัทที่ปรึกษา Private Consultant	☐ ความสัมพันธ์ทางการค้า(Trading relationship) ☐ ร่วมกันพัฒนาผลิตภัณฑ์หรือกระบวนการใหม่ (Developing new product and process) ☐ พัฒนาระบบการแลกเปลี่ยนข้อมูล (Developing information sharing platform) ☐ การใช้บริการให้คำปรึกษาเพื่อแก้ปัญหาทางเทคนิค (Provision of consultancy services to solve technical problems) ☐ การฝึกอบรมTraining courses ☐ อื่นๆ โปรดระบุกิจกรรม ………………………………………………………….(Others, please specify)

23. บริษัทของท่านมีความสัมพันธ์เชื่อมโยงกับสถาบันการศึกษาหรือไม่ Do you have linkages with academic institutions?
☐ ไม่มี No ☐ Yes มี โปรดระบุหน่วยงานและรูปแบบความสัมพันธ์ลงในตารางด้านล่าง (เลือกได้มากกว่า 1ข้อ)

If yes please specify partners and type of linkages according to the following list in the table below.

หน่วยงาน	รูปแบบความสัมพันธ์ Type of linkages
มหาวิทยาลัย Universities	☐ วิจัยร่วม (Joint research) ☐ การขออนุญาตใช้สิทธิทางเทคโนโลยี (Technology licensing) ☐ การจ้างทำวิจัย (Contract research) ☐ บริการให้คำปรึกษา (Consultancy service) ☐ การใช้บริการทดสอบ (Testing service) ☐ การแลกเปลี่ยนบุคลากร/ให้ยืมบุคลากรวิจัย (R&D personnel exchange/talent mobility) ☐ สหกิจศึกษา/โรงเรียนโรงงาน (cooperative education/ work-integrated learning) ☐ การอบรมสัมมนาและการประชุมวิชาการ (Training, seminar and conference) ☐ อื่นๆ โปรดระบุกิจกรรม …………………………………Others, please specify

สถาบันวิจัย Research Institutions	☐ วิจัยร่วม (Joint research) ☐ การขออนุญาตใช้สิทธิทางเทคโนโลยี (Technology licensing) ☐ การจ้างทำวิจัย (Contract research) ☐ บริการให้คำปรึกษา (Consultancy service) ☐ การใช้บริการทดสอบ (Testing service) ☐ การแลกเปลี่ยนบุคลากร/ให้ยืมบุคลากรวิจัย (R&D personnel exchange/talent mobility) ☐ สหกิจศึกษา/โรงเรียนโรงงาน (cooperative education/ work-integrated learning) ☐ การอบรมสัมมนาและการประชุมวิชาการ (Training, seminar and conference) ☐ อื่นๆ โปรดระบุกิจกรรม ....Others, please specify
วิทยาลัยเทคนิค Colleges/Technical Institutes	☐ วิจัยร่วม (Joint research) ☐ การขออนุญาตใช้สิทธิทางเทคโนโลยี (Technology licensing) ☐ การจ้างทำวิจัย (Contract research) ☐ บริการให้คำปรึกษา (Consultancy service) ☐ การใช้บริการทดสอบ (Testing service) ☐ การแลกเปลี่ยนบุคลากร/ให้ยืมบุคลากรวิจัย (R&D personnel exchange/talent mobility) ☐ สหกิจศึกษา/โรงเรียนโรงงาน (cooperative education/ work-integrated learning) ☐ การอบรมสัมมนาและการประชุมวิชาการ (Training, seminar and conference) ☐ อื่นๆ โปรดระบุกิจกรรม ....Others, please specify

24. บริษัทของท่านมีความเชื่อมโยงกับหน่วยงานรัฐหรือไม่ Do you have linkages with government agencies?

