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The window of opportunity: a case study of the battery electric vehicle in Thailand

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Abstract

Purpose – Thailand, although a late entrant, has emerged as a significant center for the production and export of internal combustion engine (ICE) vehicles in Asia. With the arrival of a disruptive battery-electric vehicle (BEV), this study aims to investigate whether Thailand can exploit this window of opportunity to leapfrog.

Design/methodology/approach – This paper uses data sourced from Thailand's Department of Intellectual Property to analyze electric vehicle (EV) patent applications. This paper collected qualitative data and conducted interviews with several EV manufacturers.

Findings – Although Japanese automakers dominate essential EV technology patents, they trail behind Chinese automakers, which benefited from the Free Trade Agreement (FTA) in EV sales. The incumbents, Japanese and Western, choose to expand their production of hybrid electric vehicles (HEVs) and plug-in hybrid vehicles. ICE technology does not constrain new entrants, such as Chinese automakers, Japanese newcomers and Thai newcomers. Compared to Japanese carmakers stuck with ICE and HEV technologies, they have been transitioning to BEVs at a faster pace. BEV has opened the door for large Thai indigenous energy corporations to enter the automotive industry by focusing on niche areas (nonfour-wheel vehicles) and supporting businesses like charging stations. In summary, Thailand has successfully attracted foreign direct investment (FDI) into the EV sector, but it has not yet succeeded in developing indigenous technologies related to EVs. The Thai automobile sector fails to leapfrog because it is too tied up with Japanese automotive production networks and has an unfavorable FTA with China.

Originality/value – This study sheds light on the limitations of an industrial development strategy relying on openness to trade and FDI without adequately strengthening indigenous technologies and firms, as the country adopting the strategy fails to leapfrog when the window of opportunities created by disruptive technologies arrives.

Keywords Patent, Battery electric vehicle (BEV), Automotive industry, Leapfrogging, Thailand

Paper type Research paper

1. Introduction

During this turbulent regime, there is a window of opportunity for new industries and new companies to leapfrog with disruptive technology. This study aims to determine whether it is

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true by examining Thailand's emerging battery-electric vehicle (BEV) industry as an example. The study on Thailand can be a lesson for other developing countries, as several of them and their local companies are also struggling against comparable challenges toward BEV transition.

Thailand's automotive industry has been developing since the 1960s. It has become a final assembly hub for multinational corporations (MNCs) in Asia, providing opportunities for local suppliers to produce automobile parts. It ranked 10th in global automotive production in 2022. Within ASEAN, Thailand is the largest car producer, with over 1.83 million motor vehicles in 2023 (Thailand Automotive Institute [TAI], 2024). Nonetheless, almost all of the cars produced have internal combustion engines (ICEs) and hybrids rather than BEVs.

Although Thailand lacks significant resources for producing electric batteries, it is a relatively strong production base for automotive parts and BEV-related components such as electric motors, converters and inverters. The Thai Government believes that local EV production and participation in the supply chain may be feasible (Schröder, 2021).

In 2017, the Thai Government sped up its efforts to establish itself as a major production hub for zero-emission vehicles (ZEVs). ZEVs consist of hybrid electric vehicles (HEVs), plug-in hybrid vehicles (PHEVs) and BEVs. The government implemented six demand-pull and technology-push measures, such as domestic demand creation, infrastructure building, EV standard setting, tax incentives for investment promotion and used battery handling (Kaewtatip, 2019).

Although Chinese automakers tend to prioritize BEVs, existing Japanese and European producers in Thailand are leveraging government incentives to expand and increase their production of HEVs and PHEVs, which are integral to their ICE vehicle supply chain. The Chinese investment in BEVs in Thailand helps them reduce risks from a geopolitical confrontation between the USA and China, diversify from the competitive Chinese BEV market and take advantage of the strong Thai automotive parts supply chain. In ASEAN, Thailand leads the shift toward BEV production, closely followed by Indonesia, Malaysia and Vietnam (Yean, 2022). The Global Electric Mobility Readiness Index for 2022 ranks Thailand ninth globally (Prasad *et al.*, 2022).

Neither parts suppliers nor carmakers have fully developed the new know-how required for the production of electric drivetrains. The new components and systems deployed in BEVs will create opportunities for battery makers, battery cell component makers and their suppliers while reducing the role of traditional ICE component suppliers (Bierau *et al.*, 2016). In theory, Thailand's increasing BEV production may present a window of opportunity for local part suppliers to advance into new and more profitable businesses.

This study tries to answer the question of whether Thailand can leapfrog into the BEV industry by analyzing all EV patents applied to Thailand's Department of Intellectual Property (DIP) during 1979–2022. We also collected qualitative data and conducted interviews with almost all the key automakers and concerned policymakers (Appendix).

By examining the technological strategies, patent activity and innovation capabilities of firms within Thailand's automotive sector, this research provides insights into the challenges and potential for technological leapfrogging. It extends the existing body of knowledge on technological catch-up by focusing on the BEV industry, an area with limited prior research in the context of Southeast Asian economies. This study highlights the critical role of government policies in shaping the ability of local firms to integrate into and benefit from global value chains.

The rest of the paper proceeds as follows: Section 2 reviews BEVs as windows of opportunity for technological catch-up, whereas Section 3 describes the development of BEVs in Thailand. Section 4 discusses data and research methodology, and Section 5

analyzes BEV patent applications in Thailand. Section 6 of this paper provides conclusions and policy recommendations.

2. Battery-electric vehicles present opportunities for technological leapfrog

Most studies of firms in developing countries portray them as latecomers, lagging behind technological frontiers and far from demanding customers. They catch up by assimilating and adapting forerunners mature technologies (Hobday, 1995). Some latecomers' firms achieved technological catchup not by outright following their forerunners' technological learning paths but by skipping some stages and/or creating their own paths (Lee, 2013). Several studies on latecomers' catching up focus on successful cases in newly industrialized Northeast Asian economies like Korea, Taiwan and China in technologically mature industries (Hobday, 1995; Lee *et al.*, 2005; Lee and Yoon, 2010; Lin *et al.*, 2016; Mathews and Cho, 1999; Mathews, 2007). Research on firms from other countries, especially those in industries with a wealth of opportunities due to the change in the technological paradigm, is quite limited. Perez and Soete (1988) proposed that emerging technological paradigms may serve as a window of opportunity for latecomers to leapfrog into emerging or new industries.

