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Improving the understanding of electric vehicle technology and policy diffusion across countries

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ABSTRACT

The transport sector is particularly difficult to decarbonize. Use of electric vehicles (EV)—a potentially transformative and sustainable transport technology—can reduce greenhouse gas emissions, domestic fossil fuel demand, energy import dependency, and air pollution. Policies play an important role in the diffusion of new technologies, such as EVs, principally in their formative stage as they compete with an incumbent technology. However, great discrepancies exist across countries regarding EV support and uptake.

EV diffusion is conceptualized as an outcome of policy diffusion based on national characteristics and international mechanisms. This study aims to explain the variation in EV policy diffusion across countries, by conducting an event history analysis on EV diffusion (EVs $>$ 1% market share) between 2010 and 2017, using a sample of 60 countries. It identifies characteristics and mechanisms relevant to the novel technology's "formative phase", focusing on the formation of state goals, international diffusion, and local technology adoption and deployment. The empirical contribution lies in identifying and validating socioeconomic and political factors and the international mechanisms influencing a country's position on the diffusion curve. This can help improve scenarios via better reflecting EV diffusion.

1. Introduction

Transport sector transformation is a major challenge in terms of reducing domestic fossil fuel demand (and thus imports), enhancing energy security, curbing local air pollution, and reducing greenhouse (GHG) emissions in line with the Sustainable Development Goals (SDGs) and the 2015 Paris Agreement. The transport sector is responsible for around 28% of global final energy demand, 65% of global final oil energy demand and 24% of global energy-related CO_2 emissions, of which road (mainly passenger) transport emits 77% (IEA, 2018). The road transport sector, the least diversified energy end-use sector, is almost fully reliant on fossil fuels (>95% in 2018) (IEA, 2018).

Expected growth in transport energy demand is projected to double emissions by 2050 (Rogelj et al., 2018), especially in emerging and developing economies (EIA, 2017), where demand for general mobility and individual transportation is increasing. The global number of light-duty vehicles is estimated to roughly double by midcentury, driven by rising affluence in Asian countries (Sperling and Gordon, 2009). Yet there are positive signs as well. In 2019, global transport emissions increased only by less than 0.5% (compared to previous annual increases of 1.9% since 2000). This can be traced back to efficiency improvements, electrification, and greater use of biofuels (IEA, 2020).

Transition toward transport-sector sustainability, though challenging, is thus vital. The sector must decarbonize quickly to stay within the Paris Agreement temperature guardrails (Rogelj et al., 2018). According to countries such as Germany, the transport sector is the most difficult to decarbonize (Agora Verkehrswende, 2018; Canzler and Wittowsky, 2016). Mode and demand shifts (Grubler et al., 2018), novel technologies, and incremental changes in existing technologies are all needed simultaneously (Creutzig et al., 2015).

Together with new technologies, policies play a key role in the low-carbon transformation. To achieve the SDGs, transport policies aim to support the shift to clean alternative fuels, drives, or modes, improve energy efficiency, and reduce environmental impacts. In 2017 less than 30% of transport-sector energy use was covered by mandatory policies, making it the least regulated and least improved energy-use sector over the years (Foster et al., 2018). Air pollution motivated early policy interventions in the road transport sector (e.g., Californian state regulation of new motor vehicle pollution in 1960) (Stern, 1982). Widely diffused policies have led to technological improvements and reduced environmental impacts worldwide, but more could be done (Saikawa, 2010). A trend to larger, more powerful and emission intensive cars is hampering

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decarbonization efforts of car-based passenger transport. The significant difference between real world and test cycle emissions and energy use is also posing a problem that policies have failed to tackle successfully (IEA, 2020).

Deep decarbonization will entail a shift away from fossil fuels "to biofuels, electricity, and/or hydrogen, either in dedicated battery-electric or fuel cell vehicles or in mixed configurations, such as plug-in hybrid electric vehicles" (Creutzig et al., 2015). In 2017 unexpected policy announcements in the transport sector hinted at a larger-scale transformation (Zimm et al., 2019), with several countries (e.g., France) announcing (the ambition) to ban the sales of new internal combustion engines vehicles (ICEVs) (Chrisafis and Vaughan, 2017; Plötz et al., 2019).