☐ ไม่มี No ☐ Yes มี โปรดระบุหน่วยงานและรูปแบบความสัมพันธ์ลงในตารางด้านล่าง (เลือกได้มากกว่า 1ข้อ)

If yes please specify linkages according to the following list and put number in the table

หน่วยงาน	รูปแบบความสัมพันธ์ Type of linkages
หน่วยงานให้ทุน เช่น สวทช., สกว.,NIA โปรดระบุ หน่วยงาน ……………………..	☐ .ขอทุนร่วมวิจัยรัฐเอกชน Funding for collaborative projects ☐ . มาตรการสนับสนุนทางการเงิน เช่น เงินกู้, เงินให้เปล่า Financial supports eg. loan,grants ☐ บริการให้คำปรึกษา Consultancy service ☐ บริการเชื่อมโยงไปยังหน่วยงานอื่น provide linkage to other agencies ☐ การแลกเปลี่ยน/ให้ยืมบุคลากรวิจัยR&D personnel exchange/talent mobility ☐ การอบรมสัมมนาและการประชุมวิชาการ Training, seminar and conference ☐ การจัดอบรมพนักงาน Training of employees ☐ อื่นๆ โปรดระบุ …………………………………………………...………Others, please specify
หน่วยงานสนับสนุนด้านนโยบาย เช่น BOI, สวทน. โปรดระบุหน่วยงาน ………………………….	☐ มาตรการสนับสนุนทางภาษี ☐ มาตรการสนับสนุนทางการเงิน ☐ บริการเชื่อมโยงไปยังหน่วยงานอื่น provide linkage to other agencies ☐ การอบรมสัมมนาและการประชุมวิชาการ Training, seminar and conference ☐ สนับสนุนการออกนิทรรศการ งานแสดงสินค้า Funding for attending showcase/exhibition ☐ อื่นๆ โปรดระบุ …………………………………………………...………Others, please specify
สถาบันยานยนต์	☐ บริการทดสอบและสอบเทียบTesting and calibrating services ☐ บริการให้คำปรึกษา Consultancy service ☐ บริการเชื่อมโยงไปยังหน่วยงานอื่น provide linkage to other agencies

	□ การอบรมสัมมนาและการประชุมวิชาการ Training, seminar and conference □ การจัดอบรมพนักงาน Training of employees □ อื่นๆ โปรดระบุ ………………………………………………………..……….Others, please specify

25. ถ้าบริษัทของท่านวางแผนที่จะลงทุนในเทคโนโลยีหรือผลิตภัณฑ์ด้านยานยนต์ไฟฟ้า หน่วยงานไหนเป็นหน่วยที่มีความสำคัญที่สุดต่อการพัฒนาเทคโนโลยีสำหรับบริษัทของท่าน โปรดระบุและเรียงลำดับ 3 หน่วยงานอันดับแรกที่มีความสำคัญ If you plan to invest in development of EVs related products Which of the following are the most important partners when it comes to technology development for your firm? Please choose partners who are the most important. Please give 3 ranking

หน่วยงาน **Partners**	**ลำดับ** **Rank**
ลูกค้า	
ซัพพลายเออร์	
คู่แข่งทางการค้า	
มหาวิทยาลัย	
สถาบันวิจัย	
วิทยาลัยเทคนิค	
หน่วยงานรัฐ	
สถาบันยานยนต์	
สมาคมการค้า/สมาคมผู้ประกอบการ	
บริษัทที่ปรึกษาด้านเทคนิค	
อื่นๆโปรด ระบุ………………………………………..	

26. บริษัทของท่านได้รับการสนับสนุนด้านความช่วยเหลือทางเทคนิคจากบริษัทผู้ผลิตรถยนต์หรือไม่ Do you receive technical assistance from car manufacturers?

☐ไม่ No ☐ ใช่Yes

ถ้าใช่โปรดระบุกิจกรรม If yes, how ☐ อบรม/เวิร์คชอป training/workshop ☐ ให้คำแนะนำที่โรงงาน visiting to plant

☐ อื่นๆ โปรดระบุ……………………… Others, please specify

27. บริษัทท่านมีโครงการความร่วมมือเพื่อพัฒนาซัพพลายเออร์ในเทีย 2/3 หรือไม่

Do you offer supplier development collaboration program with 2nd tier/3rd tier suppliers?

☐ ไม่No ☐ ใช่ อย่างไร Yes, if yes how

☐ อบรม/เวิร์คชอป training/workshop ☐ ให้คำแนะนำที่โรงงาน visiting to plant

☐ อื่นๆ โปรดระบุ Others, please specify………………………………….

28. ในกรณีที่ท่านมีโครงการพัฒนาเทคโนโลยียานยนต์ไฟฟ้า ท่านจะยังคงดำเนินการโครงการความร่วมมือเพื่อพัฒนาซัพพลายเออร์ต่อไปหรือไม่ (โปรดข้ามคำถามนี้หากท่านอยู่ใน Tier 2,3)

Would you continue supplier development program for your EVs development project?