In the automotive sector, much of the technical knowledge is tacit, making it difficult for latecomers to replicate the complex technologies of established incumbents. Critical know-how is deeply embedded in specialized networks and collaborations on research and development (R&D), design and component supply chains, which creates significant barriers for newcomers. As a result, building capacity in this industry often takes decades, even with strategies like imitation and reverse engineering. However, the rise of BEVs offers new opportunities for indigenous firms in developing countries. BEVs, driven by the need for energy conservation and environmental protection, represent a significant technological shift from traditional ICEs. In BEVs, motors and batteries replace conventional engines and transmissions, supported by technologies like battery management systems (BMSs), drive control units (DCUs), inverters and advanced driver assistance systems, providing new avenues for innovation and competition (Feng and Li, 2019).

The global shift toward BEVs presents a window of opportunity for latecomer firms in developing countries to achieve technological leapfrogging. Studies suggest that while latecomer firms have the potential to catch up by leveraging the technological advancements of early movers, their success depends on robust government support and the simultaneous addressing of production, demand, knowledge and infrastructure challenges – particularly through direct subsidies to automakers and consumers – as well as strong innovation capabilities and access to advanced technologies (Konda, 2023; Deqiang *et al.*, 2023). China's experience illustrates how strategic policies and partnerships can drive success in the BEV sector but challenges like infrastructure gaps, financial constraints and reliance on foreign technology pose significant barriers for other developing countries (Altenburg *et al.*, 2022; Wang and Kimble, 2011).

However, the ability to replicate China's success in other developing countries remains uncertain, as seen in a comparative study of Brazil, India and South Africa (Lema *et al.*, 2024). These countries, while having established automotive industries, face structural challenges that make it difficult to fully exploit the EV-driven window of opportunity. The study highlights that, unlike the well-documented cases in Northeast Asia, there is limited research on how developing nations outside this region can leverage EV technology for industrial catch-up. This gap underscores the need for further exploration into how diverse emerging economies can navigate the opportunities and challenges presented by the shift to electric mobility.

Thailand's automotive sector comprises 30 vehicle businesses and 13 motorcycle companies, supported by a network of 720 first-tier suppliers, with 47% of them being predominantly foreign-owned, notably Japanese. These suppliers are responsible for manufacturing critical components such as engines, drivetrains, steering systems, suspensions, brakes, wheels, tires, bodywork, interiors, electronics and electric systems. In addition, there are over 1,687 suppliers at the second and lower tiers, with 70% being small- and medium-sized Thai enterprises (Thailand Automotive Institute, 2024). Despite the presence of established Thai automakers and suppliers, they have encountered challenges in developing indigenous technologies and competing in the market for high-value vehicles.

The cumulative characteristics of the industry's capacity-building efforts have left indigenous Thai manufacturers straggling behind their leading Japanese counterparts. Thai suppliers frequently lack the necessary technological expertise and capabilities to transition into more sophisticated, higher-value-added segments and effectively compete with firms from more industrialized countries. Although there are instances of technological spillovers from foreign-owned first-tier suppliers to domestic second-tier suppliers, such occurrences typically result in only incremental advances (Natsuda and Thoburn, 2013). Thailand's automotive sector has struggled to demonstrate significant innovation, as evidenced by its relative lack of substantial advancements (Kohpaiboon, 2008). In Thailand, automotive companies have shown a tendency to be slow and passive in technological learning, with government policies and supporting organizations such as research institutes and universities falling short of adequately assisting local firms to enhance their capabilities (Intarakumnerd and Charoenporn, 2015; 2016).

Thailand's product champion approach, which was effective in increasing the production of pickup trucks, has been implemented to promote EVs through the provision of targeted incentives, such as tax exemptions. Nevertheless, this approach is less effective than in the past in the EV sector due to uncertain demand and ambiguous production targets. To thrive in the changing automotive industry, Thailand may need to transition from conventional industrial policies to more comprehensive innovation-oriented strategies (Schröder, 2021).

Theoretically, the transition from conventional ICE to EVs marks a significant technological paradigm shift, creating unique opportunities for countries like Thailand to leapfrog in automotive technology. For Thailand, which has been a major production hub for ICE vehicles but has lagged in indigenous technological development, the shift to EVs offers a chance to break free from its reliance on established foreign technologies and production networks, particularly those tied to Japanese automakers. The new EV ecosystem relies mainly on electric motors, batteries and associated components. It provides an opening for Thai companies to develop and innovate in these emerging technologies, potentially enabling them to catch up or even surpass traditional automotive leaders in specific areas. This transformation represents a unique leapfrogging opportunity for Thailand.

This research will explore whether latecomer firms outside Northeast Asia, like those in Thailand, can leverage this window of opportunity to leapfrog technologically by examining the strategies and learning paths of local EV firms and suppliers compared to incumbent MNCs in the Thai automotive industry.

3. Development of battery-electric vehicles in Thailand

Thailand has ratified the Paris Agreement, which mandates member countries to reduce greenhouse gas emissions by 20%–25% by 2030. In recognition of the critical role EVs play in mitigating global warming, the Thai Government has committed to accelerating EV adoption. The government has identified the "next-generation automotive" industry as one of the 10 key sectors to drive Thailand's future economic growth (Thananusak *et al.*, 2020).

In 2015, Thailand developed its national EV roadmap, aiming to establish itself as ASEAN's hub for EVs. The National EV Policy Committee, also known as the EV Board, first met in March 2020 and endorsed the "Thailand Smart Mobility 30@30" roadmap. This initiative aims to produce 750,000 EVs, constituting 30% of the country's automotive production capacity, by 2030. To support this ambitious goal, the Ministry of Finance has significantly reduced the EV excise tax from 20%–40% to 2%–8%. The Ministry of Industry has set national EV standards and developed plans for EV battery end-of-life management. The Board of Investment (BOI) has introduced investment incentives for the production of EVs, EV components and the establishment of charging stations.

From 2017 through July 2023, the BOI approved 29 ZEV investment projects, amounting to US$$2,084.6m with a production capacity of 718,595 vehicles (Table 1). Notably, major Thai energy conglomerates such as Energy Absolute (EA) and PTT Group have ventured into the BEV market. To produce BEVs and electric buses, EA has invested in Mine Mobility and Absolute Assembly (AAB). In addition, EA collaborates with Taiwanese company AMITA Technology to manufacture lithium-ion polymer batteries in Thailand. PTT group has formed a joint venture with Foxconn, named Horizon Plus, to produce BEVs in Thailand. PTT's subsidiaries, GPSC and Nuovo Plus, are preparing to produce lithium iron phosphate batteries for electric vehicles (EVs). Furthermore, the BOI has approved additional tax incentives for domestic production or use of critical components such as batteries, traction motors, BMSs, DCUs, inverters, onboard chargers, DC/DC converters, high-voltage harnesses, battery cooling systems and electric charging station equipment.

