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The Adoption of Electric Vehicles: Challenges and Issues for a Future Research Agenda

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Abstract
Sales of electric vehicles (EVs) grew rapidly in recent years. The vast literature on EV adoption, however, has generated regional, mixed, and sometimes contradictory results. A careful examination of the literature reveals overreliance on quantitative research methods and a dearth of qualitative, exploratory studies. The mixed findings may not stem directly from flaws in research methodology or research design, but rather reflect the inherent nature of the domain being studied. A research agenda in the tradition of qualitative, grounded theory is proposed.

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I. Introduction

The personal transportation sector historically relies heavily on fossil fuels and is one major contributor to carbon dioxide emissions (EEA, 2016). The adoption of electric vehicles (EVs) has been widely considered a key policy objective to reduce the atmospheric carbon dioxide levels (EEA, 2016). Although introduced as early as in 1828, the adoption of EVs has been slow for the past two hundred years due to limitations in battery technology (Kirsch, 2000). In recent years, stricter emission reduction policies, concerns for environmental sustainability and energy shortage, as well as progress and breakthroughs in lithium-ion battery technology made it possible for large scale adoption of EVs. The year of 2010 marks an important milestone when Nissan introduced Nissan Leaf and Chevrolet marketed Volt. This year, global EV sales reached 50,000 units and that number increased to 315,000 the next year. In the first quarter of 2020, Sales of EV grew 55% year over year despite of the sharp decline in sales of traditional internal combustion vehicles caused by Covid-19 pandemic.

Since 2010, scholarly research on EVs has increased exponentially. A brief search on the ABI/INFORM database for peer reviewed journal articles generated 16,213 entries, Scholars Portal had 3,790, and ScienceDirect turned out 1,842. With this huge body of accumulated research, some scholars feel that it might be time to synthesize and integrate in order to create a comprehensive, generalized, nomological theory for EV adoption (e.g. Kumar & Alok, 2020). However, caution must be exercised for rushing to a generalized, one size fit all theory. Literature reviews reveal regional, fragmented research results (Kumar & Alok, 2020; Li et al., 2017); vary from country to country and across different cultures (Kaptan et al., 2013; Spencer et al. 2015; Wang et al., 2015). Findings are often mixed, and sometimes even contradictory from each other. For instance, among studies on the impact of consumers' experience on their willingness to purchase, six studies reported reduced willingness to purchase as families obtained more experience (Garling & Johansson, 2000; Franke et al. 2012; Jensen et al. 2013; Skippon et al. 2016; Yong et al. 2017; Tanţău & Gavrilescu; 2019), while four studies revealed a positive relationship (Barth et al. 2016; Burgess et al. 2013, Bühler et al. 2014; Larson et al. 2014). It seems that the sheer vast size of the literature might not be a good indicator of the field's level of maturity. We feel that the fragmented literature might not be caused by flawed research design or methodologies, but rather reflects the dynamic, evolving nature of the domain being studied and may pose some serious epistemological and ontological issues.

Product Life Cycle (PLC)

Despite of its rapid growth in recent years, EV sales only account for a tiny fraction of the total vehicles sold globally. Its market share is around 2.5% of the new car sales in 2019 (Jose, 2020), well below the 6% threshold for a growth industry (Hill & Jones, 2020). On the global level, EVs are still in the early stage of product developments (IEA, 2020) and have the typical features of the embryonic or introductory stage of the product life cycle (PLC). The technology and infrastructures are undergoing continuous changes and are far from mature: government policies change over time; complementary facilities such as recharging stations are

not well developed; battery technologies keep on improving, but still have limitations compared to the matured internal combustion engines (ICEs); promotion programs are rare; different business models are in the process of being tested; and EV manufacturers rely on specialized, limited distribution channels. Encountered with this new, unfamiliar product, consumers worry and perceive high risks and consequently they are slow in the adoption process (Johnna, 2020).

At this stage of the EVs' PLC, one of the key barriers is consumers' concern over EVs' limited driving range (IEA, 2019; Kumar & Alok, 2020; Nykvist et al. 2019). EVs' driving range can be defined as the maximum distance they can travel with a fully recharged battery (Hackbarth & Madlena, 2013). Early EVs typically have limited, shorter driving ranges. Toyota Prius has an all electricity driving range of 21 KM; GM Volt is from 40-80 KMs. In 2011, EVs' average theoretical driving range was extended to 100 miles (Lee & Lovellette, 2011). With the significant improvement in battery technology in recent years, EVs' driving range was extended to 200- 300 miles (IEA, 2019) with an exception of Tesla's model S. Model S received the EPA rating of 348-402 miles, or 560-647kms with its heavy 100 KWH battery (Johnna, 2020). Considering EVs' actual driving range is way below their EPA rating, on average, EVs' driving range is still well below the 350-450 miles average driving range for conventional vehicles.