☐ ดำเนินการต่อ Yes ☐ ไม่ No

29. โปรดเลือกระดับที่ตรงกับความสามารถของบริษัทในการได้มาซึ่งความรู้จากภายนอกองค์กร (1=น้อยที่สุด 5=มากที่สุด) Please rate your company's ability to obtain external knowledges through the following mechanisms					
1) ระดับการมีปฏิสัมพันธ์กับลูกค้าและคู่แข่งในอุตสาหกรรมเพื่อเข้าถึงข้อมูลและองค์ความรู้ใหม่ Degree of interaction with clients and competitors to acquire industry information and new knowledge.	1	2	3	4	5
2) ความสามารถของบริษัทที่จะได้มาซึ่งข้อมูลที่ทันสมัยเป็นปัจจุบันหรือความรู้เกี่ยวกับลูกค้าปัจจุบันหรือลูกค้าในอนาคต Capacity to capture relevant, up-to-date information and knowledge on current and potential customers.	1	2	3	4	5
3) ความสามารถในการสังเกตแนวโน้มของตลาดและโอกาสใหม่ๆ ของตลาด Capacity to monitor market trends and to discover new opportunity.	1	2	3	4	5
4) ความสามารถในการสังเกตแนวโน้มทางเทคโนโลยี Capacity to monitor technology trends	1	2	3	4	5
5) ความเข้มแข็งในการร่วมมือกับมหาวิทยาลัย สถาบันวิจัย ในการพัฒนาเทคโนโลยีและนวัตกรรม Strength of cooperation with universities, research institutions, technological institutes as a member or sponsor to create knowledge and innovation.	1	2	3	4	5
30. **โปรดเลือกระดับที่ตรงกับ*รูปแบบการสื่อสารข้อมูล/ความรู้ภายในองค์กรของท่าน*** **Please rate to what extent the following statements fit the communication structure in your company:**					
1) ระดับของการสื่อสารข้ามแผนกหรือข้ามฝ่าย เกี่ยวกับแนวความคิดใหม่ หรือข้อมูลสำคัญ Degree of cross-departmental communication in company for the generation of new ideas.	1	2	3	4	5
2) ความสามารถในการดูดซับเทคโนโลยีใหม่หรือนวัตกรรม Capacity to assimilate new technologies and innovations.	1	2	3	4	5

3) ระดับของการเผยแพร่ความรู้ใหม่ให้ทั่วถึงภายในบริษัท Degree to which the company disseminates new knowledge throughout the firm.	1	2	3	4	5
4) ความถี่ในการที่พนักงานได้เข้าคอร์สอบรม งานแสดงสินค้า การประชุมต่างๆ Frequency of company employees attending training courses, trade fairs and meetings.	1	2	3	4	5
31. โปรดเลือกระดับที่ตรงกับระบบการประมวลความรู้ของบริษัท Please specify to what extent the following statements fit the knowledge processing system in your company:					
1) ความสามารถของบริษัทในการใช้เทคโนโลยีสารสนเทศเพื่อพัฒนาการแบ่งปันข้อมูล การแชร์ข้อมูลที่มีประสิทธิภาพ และส่งเสริมการสื่อสารระหว่างพนักงานภายในบริษัท Capacity of the company to use IT in order to improve information flow, develop the effective sharing of knowledge and foster communication between members of the firm	1	2	3	4	5
2) ความสามารถด้านเทคโนโลยีและนวัตกรรมโดยเฉพาะเทคโนโลยีหลักของบริษัท รวมถึงความสามารถที่จะกำจัดความรู้ที่ล้าสมัยภายในองค์กรออกไปและสามารถที่จะหานวัตกรรมอื่นมาทดแทน Firm's awareness of its competences in innovation, especially with respect to key technologies, and capability to eliminate obsolete internal knowledge; and ability to search for alternative innovations and their adaptation	1	2	3	4	5
3) ความสามารถที่จะปรับใช้เทคโนโลยีที่ออกแบบโดยบริษัทอื่นให้เข้ากับความต้องการของบริษัทได้ Capacity to adapt technologies designed by others to the firm's particular needs.	1	2	3	4	5
4) ความสามารถในการผสมผสานและใช้ความรู้ใหม่กับวิศวกรรมเดิม ระบบการผลิต หรือด้านการตลาด Capacity to integrate and apply new knowledge to the existing engineering, production or marketing tasks.	1	2	3	4	5
32. โปรดเลือกระดับที่ตรงกับการนำความรู้ใหม่มาใช้ในองค์กรของท่าน **Please specify to what extent the following activities fit the application of new knowledge in your company**					
1) ความสามารถของบริษัทในการใช้ประโยชน์ความรู้ใหม่อย่างรวดเร็วเพื่อตอบสนองต่อสภาวะการเปลี่ยนแปลงทางเทคโนโลยีและตลาด The organization's capacity to use and exploit new knowledge in the workplace responding quickly to changing technological and market	1	2	3	4	5