The EV/Internal combustion engine vehicle (ICEV) ratio has been on an upward trend over the past six years, as illustrated in Table 2. From 2018 to 2023, there has been a substantial increase in the registrations of HEVs, PHEVs and BEVs. This growth has been particularly pronounced following the introduction of the Thai Government's second EV Package (2022–2025) in March 2022, which aims to incentivize EV purchases by reducing their price through subsidies provided to car manufacturers. As of 2023, EVs constitute 23.7% of registered ICEVs, accounting for 19.1% of the total number of registered cars.

Table 1. BOI's promoted projects on ZEVs and ZEVs' parts and components

Item (production capacity)	No. of projects	Investment (million US$)	Promoted firms
HEVs (305,955 cars)	6	832.2	GWM, Honda, MG, Mitsubishi, Nissan, Toyota
PHEVs (132,000 cars)	7	257.2	BMW, BYD, GWM, Mercedes Benz, MG, Mitsubishi, Toyota
BEVs (276,640 cars)	14	935.3	BYD, FOMM, GWM, Honda, Horizon, Mazda, Mercedes Benz, MG, Mine Mobility, Mitsubishi, Nissan, Skywell, Takano, Toyota
Battery electric bus (4,000 cars)	2	59.9	Absolute Assembly, Sakun.C
Battery for EVs	21	260.8	DTS, Draexlmaier, Toyota, Honda, Nissan, TESM, SAIC, MMTH, GWM, BYD, Mine Mobility, STRON
EV parts and components	17	164.7	Delta, Jatco, Pioneer Motor, Nidic Dräxlmaier, Elite Group, Lumen, BYD, MCCT, Valeo

Notes: Investment values excluding cost of land and working capital 36.32 Baht = 1 USD (as of May 19/2024)
Source: The Board of Investment of Thailand (as of July 2023)

Table 2. Number of HEVs and PHEVs, BEVs and ICEVs registered in Thailand from 2018 to 2023

Year	HEVs and PHEVs	BEVs	HEVs and PHEVs and BEVs	ICEVs	EVs/ICEVs (%)
2018	20,057	190	20,247	1,047,938	1.9
2019	26,447	781	2.6%	1,055,503	2.6
2020	29,460	1,408	30,868	851,104	3.6
2021	41,399	2,111	43,510	797,730	5.5
2022	74,900	10,901	85,801	869,189	9.9
2023	96,179	78,287	174,466	737,527	23.7

Source: Thailand Automotive Institute

Local universities and public research institutes (PRIs) in Thailand play a limited role in the development of BEVs by focusing on research and innovation in key areas. With government support through funding programs like the Program Management Unit for Competitiveness Enhancement, these institutions engage in near-market research and collaborate with small Thai-owned companies to develop technologies that can give local businesses a competitive edge such as batteries, motors, inverters, controllers, electric bikes, software, battery cells and EV conversion technologies. The program's research budget for "Future Mobility" stands at approximately US$30m annually, though this amount appears modest relative to the scale of the industry. Notably, due to its emphasis on near-market technologies rather than fundamental EV technology, patenting inventions stemming from these projects could pose challenges (Thanakarn Wongdeethai, NXPO, personal communication, February 18, 2022).

4. Data and research methodology

Patent analysis may not be entirely reliable for assessing the definitive value of automotive technologies. Patents may not explicitly document key technologies in car manufacturing, which are often tacit and embedded within complex technological or social networks. For carmakers and technological innovators, patenting is merely one of several strategies for deriving economic benefits from innovations (Feng and Li, 2019). Although patents are increasingly important, acquiring intellectual property rights or patent licenses alone does not enable a firm to master the majority of knowledge within the automotive market. However, patent protection plays a significant role in helping local automotive firms advance from production to more sophisticated activities (Intarakumnerd and Charoenporn, 2015).

Despite these limitations, when combined with qualitative data from interviews and secondary sources, patent analysis can provide valuable insights in this study. Patent applications can reveal the evolution of specific firms and highlight comparative trends among different groups. In Thailand, there are notable disparities in patenting capabilities among various vehicle manufacturers. Therefore, patent analysis serves as an effective method for illustrating competence gaps.

We conducted an analysis of EV-related inventions and design patents submitted to the DIP. The DIP website provides comprehensive information for each patent, including the application date, International Patent Classification (IPC) code, title, and abstract (in Thai). We initially used the IPC codes to identify four domains of EV-related patents, including power electronics, batteries, electric motors and charging and discharging (Feng and Magee, 2020). Table 3 provides the IPC codes of EV-related patent domains and subdomains.

Table 3. IPC codes for EV-related technology domains and subdomains

Domain*	Subdomain	IPC codes	No. of patents (petty patent)
Power electronics		*B60L; B60K6; B20W20*	*455 (14)*
	Power electronics	B60K 6/00; B60K 6/42; B60K 6/44; B60K 6/442; B60K 6/445; B60K 6/448; B60K 6/46; B60K 6/48; B60K 6/485; B62M23/02; B60W 10/00; B60W 20/00	188 (2)
	Other EV power electronics	B60L 15/00; B60L 50/00; B60L 50/10; B60L 50/40; B60L 50/50; B60L 58/00;	8
Charging		*H02J*	*483 (78)*
	EV charging and discharging	H02J 7/00; H02J 7/02; H02J 7/14; H02J 7/34; H02J 53/00; B60L 11/18; B60L 53/00; B60L 53/10; H01M 10/44; H01M 10/46; H01M 10/48;	351 (53)
EV battery		*H01M*	*960 (64)*
	Lead-acid battery	H01M 2/28; H01M 4/14; H01M 4/68; H01M 10/06; H01M 4/73; H01M 4/82	82 (4)
	Nickel battery	H01M 4/32; H01M 10/42	28 (1)
	Lithium-ion	H01M 10/052; H01M 10/0525	3
	Other EV battery	H01M 4/00; H01M 4/02; H01M 50/00; H01M 10/00; H01M 10/56;	81 (12)
Electric motor		*H02K*	*952 (68)*
	Induction motor	H02K 44/06; H02K 17/00; H02K 17/02; H02K 17/04; H02K 17/12; H02K 17/16; H02K 17/22; H02K 17/26; H02K 17/28; H02K 17/30; H02K 17/32; H02K 17/34;	17 (1)
	Permanent magnet motor	H02K 1/17, H02K 1/27	111
	Other motor	H02K 1/00; H02K 5/00; H02K 7/00; H02K 11/00; H02K 21/00; H02K 29/00; F16H 59/00	153 (14)