Electric vehicles (EV),[1] promoted widely in the past decade, currently dominate novel individual transport options. Favorable EV policies in Norway, for example, have led to the world's highest EV share of vehicle stock of more than 9% in 2019 (Government of Norway, 2019). The evolution of individual motorized transport EVs is thus a prominent example of a transformative development that brings together technology and policy interventions within the wider emerging transport system. EVs have been around for a long time and are still passenger vehicles but with a different drive and require other supporting infrastructure than ICEVs. Electrification of the energy and transport systems driven by renewables will significantly reduce overall energy demand (GEA, 2012) and features strongly in mitigation scenarios (IPCC, 2018). The speed and gravity of this change will be related to:

i) Innovation in EVs and charging infrastructure to overcome remaining challenges (e.g., higher investment costs and technical issues) (IEA, 2019);
ii) ongoing improvements in ICEVs (Barton and Schütte, 2017);
iii) customer perceptions (e.g., concerns regarding range and charging) (see Abotalebi et al., 2019; Berkeley et al., 2018; Carley et al., 2013; Lieven, 2015; Rezvani et al., 2015)
iv) evolving policy frameworks (e.g., emission standards, fossil fuel taxes, standardization, ICEV bans) and major support policies.

Various combinations of support measures in leading markets aim to overcome initial adoption barriers (Bunsen et al., 2018; EAFO, 2019; Tal and Brown, 2017; Tietge and Lutsey, 2016). In their case studies of national EV markets, Altenburg et al. (2015) summarize the development in four countries: "what motivates governments and industries to pursue the electromobility transformation varies considerably from country to country" and "policies are typically the outcome of complex political negotiations [and] inherently difficult to predict" Altenburg (2015, p. 466). Country differences in initial conditions (e.g., technological capabilities, demand conditions, and energy system characteristics) are influential for EV policy design and technological engagement.

In the following, Section 2 states the research objective; Section 3 presents the theoretical framework; Section 4 introduces the research design, covering materials, and methods; Section 5 presents the results; Section 6 deals with limitations and further research; Section 7 presents a discussion and conclusions.

2. Objectives

The research examines why EVs and related policies spread the way they do. Policies play an important role in the diffusion of new technologies, such as EVs, mainly in their formative stage as they compete with the incumbent industry. Initially, EVs rely on policy support to become competitive with ICEVs (Lieven, 2015; Rietmann and Lieven, 2019). Unlike novel technologies, ICEVs benefit from lock-ins, unaccounted-for externalities, and preconceptions. The differences in national diffusion of EVs can be traced back to available policy support, principally financial incentives, in the technology's early days (Münzel et al., 2019; Santos and Davies, 2019).

The research looks at why some countries are early adopters of EV policies while others lag, and considers the question: What explains the variation in the timing of EV takeoff (as an outcome of EV policy support) across countries? This is a study of policymaking as much as a study for policymaking.

The research also aims to help improve understanding of the explanatory variables of EV takeoff across countries, first, inter alia, as a policy support outcome, and second, to provide insights into whether or not countries will reach takeoff, which countries will achieve it, when, and why. By studying the explanatory variables, the thrust of the exploration of technology adoption can be shifted to emphasize the conditions guaranteeing takeoff (Kauffman et al., 2012). To construct global transition pathways that reflect nationally differentiated technology transitions, conceptually rigorous and empirically validated answers to these questions are essential. Identification of some barriers to policy evolution can help improve guidance for policymakers.

Globally speaking, there is little empirical evidence in this realm. Previous quantitative studies have focused on the effectiveness of incentives in a certain country, for example, Sweden (Egnér and Trosvik, 2018); Norway (Mersky et al., 2016); USA (Clinton and Steinberg, 2019; Jenn et al., 2018; Plötz et al., 2016); and China (Wang et al., 2017); or on a region, for example, Europe (Münzel et al., 2019; Plötz et al., 2016); or in individual years (e.g., Sierzchula et al., 2014; Rietmann and Lieven, 2019; Sierzchula et al., 2014; Wang et al., 2019); or simply on industrialized countries (e.g., Wesseling, 2016). The latter, exceptionally, also looked at political factors.