	circumstances					
2)	ความสามารถในการแปลงความรู้ทางเทคโนโลยีให้กลายเป็นทรัพย์สินทางปัญญาCapacity to apply technological knowledge into product/process prototype/intellectual property rights.	1	2	3	4	5
3)	ความสามารถที่จะตอบสนองต่อความต้องการตลาดหรือจากแรงกดดันของคู่แข่ง โดนพัฒนาความสามารถของบริษัท พัฒนาผลิตภัณฑ์ แนวคิดด้านเทคโลยีใหม่ Ability to respond to the requirements of demand or to competitive pressure by broadening the portfolio of new products, capabilities and technology ideas.	1	2	3	4	5

ส่วนที่ 4 : นโยบายและมาตรการสนับสนุนการผลิตยานยนต์ไฟฟ้า

Part 4: Supporting policies for EV production

33. ท่านเห็นว่านโยบายสนับสนุนการพัฒนายานยนต์ไฟฟ้าดังต่อไปนี้มีส่วนในการสนับสนุนการพัฒนายานยนต์ไฟฟ้าและชิ้นส่วนที่เกี่ยวข้องได้มากน้อย เพียงใด กรุณาให้ลำดับความสำคัญมาตรการที่สำคัญสำหรับท่าน 5 ลำดับแรก
To what extent does your company perceive the following government policies/program to support your EVs development project?

มาตรการ	ลำดับความสำคัญ 5 ลำดับแรก (ลำดับ 1 คือ “มากที่สุด”)
การจัดอบรมพัฒนาบุคลากรด้านเทคโนโลยียานยนต์ไฟฟ้าและเทคโนโลยีใหม่ๆ Training of human resources program related to EVs technology and others	
การจัดหานักวิจัยหรือที่ปรึกษาเกี่ยวกับการดำเนินงานด้านการวิจัยและพัฒนา Provision of researcher or technical assistance to your firms	
สนับสนุนทุนวิจัยและพัฒนาเพื่อการพัฒนาเทคโนโลยียานยนต์ไฟฟ้า R&D funding for private sector to develop EVs technology	
การจัดตั้งกลุ่มความร่วมมือ (consortium) เพื่อร่วมกันพัฒนาเทคโนโลยีเป้าหมายร่วมกัน R&D Consortium	
มาตรการทางการเงินสนับสนุนการปรับปรุงสายการผลิต	

Funding support to change production line	
มาตรการเงินกู้ดอกเบี้ยต่ำ Low interest rate loan	
มาตรการส่งเสริมการลงทุนการผลิตยานยนต์ไฟฟ้า ชิ้นส่วนและอุปกรณ์ของสำนักงานคณะกรรมการส่งเสริมการลงทุน BOI incentives for EVs producers in producing EVs (including hybrid, plug-in) hybrid and parts)	
การลดภาษีสรรพสามิตสำหรับผู้ผลิตยานยนต์ไฟฟ้า Excise tax reduction on EVs	
การลดภาษีสรรพสามิตสำหรับแบตเตอรี่ Battery import duties reduction	
มาตรการลดหย่อนภาษีวิจัยและพัฒนา 200 R&D tax 200%	
มาตรการสนับสนุนการสร้างสถานีอัดประจุไฟฟ้า Supporting measure to build charging station	
การบริการโครงสร้างพื้นฐานสำหรับการวิเคราะห์ทดสอบ สอบเทียบ ที่มีความหลากหลายขึ้น Infrastructure on Testing /calibration service	
มาตรการจัดซื้อจัดจ้างภาครัฐสำหรับยานยนต์ไฟฟ้า Government procurement on EVs	
มาตรการอุดหนุนทางการเงินหรือภาษีสำหรับผู้ซื้อยานยนต์ไฟฟ้า Grants or tax relief for buyers	
อื่นๆ โปรดระบุ…………………………………………………………………….	