One side effect of the limited driving range and the inadequate recharging infrastructure is range anxiety. Range anxiety is a common issue among EV drivers reported by the existing literature (Tanţău & Gavrilescu; 2019). It can be defined as the fear, worries, and stress caused by concerns over being stranded in the middle of the trip due to depleted battery before reaching the recharging station (Rauh et al, 2015; Sala & Kama, 2017). Consumers' level of range anxiety varies at different stages of EVs' PLC. At the embryonic stage, consumers tend to have high levels of range anxiety and it turns out to be one of the most significant barriers for consumers' choice of EVs (Kumar & Alok, 2020). Consequently, they do not consider EVs as real alternatives to conventional vehicles. Nevertheless, as EVs evolve into the growth stage or later into the maturity stage of the PLC, the recharging infrastructure will be well developed and EVs' driving range might catch up or surpass the driving range of traditional vehicles. As a result, consumers' range anxiety might decline or disappear, which implies that driving range will no longer be a significant factor when consumers choose between different brands of EVs. Conceivably, studies conducted at the early stage of the PLC will generate different results from studies conducted at later stages of EVs' PLC. Therefore, research findings generated at the current embryonic stage might not be applicable to later versions of EVs.

Competitive Chasm

According to the technology diffusion model (Rogers, 2010), EVs will encounter different consumer groups along its adoption process. The first wave of consumers is typically innovators (Moore, 1995). They are dreamers and risk takers, more concerned about image and environment (Meltona et al. 2020; Barth et al. 2016; He et al. 2018; White & Sintov, 2017), willing to try new things, are price insensitive, and tend to have higher income (Rogers, 2010). Early adopters are the second group of consumers (Moore, 1995). This group of consumers are technology proficient and can deal with imperfect technology with their own solutions. Innovators and early adopters correspond to the embryonic stage of the PLC and represent a niche of the EV market. The widespread adoption of EVs depends on a large number of buyers who typically showing up at the growth stage of the product life cycle: the early majority. The early majority are pragmatists. Although still willing to try new things, they are much less technically proficient, more cost conscious, and need to be convinced by the benefit of the new technology (Moore, 1995). Innovators and early adopters make up 6% of the market share, while early majority make up around 24% (Rogers, 2010*).* When a product evolves from the embryonic to the growth stage of the PLC, it is not simply a transition from 6% to the 24% of the market. There exist a chasm between Innovators/early adopters and early majorities (Moore, 1995). Innovators/early adopters are comfortable with deficient technology, specialized distribution channels, while early majority looks for mature, user-friendly, and economically viable products. Mass distribution channels, mass advertising programs, well developed after sale service, warrantee, and complementary infrastructures are essential for the wide spread adoption of EVs by early majority.

The mass commercialization of EVs depends on recognition and understanding of the differences between innovators/early adopters and early majorities. However, the current literature is heavily concentrated with studies conducted over innovators/early adopters. Therefore, limited merit might exist in assisting companies and public agencies to develop appropriate programs to cross the chasm and cautions must be exercised in the tendency to apply findings from the current literature to the coming growth stage of the PLC.

Market Segmentation

Market segmentation is an area that has been overlooked by the current literature. Indeed, some review articles noticed the abundance of regional findings (Kumar & Alok, 2020; Li et al. 2017) and many studies reported significant variations among different segment of the EV market. For instance, four wheel drive, access

to the bus lane, exemption from road tolls and parking charges, significantly reduced ferry fares, and free recharging in public parking lots, are major factors consumers in Norway consider when selecting EVs (Østli et al. 2017), meanwhile the exemption from license plate control is one of the major driving forces buying EVs in major Chinese cities (Lu, et al, 2020). Consumers under cold climate are concerned with the battery's reliability whereas the battery's safety feature draws more attention from consumers in tropical zones (Kumar & Alok, 2020).

For driving range, several studies conducted over heavily populated urban areas such as New York, Paris, Beijing, Shanghai, Los Angeles suggest that average drivers in these areas travel from 31.4km to 48km per day, which is well within the range of existing EV technology (Lee & Lovellette, 2011; Wang et al., 2015; Sang & Bekhet, 2015; Green Car Institute, 2011; McKinsey, 2009; Eberle & Helmolt, 2010; Hessman, 2011). In these urban areas, 60-100km driving range could meet 70 % of urban daily driving demands and range anxiety might decline to such a level that driving range will cease to be a significant barrier. Consumers would purchase EVs with lower prices and further increase in driving range will not bring in significant increase in EV adoptions (Wang et al. 2015; Adepetu & Keshav, 2017). Other studies reveal that driving range poses as one of the most important barriers for the adoption of EVs in rural areas, in countries where people prefer longer trips, or under extreme climate where heating or air conditioning can cause significant decline in the EIA certified range (Lee & Lovellette, 2011; Gnann et al., 2015; Travesset-Baro et al., 2015). Therefore, it will be problematic to apply knowledge acquired from one segment of the market to another different segment. In other words, the segmented nature of the EV market casts doubts on the need for generalized, universal, grand theories.