Other literature includes individual or comparative country case studies on policy evolution (e.g., Gass et al., 2014; Altenburg et al., 2015; Liu et al., 2017; Meckling and Nahm, 2018) the diffusion of EVs from a consumer goods perspective (Kim et al., 2018); identifying the predictors of EV adoption among consumers for individual markets (Priessner et al., 2018; Zarazua de Rubens, 2019); or diffusion of policies, including energy technology policy, across countries, such as support policies for renewable energy technologies (e.g., Vinichenko, 2018).

The diffusion of EV support policies or technologies and the underlying political and economic dimensions that lead to policy engagement have not been studied in a similar way. Deepening the understanding of the variation across countries will help improve predictions about which countries will, or will not, adopt policies and reach takeoff, and when. So far, the transport sector has been largely neglected in the policy diffusion literature, despite being a policy area with a large potential (Schmidt and Fleig, 2018).

3. Theoretical framework

Socio-technical transitions result from combinations of different mechanisms across multiple levels. I identify processes influencing the adoption of EVs (Fig. 1) at three levels following the multi-level perspectives (MLP) concept of Geels (2012), adjusted by Figenbaum (2017), for the case of EVs:

i) the technology niche where innovations happen;
ii) socio-technical regimes with established practices and institutions, in this paper, the transport regime at the national state level; and
iii) the exogenous socio-technical landscape at the global level.

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[1] The following definitions, commonly used in studying EVs (Barton and Schütte, 2017), are used throughout: electric vehicle (EV) refers to passenger "battery electric vehicles" (BEVS) with a battery-powered electric engine that derives all its energy from electricity and "plug-in hybrids" (PHEVs) that can derive some of their power from electricity.

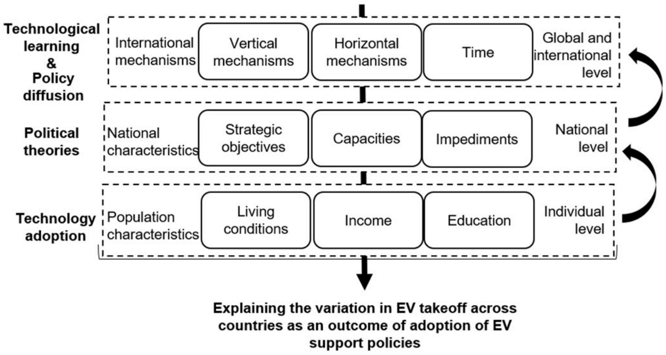

Fig. 1. Theoretical framework of the different theories underlying this research, including three levels of processes influencing adoption of EVs at takeoff level.

The adoption of a technology happens at the level of the individual, which I introduce as the basic level. The national level is based on national strategic objectives, characteristics, and impediments (e.g., the national ICEV regime) with different starting conditions across countries that influence the technology path and diffusion (Altenburg et al., 2015; Arthur, 2009). Innovation in major markets (e.g., regulations or targets) or actors (e.g., improved models or price reductions) can influence other markets through their leverage at the global level. The global landscape describes supranational strategies, legislation, or standards (e.g., EU), relevant geopolitics (e.g., related to oil prices, global economy), attention to policy fields (e.g., climate change or sustainability), and also developments within the global car industry. Details on the variables for the different levels are given in section 4.3.

3.1. Technology adoption and population characteristics

The differences in characteristics between (early) EV adopters and non-adopters and consumer heterogeneity are important when analyzing and modeling EV market development (Brand et al., 2017; Gnann et al., 2018).

On the individual level, some population segments are more likely than others to adopt an innovation (Rogers, 2010) or new vehicles in general (Figenbaum et al., 2015; Hjorthol, 2013). These include those with a high income (Hardman et al., 2016; Vassileva and Campillo, 2017) and the educated (Figenbaum and Kolbenstvedt, 2015). Empirical studies also conclude that EV adopters differ from non-adopters, being more likely to live in peri-urban areas (Plötz et al., 2016); be multi-vehicle owners (Campbell et al., 2012; Hardman et al., 2016; Jakobsson et al., 2016; Karlsson, 2017; Plötz et al., 2014); previous hybrid owners (Carley et al., 2013); male (Hardman et al., 2016; Trommer et al., 2015); middle-aged (Plötz et al., 2014; Westin et al., 2018); aware of environmental issues, therefore having high degrees of personal and social norms (Jansson et al., 2017; Mohamed et al., 2016) and being more highly aware of national energy security (Carley et al., 2013; Trommer et al., 2015).