34. จากประสบการณ์ของท่าน มาตรการภาครัฐที่มีอยู่ในปัจจุบัน ก่อให้เกิดความร่วมมือระหว่างบริษัท มหาวิทยาลัย/สถาบันวิจัย ในการพัฒนาความสามารถทางเทคโนโลยีของบริษัทหรือไม่
Have government policies helped promoting collaboration among firms, university and government agencies to develop technological capability of your firm?

☐ ไม่No ☐ ใช่Yes

ถ้ามีส่วน โปรดระบุชื่อ

มาตรการ..

If yes, please specify the policy support youobtained

โปรดให้ความเห็นถึงความมีประสิทธิภาพของมาตรการข้างต้น And please comment on the effectiveness of its implementation

....
....

ขอขอบคุณเป็นอย่างสูงในความร่วมมือ

Thank you for your cooperation

D. Permission letter for fieldwork in Thailand

University of Strathclyde
Engineering

The University of Strathclyde
16 Richmond St, Glasgow
G1 1XQ, UK

17 June 2019

Subject: Permission Letter for fieldwork in Thailand

To Whom It May Concern:

I am writing to let you know that I am permitting my student, MS.PATTARAWAN CHARUMILIN who is a postgraduate student at the University of Strathclyde, Glasgow, United Kingdom, to travel to Thailand to collect data for her Ph.D. research.

Her research is on 'Evolution of knowledge networks, technological learning and development of SMEs : A multi-level perspective of innovation and environmental trends in the automotive sector in Thailand. She would need primary data to be obtained through fieldwork to be able to complete his Ph.D. thesis.

The fieldwork will span three months from 9th July 2019 – 16th October 2019. While on fieldwork, she will regularly report to me on the progress of her fieldwork.

Respectfully yours,

[redacted]

Dr.Girma Zawdie
Supervisor
Senior lecturer
Department of Civil and Environmental Engineering
The University of Strathclyde, Glasgow, UK.

E. Cronbach's Alpha :

1) Source of Knowledge

Case Processing Summary

		N	%
Cases	Valid	35	70.0
	Excluded[a]	15	30.0
	Total	50	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.782	.789	12

2) Application

Case Processing Summary

		N	%
Cases	Valid	41	82.0
	Excluded[a]	9	18.0
	Total	50	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.860	.874	5

3) Assimilation

Case Processing Summary

		N	%
Cases	Valid	41	82.0
	Excluded[a]	9	18.0
	Total	50	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.882	.883	4

4) Transformation

Case Processing Summary

		N	%
Cases	Valid	41	82.0
	Excluded[a]	9	18.0
	Total	50	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.882	.883	4

5) Application

Case Processing Summary

		N	%
Cases	Valid	41	82.0
	Excluded[a]	9	18.0
	Total	50	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.866	.867	3

F) Mann-Whitney Test of Table 5.13

Ranks

	FirmSize	N	Mean Rank	Sum of Ranks
AcquisitionMedian	SMEs	18	16.75	301.50
	Large Firms	24	25.06	601.50
	Total	42		
AssimilationMedian	SMEs	18	16.69	300.50
	Large Firms	23	24.37	560.50
	Total	41		
TransformationMedian	SMEs	18	15.28	275.00
	Large Firms	23	25.48	586.00
	Total	41		
ExploitationMedian	SMEs	18	19.69	354.50
	Large Firms	23	22.02	506.50
	Total	41		
PACAPMedian	SMEs	18	16.61	299.00
	Large Firms	24	25.17	604.00
	Total	42		
RACAPMedian	SMEs	18	17.58	316.50
	Large Firms	23	23.67	544.50
	Total	41		
APCMedian	SMEs	18	16.42	295.50
	Large Firms	24	25.31	607.50
	Total	42		

Test Statistics[a]

	AcquisitionMedian	AssimilationMedian	TransformationMedian	ExploitationMedian	PACAPMedian	RACAPMedian	APCMedian
Mann-Whitney U	130.500	129.500	104.000	183.500	128.000	145.500	124.500
Wilcoxon W	301.500	300.500	275.000	354.500	299.000	316.500	295.500
Z	-2.519	-2.157	-2.961	-.701	-2.527	-1.853	-2.616
Asymp. Sig. (2-tailed)	.012	.031	.003	.483	.012	.064	.009

a. Grouping Variable: FirmSize

G) Chi-Square test of Table 5.16

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Size * Triplehelixlink	41	95.3%	2	4.7%	43	100.0%