These mixed or contradictory findings are not the result of misconducted studies or inappropriate methodologies. Instead they reflect the inherent nature of the domain being studied: the PLC, the competitive chasm, existence of different market segments, different consumer behaviour, as well as the different nature, climate, geography, and institutions settings. At surface, these mixed and contradictory findings might jeopardize efforts to collate regional findings to draw judiciary conclusions and pose serious challenge to the construction of generalized, grand, one fit all model of EV adoptions. As marketers, however, we would rather look at this as strength, or blessing since segmentation, targeting, and positioning are always the central thesis for marketing. An EV marketer in Toronto will have major concern over the consumer behavior for her/his targeted market: Toronto, and would have slight interest in how the consumer will behave in Paris. As marketers, we need rich and in-depth understanding of market segment we serve and this calls for more regionalized, context based knowledge.

Epistemological and Ontological Issues

The literature on EV adoption also raises important epistemological and ontological Issues. At the embryonic stage of product life cycle: the technology (especially the battery technology) still has limitations and is not mature; the infrastructure is underdeveloped; public policies keep on changing; there are far less EV marketing promotions than conventional vehicles; consumers awareness of EVs and their features is low (Meltona et al. 2020); the majority of EVs are sold through specialized, narrow distribution channels and EV manufacturers are in the process of exploring different business models (Liao et al. 2018). Consequently, the adoption of EV is a dynamic and ongoing process, which implies that the knowledge and understanding we captured at one point of time may differ from the knowledge and understanding we acquired at another point of time. We might need studies to take a snapshot of the EV adoption at one specific point of time, but more importantly we need research tools that offer details about the dynamics and the mechanisms of how it moved from one point to another point. While quantitative methodology is more suitable to study a static, relatively mature field; qualitative, exploratory research is better equipped to tap into the dynamic process of the evolving process.

The adoption of EV is not a purely functionality driven objective process, but rather embedded with social status, symbolic interactions, normative face influence (Barth et al., 2016), values, genders (Bennett et al., 2016; Rasouli & Timmermans, 2016), and sense making (Schuitema et al.,2013; White & Sintov, 2017; Jansson et al., 2017: Huang & Qian, 2018). Consumers' perceptions, attitudes, and intensions are affected and shaped through their interactions with different forms of promotions, public policies, cultures, and social norms. It reflects the tenants of constructionism that recognize multiple perspectives and subjectivities inherent both in a symbolic interactionist world view and in the engagement of the participants in the interpretative work of generating new understandings (Pidgeon, 2002). It is imperative to explore in more depth of the dynamic process and consumers` live experiences. Consequently, our understanding of what drives consumers purchase EVs can be enriched through qualitative research, especially in the tradition of grounded theory (Glaser & Strauss, 1967).

However, among the vast body of studies, there is an unproportioned overweight on quantitative research and a dearth of qualitative, exploratory works. For instance, Kumar & Alok (2020) reviewed scholarly research on the adoption of EVs. Their extensive search found 239 articles published in academic refereed journals since 2010. 224 (94%) of them are quantitative studies based on structured survey, secondary data, simulation, or optimization. Among the scant 15 qualitative studies, the majority are literature reviews, case studies, or semi-structured interviews. There is a stunning lack of knowledge based on well grounded, qualitative, exploratory works.

Overall, there is a mismatch between the methodology and the domain being studied. While quantitative research is structured, rely on predetermined framework of analysis, qualitative, especially grounded, exploratory research is open ended, has a close touch with consumers` life experience, are better equipped to reveal in depth what drives consumer behavior, and therefore are more suitable to study the new phenomenon and to capture the dynamic process of EV adoption. The unbalanced literature calls for more qualitative, exploratory studies to assist companies and marketers to better identify, understand consumers' needs and develop appropriate market offerings. In the context of an expensive and highly risky product category: the EVs, the field calls for a qualitative, grounded, exploratory research agenda to fill this research gap.

Grounded Theory: A Research Agenda

EVs' stage of product life cycle and the competitive chasm imply that the knowledge we acquired about the adoption of EVs might be time dependent. The research findings generated at one point of time might be different from research findings acquired later. At EVs' current stage of PLC that is featured with dynamic and evolving changes, it is at least of equal importance to reveal the process, the dynamics, and the mechanisms over time as to discover the common, generalized patterns. We need research tools that facilitate the exploration of the process, the dynamics, and the mechanisms.