Notes: Categorization of domains and subdomains are adapted from Feng and Magee (2020) and Schmitt *et al.* (2016)
Source: Thailand's Department of Intellectual Property

In this study, we used a range of keywords related to "electric vehicles" and company names (in the Thai language) to search within the "titles" and "abstracts" of invention and design patents filed with the DIP between January 1979 and May 2024. In addition, we analyzed the patent applications of 16 BOI-promoted EV projects. We classified these projects into five categories: Japanese incumbents such as Toyota, Honda, Nissan, Mitsubishi and Mazda; European incumbents like Mercedes-Benz and BMW; Chinese new entrants like BYD, Great Wall Motors (GWM), SAIC-CP and Skywell; Japanese new entrants like FOMM and Takano; and Thai new entrants like Mine Mobility, AAB, Horizon and Sakun.C.

Furthermore, we conducted interviews with senior management personnel, including general managers, vice presidents and R&D/technology managers, from most of these 16 companies during the period of 2020–2023. These interviews aimed to gain insights into their strategies for EV production and technological development. We collected secondary data from company reports and media sources to support our analysis.

Table 3 illustrates that within the four key EV domain technologies, there is a higher number of patent applications for traditional motors and lead-acid-based electric batteries, which cannot be used for today's EVs. This trend is attributed to Thailand's robust and longstanding production base in traditional electrical and consumer electronics industries. Conversely, there are relatively fewer patents concerning today's core EV technologies, such as lithium-ion battery technology and essential power electronics. Specifically, there are 2,740 patent applications (alongside 223 petty patent applications) within these four EV technology domains. Thai nationals have contributed 228 patent applications (or 8.3%) and 180 petty patents (or 80.7%), with the majority of petty patents being held by Thai individuals. The strength in petty patent registration but the weakness in invention patent registration of Thai nationals demonstrate that Thai firms are weak in *radical* technological invention but there are some *incremental* improvements in core EV technology areas. Furthermore, Thai companies lead in the market for charging and discharging technologies, a trend consistent with their established core energy businesses that are now expanding into the EV sector.

Table 4 presents the number of patent applications filed by BOI-promoted EV producers from 1979 to May 2024. BOI-supported EV manufacturers hold a total of 5,060 invention patents and 1,414 design patents. Following the introduction of Thailand's ZEV promotion program in 2017, there has been an increase in the number of EV-related patent applications. Nevertheless, EV-related patents remain a minority, comprising only 13% of all carmakers' innovative patents. Beyond car manufacturers, Japanese electronics firms and suppliers operating in Thailand, such as Mitsubishi Electric Corporation (Induction Motor), DENSO Corporation (Permanent Magnet Motor) and Shin-Kobe Electric (Lithium-ion Battery), have also filed EV-related patents.

In terms of patent portfolios throughout the five categories, Japanese incumbents are very active in using patent protection. They have 5,015 invention patents (which account for 99.1% of all invention patents) and 1,289 design patents (which account for 91.2% of all design patents). Western incumbents pursuing HEV manufacturing in Thailand have filed only two hybrid technology invention patent applications but they have yet to file design patents. FOMM, a new Japanese entrant, has four EV-related patents but no design patent. New Chinese carmakers have 35 invention patents and 75 design patents. Among the new Thai entrants, there are three invention patents about EV charging technology and 50 design patents. The group of new Thai carmakers has a clear weakness in invention patent applications, as all of their patents are design patents (Table 4).

Table 4. Patent application counts by BOI-promoted ZEV manufacturers (1979 to May 2024) for four-wheel vehicles

Promoted ZEV firms	Investment (mil. Baht)	Starting year	Design patent	Total invention patent	Key 4 EV's domains	Power elec.	Battery	Charging	Motor
Nissan	10,960	2020	172	733	272	119	102	41	16
Toyota	19,020	2023	357	1,366	249	101	95	35	30
Honda	5,821	2019	683	2,792	131	59	25	22	41
Mitsubishi	6,500	2021	71	59	1	1	–	–	–
Mazda	3,247	2019	6	65	–	–	–	–	–
Mercedes	342	2020	–	–	–	–	–	–	–
BMW	705	2019	–	2	2	2	–	–	–
Takano	90	2020	–	–	–	–		–	–
FOMM	716	2018	–	4	–	–	–	–	–
SAIC-CP	1,290	2019	20	4	–	–		–	–
GWM	559	2021	47	26	–	–		–	–
BYD auto	17,900	2024	8	5	–	–		–	–
Skywell	200	2021	–	–	–	–		–	–
Horizon^{+}	36,000	2024		–	–	–		–	–
MineMobility	2,900	2021	5	3	3	–	–	3	–
AAB	2,664	2021	–	1	–	–		–	–
Sakun C.	346	2021	45		–	–		–	–
Total	*109,260*		*1,414*	*5,060*	*658*	*282*	*222*	*101*	*87*

Notes: Some patents are categorized under multiple IPC codes or involve various EV technology domains. To accurately determine the total count across all four domains, it is necessary to eliminate any double-counted patents. Consequently, the aggregate number of patents across the four key EV domains does not correspond to the simple sum of the final four columns

Source: Thailand's Department of Intellectual Property and Thailand's Board of Investment

The patent data indicates a difference in EV carmakers' IP strategies in the Thai market. Japanese and European incumbents that focus on patent-pending EV technologies produce HEVs rather than BEVs. Despite filing a significantly smaller number of patent applications, Chinese new entrants are concentrating on importing and planning to manufacture BEVs in Thailand. New Japanese entrants began filing patent applications for products invented in Japan but manufactured and sold in Thailand. Some Thai new entrants developed non-core EV technologies and designs that did not meet the patentable threshold for invention patents. The details for each group are outlined below:

4.1 Japanese incumbents

At the global level, leading Japanese companies are consistently active in filing patent applications. Japanese automakers are at the forefront of research and development in BEV technology, holding a significant share of global patent applications in this field. Toyota Motor Corporation is a dominant force in BEV technology R&D (Yurong *et al.*, 2018).