Size * Triplehelixlink Crosstabulation

			Triplehelixlink		Total
			Triple helix	No Triple helix	
Size	SMEs	Count	7	10	17
		Expected Count	10.8	6.2	17.0
		% within Size	41.2%	58.8%	100.0%
		% within Triplehelixlink	26.9%	66.7%	41.5%
	Large firms	Count	19	5	24
		Expected Count	15.2	8.8	24.0
		% within Size	79.2%	20.8%	100.0%
		% within Triplehelixlink	73.1%	33.3%	58.5%
Total		Count	26	15	41
		Expected Count	26.0	15.0	41.0
		% within Size	63.4%	36.6%	100.0%
		% within Triplehelixlink	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.190[a]	1	.013		
Continuity Correction[b]	4.661	1	.031		
Likelihood Ratio	6.252	1	.012		
Fisher's Exact Test				.021	.015
Linear-by-Linear Association	6.039	1	.014		
N of Valid Cases	41				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 6.22.

b. Computed only for a 2x2 table

H) Multiple Regression

a) Enter Model : Dependent Variable: APC

Descriptive Statistics

	Mean	Std. Deviation	N
AbsorptiveCapacity	3.6109	.62025	40
FirmSize=Large Firms	.6000	.49614	40
Turbulence	3.4010	1.20268	40
InterfirmDepth	6.70	4.952	40
TriplehelixDepth	8.55	6.587	40
BREADTH	1.75	.543	40

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.377[a]	.142	.096	.58974	.142	3.070	2	37	.058
2	.549[b]	.301	.198	.55543	.159	2.571	3	34	.070

a. Predictors: (Constant), Turbulence, FirmSize=Large Firms

b. Predictors: (Constant), Turbulence, FirmSize=Large Firms, InterfirmDepth, BREADTH, TriplehelixDepth

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.135	2	1.068	3.070	.058[b]
	Residual	12.868	37	.348		
	Total	15.004	39			
2	Regression	4.515	5	.903	2.927	.027[c]
	Residual	10.489	34	.309		
	Total	15.004	39			

a. Dependent Variable: AbsorptiveCapacity

b. Predictors: (Constant), Turbulence, FirmSize=Large Firms

c. Predictors: (Constant), Turbulence, FirmSize=Large Firms, InterfirmDepth, BREADTH, TriplehelixDepth

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	3.354	.336		9.986	.000	2.674	4.035		
	FirmSize=Large Firms	.467	.196	.374	2.389	.022	.071	.864	.946	1.057
	Turbulence	-.007	.081	-.014	-.087	.931	-.171	.157	.946	1.057
2	(Constant)	3.046	.454		6.714	.000	2.124	3.968		
	FirmSize=Large Firms	.366	.189	.293	1.940	.061	-.017	.750	.902	1.108
	Turbulence	.072	.081	.139	.880	.385	-.094	.237	.827	1.209
	InterfirmDepth	-.003	.021	-.023	-.137	.892	-.045	.040	.737	1.357
	TriplehelixDepth	.048	.018	.505	2.689	.011	.012	.084	.582	1.717
	BREADTH	-.163	.206	-.143	-.795	.432	-.581	.254	.635	1.574

a. Dependent Variable: AbsorptiveCapacity

b) Stepwise Model : Dependent variable APC

Descriptive Statistics

	Mean	Std. Deviation	N
AbsorptiveCapacity	3.6109	.62025	40
FirmSize=Large Firms	.6000	.49614	40
Turbulence	3.4010	1.20268	40
InterfirmDepth	6.70	4.952	40
TriplehelixDepth	8.55	6.587	40
BREADTH	1.75	.543	40