The market segmentation and the competitive chasm suggest that knowledge could be regional and context dependent. Research findings generated from one consumer group might be different from research findings generated from another consumer group. Instead of searching for commonalities among different market segments, as marketers, we are more interested to find out what our consumers are looking for in order to better serve our targeted customers. This practical mandate asks for research tools that focus on regional findings that are grounded in certain contexts.

Market segmentation and competitive chasm also coincide with the epistemological and ontological point of view that there might coexist multiple truths. Just like that one color could be interpreted in different ways among different cultures, one identical EV could be interpreted differently among different consumer groups. For instance, some consumers might treat their EVs as symbols of social status, while other consumers might buy EVs simply as means to fulfill their transportation needs.

This could be further exemplified by the path dependence nature for the formation of consumers' attitudes and perceptions. The formation of consumers' perceptions and attitudes is a sense making process that undergoes interactions with families, friends, peers, cultures, norms, medias, marketing promotions, and other social surroundings. This process is path dependent. For instance, the same consumer, through interactions with different marketing programs, or even through interactions with researchers, might form different attitudes and perceptions towards the same EVs. Therefore, instead of seeking one fit all grand theories, this epistemological and ontological stand calls for more exploratory studies and research findings grounded in consumers' life experiences.

Overall, we need research tools that focus on regional findings rooted in rich contexts, tap into the process, the dynamics, and the mechanisms, and enable us to reach deep into consumers' life experience. This is a perfect match with grounded theory (Glaser & Strauss, 1967).

Originated from the methodological approach associated with symbolic interactivism (Glaser & Strauss, 1967), grounded theory is an inductive research method emphasizes theory building from naturally occurring field data (Glaser & Strauss, 1967). Its central premise is to identify, map, and conceptualize constructs and patterns of interactions among social actors. It seeks to develop novel understandings and emerging theories about an under-researched domain by "grounding" them in the empirical real-life observations (Corbin & Strauss, 2009). From its epistemological stands, grounded theory employs a research process that focuses on discovery from empirical field data and avoids theoretical frameworks and preconceived hypotheses from prior literature (Glaser & Strauss, 1967). Since it does not rely on a pre-determined framework of analysis, grounded theory provides high degrees of freedom in examining the focal phenomena, and therefore is considered especially useful in acquiring rich insights and developing context-based, process-oriented, descriptions, explanations, and understandings of complex managerial processes (Urquhart& Fernandez, 2013).

Grounded theory has a highly iterative research process, which is guided by insights emerging from the accumulated field data (Martin & Turner, 1986). It is featured with open ended or semi-structured interviews, constant comparison between data, theoretical sampling, theoretical coding, theoretical saturation, and

theoretical sensitivity (Strauss and Corbin, 1990). These characteristics make it a perfect match to study key issues in the adoption of EVs, such as the complex consumers' purchasing process, the dynamics and the mechanisms of the domain, the formation/changes of consumers' perception and attitudes, as well as consumers' interactions with promotion programs, social networks, and public policies, as they often require in-depth analysis of the empirical data from a real-life setting. With the assistance of grounded theory, we wish to address the following research questions:

1. What are the major constructs of the domain?
2. What are the typical consumers' purchasing processes?
3. What is the relationship among the major constructs of the domain?
4. What life experience does a consumer go through when buying an EV?
5. What are the major factors influencing consumers adoption of EVs? What are the Commonalities and differences in these factors, across different times and different consumer groups?
6. What are the major drivers of changes? Are they technology? public policy? business model? promotions? Or experience related factors?

II. Conclusions

The vast literature on EV adoption has generated regional, mixed, and sometimes conflicting results. This might not be caused by flawed research methodology and mis-constructed research designs, but rather reflect the dynamic, evolving nature of the domain being studied. The embryonic stage of EVs' product life cycle and the competitive chasm imply that the knowledge we acquired might be time dependent. The research findings generated at one point of time might be different from research findings generated at a later point of time. Our knowledge is also regional and context dependent because of market segmentation and the competitive chasm. The research findings generated from one consumer group might be different from research findings generated from another consumer group. Our knowledge about the truth might also be path dependence since the formation of consumers' attitudes and perceptions is a sense making process. They are socially constructed reality and undergo interactions with families, friends, peers, culture, norms, media, marketing promotions, and other social surroundings.

The status of the domain under study makes it difficult to reach stable and consistent observations. We need research tools that provide in-depth understanding of the dynamics and mechanisms of the processes and keep us to close to consumers' life experience. As marketers, we will be blessed with regional findings rooted in specific contexts. Currently, the literature is crowded with quantitative research and a dearth of qualitative, exploratory studies. To overcome this drawback, this study calls for a research agenda based on more qualitative, exploratory studies to assist companies and marketers to identify and understand consumers' needs in order to develop appropriate market offerings.

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