Japanese incumbents lead in implementing patenting strategies, representing the majority of vehicle patents filed in Thailand. Nissan, Toyota and Honda are the top three applicants for automotive invention patents in Thailand, making up 97.5% of the patents filed by the five leading Japanese incumbents. Notably, Nissan has filed more EV-related patent applications than Toyota. Both Nissan and Honda have explicitly announced plans to use Thailand as an additional EV production base alongside Japan (Schröder, 2021). Honda maintains a significant number of patents in Thailand and established Honda R&D Asia Pacific in 2005 to serve as the car design and R&D center for 12 Asian and Oceanian countries. In addition, Honda R&D Southeast Asia, founded in 2004, focuses on developing innovative ideas and designs for future Honda motorcycles. Mitsubishi Motor, under Mitsubishi Electric Co., Ltd., holds numerous patents related to motors, charging and batteries, despite holding only one invention patent in EV technology.

Japanese corporations primarily submitted their patent applications through entities registered in Japan, suggesting minimal contributions from their subsidiaries and R&D/technical centers in Thailand. For example, despite applying for 1,366 invention patents in Thailand, Toyota Motor Corporation (Japan) only has two registered under Toyota Motor (Thailand). Toyota Motor Asia Pacific Engineering & Manufacturing Co., Ltd., established in Thailand in 2003 for R&D purposes and renamed Toyota Daihatsu Engineering & Manufacturing Co., Ltd. in 2017, has filed only two invention patents and three utility model applications over the past 20 years. Similarly, neither Nissan Motor Asia Pacific R&D Test Center (Thailand) nor Honda R&D Asia Pacific (Thailand) have filed any patent applications, although some cases cite Honda R&D Asia Pacific (Thailand) as the inventors' address.

Offshore R&D operations may help multinationals localize technologies to meet market conditions or gather customer insights for global R&D improvements. However, Japanese multinationals like Toyota do not empower their Thai subsidiaries to develop significant technological capabilities in EVs locally.

In Thailand, Japanese automakers have traditionally prioritized HEVs over PHEVs and BEVs. Japanese incumbents perceive the Thai market as relatively limited and view the country as not currently a significant source of raw or intermediate materials for lithium-ion battery production. Since the 2000s, automotive manufacturers like Toyota, Honda and Nissan, along with first-tier suppliers, have established R&D and technical centers in Thailand. However, their R&D efforts have focused primarily on ICE and HEV technologies rather than BEVs (Neran Suwanchotchuang, Toyota Motor Thailand, personal communication, July 18, 2022).

Up until 2022, Japanese carmakers decided to delay any new investments in BEVs, contingent upon Thailand developing a sufficiently large demand for EVs and a robust charging infrastructure (Udomwit Katepong, Mitsubishi Motor Thailand, personal communication, November 22, 2022). However, the emergence of Chinese BEV manufacturers may compel them to revise their business strategies. For instance, Toyota has announced the release of the Hilux Revo BEV concept, whereas Honda introduced the e-NS1 in Thailand in 2023.

4.2 Western incumbents

Western automakers, in contrast to their Japanese counterparts, have shown a stronger commitment to localizing battery manufacturing and EV assembly in the Thai market. Mercedes-Benz AG, in collaboration with its local partners Thonburi Automotive Assembly Plant and Thonburi Energy Storage Systems, established a plug-in hybrid battery facility in 2019 (Mercedes-Benz Group, 2019). Similarly, BMW partnered with Dräxlmaier to initiate in-house high-voltage battery production in 2019. Given the small size of Thailand's luxury car market, setting up manufacturing operations or achieving a local content ratio that meets Thai Government standards is not practical for these companies. European automakers do not conduct R&D in Thailand and rarely file patent applications there (Krisda Utamote, BMW Group, personal communication, April 18, 2022). Notably, only BMW has two HEV invention patents registered with the DIP.

4.3 Chinese new entrants

Chinese newcomers are advancing more rapidly toward BEVs compared to Japanese automakers, who remain focused on ICEs and HEVs. Leveraging the ASEAN-China Free Trade Agreement, Chinese companies can import BEVs and parts from China without incurring import tariffs.

GWM acquired General Motors' production plant in Thailand and started assembling automobiles there in 2021. GWM has filed 26 invention patent applications, primarily for driving assistance systems. Contemporary Amperex Technology Co., Limited (CATL), a global leader in lithium-ion battery technology, has not filed any patents in Thailand. BYD, the world's largest EV manufacturer, has applied for eight design patents but has not filed invention patents for four-wheel BEVs. SAIC Motor, the MG brand's producer, along with GWM and BYD, have all applied for design patents for vehicles intended for sale and manufacture in Thailand.

Chinese automakers are engaging with educational institutions to train workforces related to BEVs, although no R&D collaborations are currently in place. Recently, GWM and its battery manufacturing affiliate, SVOLT, announced plans to establish an R&D facility in Thailand focused on developing right-hand drive automobiles and batteries (Khanchit Chaisupho, GWM, personal communication, March 17, 2022).

Prior to 2017, Chinese automobile manufacturers had no interest in producing ZEVs in Thailand. This stance shifted following the Thai Government's introduction of the 30@30 policy, which included subsidy incentives. In response, Chinese carmakers relocated their production lines to Thailand. However, they missed opportunities in filing numerous EV patents, originally developed in China during the 2010s, in Thailand. Looking ahead to the period post-2024, we anticipate a rise in the number of invention patent applications from emerging Chinese automakers as they expand their manufacturing of BEVs within Thailand.

4.4 Japanese new entrants

Two small Japanese newcomers have entered Thailand's BEV market. In 2020, Takano Auto Thailand, a Thai–Japanese joint venture, began manufacturing BEVs. Takano Auto Accessories MFG, the Japanese parent company, specializes in the design of pickup trucks and heavy vehicles and holds numerous patents in Japan but none in Thailand. Listed on the Thai Stock Exchange in 2018, Takano manufactures and sells the TAKANO TTE 500, a compact, low-cost electric pickup truck capable of traveling 100–120 km on a single charge. This vehicle targets niche markets such as hotels, resorts and colleges. Takano imports critical EV components from China, including batteries and traction motors, while relying on several locally made automotive parts.

FOMM Corporation, a Japanese start-up, expanded to Thailand in 2016 by forming FOMM (Asia), a Thai–Japanese joint venture to produce BEVs. FOMM conducts R&D and product development in Japan before transferring technologies to its production plant in Thailand. Thailand builds the FOMM One, a compact floating BEV, sells it locally and exports it to Japan. In Thailand, FOMM has applied for four patents, one of which covers FOMM One. In 2019, Banpu, a Thai energy company, became a major shareholder in FOMM. The FOMM One will be part of the Banpu Next EV Car Sharing service and will use lithium-ion batteries from Banpu's joint venture, Durapower Technology (Singapore). FOMM supplies various EV parts and technical services to BEV manufacturers in Thailand and the ASEAN region (Takayuki Ueda, FOMM [Asia], personal communication, May 11, 2022).