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.377[a]	.142	.120	.58199	.142	6.297	1	38	.016
2	.519[b]	.270	.230	.54421	.127	6.459	1	37	.015

a. Predictors: (Constant), FirmSize=Large Firms

b. Predictors: (Constant), FirmSize=Large Firms, TriplehelixDepth

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.133	1	2.133	6.297	.016[b]
	Residual	12.871	38	.339		
	Total	15.004	39			
2	Regression	4.046	2	2.023	6.830	.003[c]
	Residual	10.958	37	.296		
	Total	15.004	39			

a. Dependent Variable: AbsorptiveCapacity

b. Predictors: (Constant), FirmSize=Large Firms

c. Predictors: (Constant), FirmSize=Large Firms, TriplehelixDepth

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	3.328	.145		22.874	.000	3.034	3.623		
	FirmSize=Large Firms	.471	.188	.377	2.509	.016	.091	.852	1.000	1.000
2	(Constant)	3.102	.163		19.080	.000	2.773	3.431		
	FirmSize=Large Firms	.352	.182	.282	1.939	.060	-.016	.721	.934	1.071
	TriplehelixDepth	.035	.014	.370	2.541	.015	.007	.063	.934	1.071

a. Dependent Variable: AbsorptiveCapacity

c) Enter Model : Dependent Variable PACAP

Descriptive Statistics

	Mean	Std. Deviation	N
PACAP	3.6889	.62612	40
FirmSize=Large Firms	.6000	.49614	40
Turbulence	3.4010	1.20268	40
InterfirmDepth	6.70	4.952	40
TriplehelixDepth	8.55	6.587	40
BREADTH	1.75	.543	40

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Turbulence, FirmSize=Large Firms[b]	.	Enter
2	InterfirmDepth, BREADTH, TriplehelixDepth[b]	.	Enter

a. Dependent Variable: PACAP

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.403[a]	.162	.117	.58838	.162	3.582	2	37	.038
2	.558[b]	.312	.211	.55628	.150	2.465	3	34	.079

a. Predictors: (Constant), Turbulence, FirmSize=Large Firms

b. Predictors: (Constant), Turbulence, FirmSize=Large Firms, InterfirmDepth, BREADTH, TriplehelixDepth

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.480	2	1.240	3.582	.038[b]
	Residual	12.809	37	.346		
	Total	15.289	39			
2	Regression	4.768	5	.954	3.082	.021[c]
	Residual	10.521	34	.309		
	Total	15.289	39			

a. Dependent Variable: PACAP

b. Predictors: (Constant), Turbulence, FirmSize=Large Firms

c. Predictors: (Constant), Turbulence, FirmSize=Large Firms, InterfirmDepth, BREADTH, TriplehelixDepth

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	3.533	.335		10.543	.000	2.854	4.213		
	FirmSize=Large Firms	.478	.195	.379	2.449	.019	.083	.874	.946	1.057
	Turbulence	-.039	.081	-.074	-.480	.634	-.202	.125	.946	1.057
2	(Constant)	3.232	.454		7.111	.000	2.308	4.155		
	FirmSize=Large Firms	.378	.189	.300	2.001	.053	-.006	.762	.902	1.108
	Turbulence	.038	.081	.073	.470	.642	-.127	.204	.827	1.209
	InterfirmDepth	-.004	.021	-.029	-.174	.863	-.046	.039	.737	1.357
	TriplehelixDepth	.047	.018	.492	2.638	.012	.011	.083	.582	1.717
	BREADTH	-.157	.206	-.136	-.764	.450	-.576	.261	.635	1.574

Dependent Variable: PACAP

d) Stepwise model : Dependent Variable PACAP

Descriptive Statistics

	Mean	Std. Deviation	N
PACAP	3.6889	.62612	40
FirmSize=Large Firms	.6000	.49614	40
Turbulence	3.4010	1.20268	40
InterfirmDepth	6.70	4.952	40
TriplehelixDepth	8.55	6.587	40
BREADTH	1.75	.543	40

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	FirmSize=Large Firms	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	TriplehelixDepth	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: PACAP