Not all these characteristics, however, can be operationalized for quantitative analyses.

3.2. Political theories regarding national characteristics

In the early stage of technology diffusion, effective support policies are important. Introducing EV support policies is a political decision by a jurisdiction, such as a nation or federal state, or a city. How these political decisions are taken is influenced by domestic and external factors, reflecting a jurisdiction's political, economic, and social characteristics, as well as international diffusion mechanisms (Berry and Berry, 2007; Cherp et al., 2018; Kern et al., 2001; Tews, 2005; Tews et al., 2003). Tews et al. (2003) argue that political and technical feasibility influence the "diffusability" of policy innovations and that national contexts need to be considered. Studies covering several countries indicate that national differences can lead to different transition pathways in transport electrification, depending on countries' technological capabilities, demand conditions, political priorities, and economic governance (Altenburg et al., 2015; Wesseling, 2016).

According to the state-centric approach, which stresses government's role in civil society (Amenta, 2005) certain states have more capacity to implement certain policies and/or more interest in doing so. On the other hand, some states experience stronger vested interest in supporting—or not opposing—certain policies voiced by actor groups or coalitions (Meckling and Nahm, 2018; Moe, 2016). I also draw upon insights from political science, the Advocacy Coalition Framework (ACF) by Sabatier (1998), to explain the variation across states that are not exclusively based on structuralist and state-centric approaches to policy processes and the role of government. This leaves us with the following three broad categories i) national characteristics; ii) national capacities; and iii) national impediments.

3.3. International mechanisms in policy diffusion and technological learning

National innovation systems are not, however, closed systems. They interplay with the driving forces of technological and policy development outside national boundaries (Altenburg et al., 2015), especially when related to a consumer product of a global industry. Absorption of foreign knowledge depends upon an existing domestic knowledge capacity (see national characteristics above). Foreign and domestic innovation activities are interacting and complementary (Bell and Pavitt, 1996).

In the literature, international diffusion mechanisms (Berry and Berry, 2007; Dobbin et al., 2007; Karch, 2007; Shipan and Volden, 2008) are often broken down into horizontal and vertical mechanisms. The horizontal mechanisms are proximity, competition, learning, and emulation. The vertical mechanisms, coercion, imitation, and also learning, can emerge from powerful countries, country groups, or international organizations. Based on organizational decision-making theory, this research can facilitate the work of policymakers with capacity constraints who are seeking information on policy experiences in other countries.

The mechanisms mentioned above are partially entangled, difficult to separate from each other and to test empirically (Dobbin et al., 2007). I focus on learning, proximity and coercion which can be operationalized best.

In parallel to this, there is technology improvement. This is tied to technological learning and related improvements in cost-effectiveness, performance, and knowledge about the technology with increasing cumulative outputs over time.

4. Research design (materials and methods)

To answer the research questions, the following steps were taken (Fig. 2): i) identifying a method; ii) defining the outcome (dependent) variable; iii) identifying explanatory (independent) variables representing mechanisms in line with the theoretical framework; iv) defining

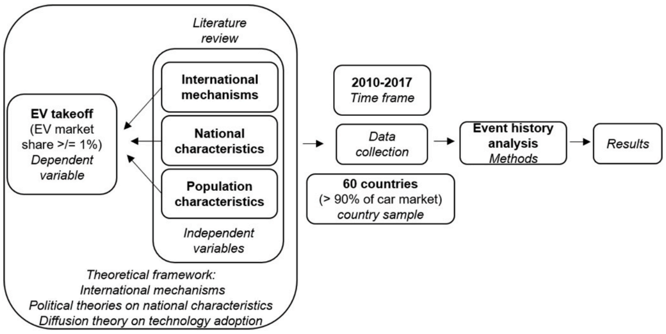

Fig. 2. Research steps: starting at the far left, from defining the dependent variable to going through the identification of independent variables within the broader theoretical framework. In a next step, collecting data for the country sample and the study period, then analysis with the chosen method to obtain the results (far right).

the period of investigation; v) defining the country sample; vi) collecting data; and vii) testing the relations between the variables in event history analysis.