4.5 Thai new entrants

BEVs present a significant opportunity for Thai energy conglomerates to enter the automotive industry and acquire EV technology from their foreign partners. This opportunity also fosters collaboration among Thai EV battery makers, parts suppliers, car body manufacturers and EV start-ups.

Thai energy companies such as PTT and EA are actively investing in EV-related businesses. PTT has invested in Horizon Plus, whereas EA has invested in Mine Mobility and AAB. These new local entrants, lacking accumulated technology, developed their initial products primarily by mimicking existing products and learning through reverse engineering. For example, Mine Mobility Research submitted four design patent applications, and Amita Technology Inc., EA's Taiwanese affiliate, sought one invention patent on battery technology in 2021. PTT's Innovation Institute holds several invention and design patents related to EV charging technology.

Despite having fewer patent filings, these new local entrants are committed to developing their own technologies through three main approaches:

(1) *Investment in in-house R&D:* Since 2017, EA's subsidiary, Mine Mobility Research, has been conducting experimental R&D on BEV passenger cars, trucks, ferries, trains (in collaboration with China Railway Construction Southeast Asia) and buses (Energy Absolute, 2022). Another EA research company focuses on lithium-ion batteries and energy storage technology, although neither has applied for invention patents. Similarly, PTT established the PTT Innovation Institute in 2018, which holds one invention patent and two design patents for energy storage and EV charging service platforms, employing around 100 researchers (PTT, 2022).

(2) *Supplier collaboration:* To establish a supply system for key BEV parts, these companies collaborate with local and non-Japanese first-tier parts suppliers and

local bus assemblers. These suppliers, who often learn from long-term partnerships with Japanese first-tier suppliers, provide key technical modules like air conditioning, automotive electronics and stamping molds. The Thai new entrants also benefit from the Thailand–China Free Trade Agreement (FTA), which allows them to purchase BEV parts from China with zero tariffs. Notably, EA collaborated with Nex Point to establish AAB, a BEV manufacturer, in 2021. Banpu has partnered with Cherdchai Motor and Thai Rung Union Car to manufacture BEV buses and tricycles for its Next EV Car Sharing platform (Banpu, 2022).

(3) *Technical cooperation with foreign firms:* Following the USA–China trade war in July 2018, some Chinese and Taiwanese manufacturers moved operations to Thailand, enabling Thai newcomers to acquire technical services and collaborate with these partners. For instance, PTT collaborated with Foxconn to establish Horizon Plus for BEV manufacturing and assembly and with CATL, Gotion Hi-tech and 24M Technologies Inc. for lithium-ion battery production. However, these joint ventures have not filed any patent applications (PTT, 2022). EA invested in Amita Technology Inc. (Taiwan) to acquire Li-ion polymer batteries, ultra-fast charging and solid-state battery technology (Ahunai, 2022). Banpu invests in FOMM Corporation, a Japanese EV startup, and Durapower, a Singapore-based company for technology solutions and lithium-ion batteries (Banpu, 2022).

These strategic activities demonstrate the dedication of Thai energy conglomerates to develop a robust EV ecosystem, encompassing charging stations, EV cars and EV-sharing platforms, while utilizing design patents and trade secrets to protect their technologies.

4.6 Local universities and public research institutes

Since 2017, Thai universities and PRIs have increasingly focused on the investigation of EVs and energy storage technologies. By 2024, within four key EV-related technological domains, Thai universities are projected to hold 38 patents and 57 petty patent applications. Concurrently, the National Science and Technology Development Agency (NSTDA) has 41 patents and 21 petty patent applications in these fields. Collaborating with Thailand's Electricity Generating Authority, NSTDA is involved in developing prototype technologies for EV conversion, having secured one invention patent in this area. In 2021, NSTDA partnered with Chinese SAIC Motor to establish a certification system and standard for EV charging stations. Moreover, NSTDA launched its fifth national research center, the National Energy Technology Center (ENTEC), in October 2020, with a focus on energy technology research and development, encompassing EV batteries and energy storage technology. Researchers at ENTEC have numerous patents related to energy storage technology. It is important to highlight that the NSTDA currently lacks collaborative engagements with automotive manufacturers. Consequently, the implementation of patented innovations has not been actualized.

PTT established Thailand's inaugural research university, the Vidyasirimedhi Institute of Science and Technology (VISTEC). With support from the Energy Conservation Promotion Fund, VISTEC researchers have filed 10 PCT applications and approximately 60 applications with the DIP for lithium-ion and lithium batteries, as well as energy storage systems. VISTEC aims to license these patents to Thai companies (Sawangphruk, 2023).

Despite a notable rise in local patent filings by automobile businesses from 1990 to 2018, collaborative patents between academia and industry remain relatively scarce (Motohashi, 2020). Chulalongkorn University, for instance, collaborated with Toyota Motor Thailand to establish Ha:mo, a campus EV-sharing system. The TAI, a sector-specific promotion agency,

plays a limited role in fostering cooperation between government agencies, universities and private firms. Furthermore, the Thailand Energy Storage Technology Association (TESTA) and the Electric Vehicle Association of Thailand (EVAT) were founded in 2015 and 2020, respectively, to promote collaboration with universities and cultivate Thailand's EV ecosystem (Yossapong Laoonual, EVAT, personal communication, July 30, 2021).

A notable challenge hindering the expansion of Thai firms into BEVs is the absence of standards and testing facilities, particularly for passenger cars. The Automatic and Tire Testing, Research and Innovation Center commenced operations in 2019, with EV battery testing facilities becoming operational in 2022. In 1998, the National Electronics and Computer Technology Center established the Electrical and Electronic Products Testing Center to assess electrical and electronic products, including electric bikes and EV chargers. Despite their contributions, the collaboration between academia and industry in Thailand's EV sector is still evolving, and there is room for strengthening these partnerships to enhance the country's technological capabilities in the EV industry.

In sum, Thailand's BEV supply chain presents a significant window of opportunity, driven by increasing patent activity and substantial foreign direct investment (FDI) from global automakers and local energy conglomerates. The analysis of patent applications in Thailand reveals that there is a growing interest in EV-related technologies, with patents filed across key domains such as power electronics, batteries, electric motors and charging systems. Although Thai firms have contributed a relatively small portion of these patents, the presence of patents in these critical areas indicates that there is an opportunity for local firms to develop and innovate within the EV supply chain. However, our findings also highlight challenges, such as the limited indigenous technological development among Thai firms, with innovation largely dominated by foreign companies. The full potential of this opportunity hinges on Thai firms enhancing their technological capabilities and moving beyond low-value activities to become competitive players in the global EV market.