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.396[a]	.157	.135	.58239	.157	7.076	1	38	.011
2	.540[b]	.292	.254	.54088	.135	7.057	1	37	.012

a. Predictors: (Constant), FirmSize=Large Firms

b. Predictors: (Constant), FirmSize=Large Firms, TriplehelixDepth

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.400	1	2.400	7.076	.011[b]
	Residual	12.889	38	.339		
	Total	15.289	39			
2	Regression	4.465	2	2.232	7.630	.002[c]
	Residual	10.824	37	.293		
	Total	15.289	39			

a. Dependent Variable: PACAP

b. Predictors: (Constant), FirmSize=Large Firms

c. Predictors: (Constant), FirmSize=Large Firms, TriplehelixDepth

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	3.389	.146		23.276	.000	3.094	3.684		
	FirmSize=Large Firms	.500	.188	.396	2.660	.011	.119	.881	1.000	1.000
2	(Constant)	3.154	.162		19.519	.000	2.827	3.481		
	FirmSize=Large Firms	.376	.181	.298	2.084	.044	.010	.743	.934	1.071
	TriplehelixDepth	.036	.014	.380	2.657	.012	.009	.064	.934	1.071

a. Dependent Variable: PACAP

e) Enter Model : Dependent Variable RACAP

Descriptive Statistics

	Mean	Std. Deviation	N
RACAP	3.4982	.64379	39
FirmSize=Large Firms	.5897	.49831	39
Turbulence	3.4260	1.20788	39
InterfirmDepth	6.59	4.967	39
TriplehelixDepth	8.41	6.612	39
BREADTH	1.74	.549	39

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.333[a]	.111	.062	.62360	.111	2.250	2	36	.120
2	.516[b]	.266	.155	.59177	.155	2.326	3	33	.093

a. Predictors: (Constant), Turbulence, FirmSize=Large Firms

b. Predictors: (Constant), Turbulence, FirmSize=Large Firms, InterfirmDepth, BREADTH, TriplehelixDepth

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.750	2	.875	2.250	.120[b]
	Residual	14.000	36	.389		
	Total	15.750	38			
2	Regression	4.193	5	.839	2.395	.059[c]
	Residual	11.556	33	.350		
	Total	15.750	38			

a. Dependent Variable: RACAP

b. Predictors: (Constant), Turbulence, FirmSize=Large Firms

c. Predictors: (Constant), Turbulence, FirmSize=Large Firms, InterfirmDepth, BREADTH, TriplehelixDepth

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	3.105	.357		8.703	.000	2.382	3.829		
	FirmSize=Large Firms	.441	.208	.342	2.121	.041	.019	.863	.952	1.050
	Turbulence	.039	.086	.073	.451	.654	-.135	.213	.952	1.050
2	(Constant)	2.803	.484		5.795	.000	1.819	3.786		
	FirmSize=Large Firms	.342	.202	.265	1.691	.100	-.069	.753	.909	1.100
	Turbulence	.117	.087	.220	1.347	.187	-.060	.294	.837	1.195
	InterfirmDepth	-.003	.022	-.023	-.132	.895	-.049	.043	.742	1.348
	TriplehelixDepth	.048	.019	.497	2.564	.015	.010	.087	.592	1.688
	BREADTH	-.169	.219	-.144	-.770	.447	-.614	.277	.638	1.567

Dependent Variable: RACAP

f) Stepwise Model : Dependent Variable RACAP

Descriptive Statistics

	Mean	Std. Deviation	N
RACAP	3.4982	.64379	39
FirmSize=Large Firms	.5897	.49831	39
Turbulence	3.4260	1.20788	39
InterfirmDepth	6.59	4.967	39
TriplehelixDepth	8.41	6.612	39
BREADTH	1.74	.549	39

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.326[a]	.106	.082	.61686	.106	4.391	1	37	.043
2	.460[b]	.211	.167	.58741	.105	4.802	1	36	.035

a. Predictors: (Constant), FirmSize=Large Firms

b. Predictors: (Constant), FirmSize=Large Firms, TriplehelixDepth

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.671	1	1.671	4.391	.043[b]
	Residual	14.079	37	.381		
	Total	15.750	38			
2	Regression	3.328	2	1.664	4.822	.014[c]
	Residual	12.422	36	.345		
	Total	15.750	38			

a. Dependent Variable: RACAP

b. Predictors: (Constant), FirmSize=Large Firms

c. Predictors: (Constant), FirmSize=Large Firms, TriplehelixDepth

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	3.250	.154		21.075	.000	2.938	3.562		
	FirmSize=Large Firms	.421	.201	.326	2.096	.043	.014	.828	1.000	1.000
2	(Constant)	3.038	.176		17.285	.000	2.682	3.395		
	FirmSize=Large Firms	.315	.197	.244	1.599	.119	-.085	.715	.940	1.063
	TriplehelixDepth	.033	.015	.334	2.191	.035	.002	.063	.940	1.063

a. Dependent Variable: RACAP