5. Conclusion and policy recommendations

This research highlights the limitations of industrial development strategies that rely heavily on trade openness and FDI without adequately strengthening indigenous technologies and firms. Such strategies can hinder a country's ability to leapfrog when windows of opportunity created by disruptive technologies emerge.

In Thailand, sector-specific industrial policy has been generally limited and not very successful, with the notable exception of the automotive industry. The implementation of local content requirements since the 1960s has led to the development of a robust local supplier network. In addition, the country effectively used tax incentives to promote specific product champions, such as one-ton pickups in the 1990s and eco-cars in the 2000s. The country has targeted BEVs as the next product champion since 2016.

Theoretically, BEVs, representing disruptive technologies, could offer profitable and feasible opportunities for Thailand to leapfrog. However, in reality, Japanese automakers dominate essential EV technology patents but lag behind Chinese automakers, who have capitalized on the FTA to boost EV sales (NBC News, 2023). Unlike Japanese carmakers, who remain invested in ICE and HEV technologies, Chinese automakers have transitioned more swiftly to BEVs. Although a few Japanese firms and startups have recently entered the market with new BEV passenger cars and pickup trucks, their impact on the Thai automotive industry is likely to be minimal. BEVs have created opportunities for large Thai indigenous energy corporations to enter the automotive sector, particularly in niche markets and supporting businesses like charging stations. Although Thailand has succeeded in attracting FDI into the EV sector, it has yet to develop indigenous EV-related technologies. The Thai

automotive sector's reliance on Japanese production networks and an unfavorable FTA with China have impeded its ability to leapfrog.

To effectively address emerging challenges like BEV technology and capitalize on the window of opportunities, Thailand's automotive sector should focus on enhancing local innovation, fostering partnerships and implementing supportive government policies. The government should provide direct subsidies and tax incentives to both foreign and local firms for research and innovation in BEVs, alongside subsidies for consumers and public procurement to boost BEV adoption. Investments in BEV infrastructure, particularly charging stations, are crucial, as are substantial increases in grants for research collaborations between universities, PRIs and companies. In addition, to strengthen sector-specific promotion agencies and associations like TAI, TESTA and EVAT, the government should allocate more funds and projects. By investing in R&D and encouraging collaborations, Thailand can build the technological expertise needed to leapfrog in the global automotive industry, while maintaining flexibility and responsiveness to market and technological changes.

This study highlights the significant challenges that latecomer economies face in achieving technological leapfrogging, particularly in industries with high technological barriers and established global value chains. Although disruptive technologies like BEVs offer opportunities for leapfrogging, success greatly depends on the strength of local innovation systems, effective government policies and the ability to integrate into global networks. The research emphasizes the need for building indigenous technological capabilities rather than relying solely on foreign investment and imported technologies. The complexity of this process is evident in the extreme difficulties faced by firms outside Northeast Asia, reinforcing the necessity of strategic innovation, continuous efforts and supportive policies. Future studies should explore these dynamics in other latecomer economies, particularly in the automotive sector across Asian countries like India, Malaysia, Vietnam and Indonesia, to provide comparative insights alongside the findings on Thailand.

References

Ahunai, S. (2022), "Thailand is about to fall off the electric vehicle convoy? | *The Secret Sauce* EP.516", [online video], available at: www.youtube.com/watch?v=QD-zglHX23s (accessed 20 March 2023).

Altenburg, T., Corrocher, N. and Malerba, F. (2022), "China's leapfrogging in electromobility: a story of green transformation driving catch-up and competitive advantage", *Technological Forecasting and Social Change*, Vol. 183, p. 121914.

Banpu (2022), "Banpu Annual Report 2022", available at: file:///C:/Users/mr_pe/Downloads/BANPU_One-Report-2022_EN_24-Mar-23.pdf (accessed 6 April 2023).

Bierau, F., Perlo, P., Müller, B., Gomez, A.A., Coosemans, T. and Meyer, G. (2016), "Opportunities for European SMEs in global electric vehicle supply chains in Europe and beyond", *Advanced Microsystems for Automotive Applications 2015: Smart Systems for Green and Automated Driving*, Springer International Publishing, Berlin, pp. 223-235.

Deqiang, S., Zhijun, C. and Rafique, M.Z. (2023), "Late-mover advantages, innovation capability, and leapfrogging upgrading of low-carbon technology: evidence from Chinese enterprise groups", *Environ Sci Pollut Res Int.*, Vol. 30 No. 42, pp. 96515-96530.

Energy Absolute (2022), "Energy Absolute Annual Report 2022", available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.energyabsolute.co.th/calendar/presentation/20221123161127.pdf (accessed 6 April 2023).

Feng, K. and Li, J. (2019), "Challenges in reshaping the sectoral innovation system of the Chinese automobile industry", *Innovation, Economic Development, and Intellectual Property in India and China: Comparing Six Economic Sectors*, Springer Open, Singapore, pp. 415-438.

Feng, S. and Magee, C.L. (2020), "Technological development of key domains in electric vehicles: improvement rates, technology trajectories and key assignees", *Applied Energy*, Vol. 260, p. 114264.

Hobday, M. (1995), "East Asian latecomer firms learning the technology of electronics", *World Development*, Vol. 23 No. 7, pp. 1171-1193.

Intarakumnerd, P. and Charoenporn, P. (2015), "Impact of stronger patent regimes on technology transfer: the case study of Thai automotive industry", *Research Policy*, Vol. 44 No. 7, pp. 1314-1326.

Intarakumnerd, P. and Techakanont, K. (2016), "Intra-industry trade, product fragmentation and technological capability development in Thai automotive industry", *Asia Pacific Business Review*, Vol. 22 No. 1, pp. 65-85.

Kaewtatip, P. (2019), *Thailand's Automotive Industry and Current EV Status*, One Start One Stop Investment Center, Bangkok.

Kohpaiboon, A. (2008), "Thai automotive industry: multinational enterprises and global integration", Economic Research and Training Center, Thammasat University, Discussion paper series, 4.

Konda, P. (2023), "Domestic deployment in the formative phase of the Chinese electric vehicles sector: evolution of the policy-regimes and windows of opportunity", *Innovation and Development*, Vol. 13 No. 3, pp. 493-516.

Lee, K. (2013), *Schumpeterian Analysis of Economic Catch-up: Knowledge, Path-Creation and the Middle Income Trap*, Cambridge Univ Press, Cambridge.

Lee, K. and Yoon, M. (2010), "International, intra-national, and inter-firm knowledge diffusion and technological catch-up: the US, Japan, Korea, and Taiwan in the memory chip industry", *Technology Analysis and Strategic Management*, Vol. 22 No. 5, pp. 553-570.

Lee, K., Lim, C. and Song, W. (2005), "Emerging digital technology as a window of opportunity and technological leapfrogging: catch-up in digital TV by the Korean firms", *International Journal of Technology Management*, Vol. 29 Nos 1/2, pp. 40-63.

Lema, R., Wuttke, T. and Konda, P. (2024), "The electric vehicle sector in Brazil, India, and South Africa: are there green windows of opportunity?" *Industrial and Corporate Change, p.dtae014*,

Lin, R., Zhou, C., Li, K. and Xie (2016), "Innovation ability building of the latecomer firms in the process of technological catch-up a case study based on China XD Group Co", *Ltd. R&D Management*, Vol. 28 No. 1, pp. 40-51.

Mathews, J. (2007), "Latecomer strategies for catching-up: the cases of renewable energies and the LED programme", *International Journal Technological Learning, Innovation and Development*, Vol. 1 No. 1, pp. 34-42.

Mathews, J. and Cho, D. (1999), "Combinative capabilities and organizational learning in latecomer firms: the case of the Korean semiconductor industry", *Journal of World Business*, Vol. 34 No. 2, pp. 139-156.

Mercedes-Benz Group (2019), "Mercedes-Benz cars starts local battery production in Bangkok", available at: https://group.mercedes-benz.com/innovation/digitalisation/industry-4-0/battery-factory-bangkok.html (accessed 20 August 2022).

Motohashi, K. (2020), "Development of patent database in Thailand for assessing local firms' technological capabilities", *World Patent Information*, Vol. 63, p. 101998.

Natsuda, K. and Thoburn, J. (2013), "Industrial policy and the development of the automotive industry in Thailand", *Journal of the Asia Pacific Economy*, Vol. 18 No. 3, pp. 413-437.

NBC News (2023), "How a small China-made EV put global auto execs and politicians on edge", NBC News, 30 August, available at: www.nbcnews.com/business/autos/small-china-made-ev-global-auto-execs-politicians-edge-rcna144613

Perez, C. and Soete, L. (1988), *Catching-up in Technology: Entry, Barriers and Windows of Opportunity*, Pinter Publishers, London.

Prasad, A., Uchida, H. and Tran, D. (2022), Unleashing Thailand's Electric Mobility Potential: A comprehensive report on the future potential of EVs in Thailand, Arthur D. Little Report, November 2022.

PTT (2022), "PTT Annual Report 2022", available at: www.pttplc.com/en/Media/Publications/Report.aspx (accessed 6 April 2023).

Sawangphruk, M. (2023), "Can Thai EV *Battery Dismantle?* | *Executive Espresso* EP.409", [online video], available at: www.youtube.com/watch?v=9yyjm0KOy0Q&t=2753s (accessed 20 February 2023).

Schmitt, G., Scott, J., Davis, A. and Utz, T. (2016), "Patents and progress; intellectual property showing the future of electric vehicles", *World Electric Vehicle Journal*, Vol. 8 No. 3, pp. 635-645.

Schröder, M. (2021), "Electric vehicle policy in Thailand: limitations of product champions", *Journal of the Asia Pacific Economy*, Vol. 28 No. 4, pp. 1-26.

Thailand Automotive Institute (2024), *Thailand's Automotive Industry Statistics*, available at: https://data.thaiauto.or.th/ (accessed 19 April 2024).

Thananusak, T., Punnakitikashem, P., Tanthasith, S. and Kongarchapatara, B. (2020), "The development of electric vehicle charging stations in Thailand: policies, players, and key issues (2015–2020)", *World Electric Vehicle Journal*, Vol. 12 No. 1, p. 2.

Wang, H. and Kimble, C. (2011), "Leapfrogging to electric vehicles: patterns and scenarios for China's automobile industry", *International Journal of Automotive Technology and Management*, Vol. 11 No. 4, pp. 312-325.

Yean, T.S. (2022), "2022/112 "Mapping the surge in EV production in Southeast Asia", by Tham Siew Yean.

Yurong, H., Yuanyuan, H., Jingyan, Z. and Ru, L. (2018), "Analysis of the BEV technology progress of America, Europe, Japan and Korea based on patent map", *IOP Conference Series: Earth and Environmental Science*, Vol. 113 No. 1, p. 12027.

Further reading

Intarakumnerd, P. (2021), "Technological upgrading and challenges in the Thai automotive industry", *Journal of Southeast Asian Economies*, Vol. 38 No. 2, pp. 207-222.

Intarakumnerd, P. and Charoenporn, P. (2022), "Opportunities for the development of Thailand's battery electric vehicle (BEV) industry: an analysis of patent data", Presented at the Asialics Conference, *Hsinchu, Taiwan*, June 30.

Intarakumnerd, P. and Jutarosaga, A. (2023), "The evolution of university–industry linkages in Thailand", *Asian Economic Policy Review*, Vol. 18 No. 2, pp. 265-282.

Krungsri Research (2023), "Business/industry trends 2023-25 automotive parts industry", March 2023.

Mohamad, M. and Songthaveephol, V. (2020), "Clash of titans: the challenges of socio-technical transitions in the electrical vehicle technologies–the case study of Thai automotive industry", *Technological Forecasting and Social Change*, Vol. 153, p. 119772.

Appendix

Table A1. List of interviewees

Name	Organizations/companies	Date of interviews
Yossapong Laoonual	Thailand's National Electric Vehicle Policy Committee (EV Board) and Electric Vehicle Association Of Thailand (EVAT)	July 30, 2021
Thanakarn Wongdeethai	Office of National Higher Education Science Research and Innovation Policy Council	February 18, 2022
Khanchit Chaisupho	Great Wall Motor (Thailand)	March 17, 2022
Krisda Utamote	BMW Group (Thailand) and EVAT	April 18, 2022
Takayuki Ueda	FOMM (Asia)	May 11, 2022
Anchalee Chaleechan	Honda Automobile (Thailand)	June 17, 2022
Neran Suwanchotchuang	Toyota Motor Thailand	July 18, 2022
Pongpan Kaewtatip	Thailand Science Research and Innovation (TSRI), EVAT, and Thailand Energy Storage Technology Association (TESTA)	November 15, 2022
Udomwit Katepong	Mitsubishi Motor Thailand	November 22, 2022

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