4.1. Methods: event history analysis

In the literature, explanatory variables for technology or policy adoption have been estimated by discrete-time or event history models (Berry and Berry, 2007; Biesenbender and Tosun, 2014; Stadelmann and Castro, 2014; Strebel, 2011; Yi et al., 2017). Sustainable policy diffusion has been studied via event history analysis for renewable energies globally (Alizada, 2018) across developing and emerging economies (Stadelmann and Castro, 2014), and across Europe (Jenner et al., 2012; Zhou et al., 2019) and members of the International Energy Agency (IEA) (Schaffer and Bernauer, 2014). This technique takes data structure in a time-to-event format, with the objective being to understand the probability of the occurrence of an event—in this case, reaching takeoff. It looks into the similarities and differences encountered by different subjects (countries) that might affect survival or failure (adoption/takeoff or not) and provides explanations for them. It specifies hazard and survival functions that show the adoption pattern of a sample (Kauffman et al., 2012).

In the transport sector, an application of event history analysis is provided by Saikawa (2013) who studied the diffusion of automobile emission standards and found that standard adoption is related to countries' efforts to stay competitive. Event history analysis has not been used to study EV deployment which is continuous and not a single or recurring event. The innovation in this study is to introduce the concept of takeoff as a discrete event that allows event history analysis to be used with respect to the diffusion of EVs. This kind of operationalization has been used elsewhere in the literature for other technologies (e.g., energy technologies (Bento et al., 2018; Vinichenko, 2018), and mobile phone penetration (Techatassanasoontorn and Kauffman, 2014).

Compared to descriptive S-curve methods used in diffusion theory, event history methods help explain the relative importance and marginal effects of various factors and their relationships (Kauffman et al., 2012). Event history methods usually apply time-series and cross-sectional data (country-year data points in this study). The data from different observations are not compared to each other based on calendar time (as in usual panel data research) but based on their relative distance to the start of every subject's failure process (Kauffman et al., 2012). For each subject and time period there is an observation until a subject reaches the event (here, a country after takeoff).

In the literature on international technology and policy adoption with time-varying and time-invariant covariates, semi- and fully parametric methods (i.e., Cox) (e.g., Vinichenko (2018) and logistic regression (e.g., Tellis et al. (2003) are the dominant approaches, with Cox regression dominating in political science (Box-Steffensmeier et al., 2004). Both methods assume that takeoff is a probabilistic event, whose probability in a given year is determined by independent variables. This study will apply both, with Cox regression being the main method and logistic regression with time variables being used as a secondary method to validate the results (see Vinichenko (2018). For details on the two methods, see Appendix B.

A difference has to be made when interpreting the coefficients or exponentials of the coefficients (Steele and Washbrook, 2013): Cox estimates are effects on the log scale, and exp(β) are hazard ratios, denoting the relative risks. Logit estimates are effects on the log-odds scale, and exp(β) show hazard-odds ratios.

The seven-step approach for purposeful selection of covariates by Hosmer et al. (2013) is followed, representing an iterative process starting at univariate analyses to test different hypotheses based on theory. The free software environment "R," principally the package's "survival" and "glm," are used for model building and diagnostics.[2]

4.2. Dependent variables

To date EVs have been uncompetitive without public policy support (IEA, 2016). The diffusion of EVs, and their market takeoff thus represent an outcome of the available transport policy mix, showing which countries have implemented effective EV support policies for the formative stage.

Conceptually, takeoff describes the point of transition from the introductory or formative phase to the growth phase in the diffusion of an innovation. It describes a tipping point as a signal of mass adoption of a product and its ultimate commercial success, at which policy support is no longer crucial.

Previous literature in this field focused on the diffusion of policy instruments (Biesenbender and Tosun, 2014; Schaffer and Bernauer, 2014; Stadelmann and Castro, 2014) rather than on outcomes (Bento et al., 2018). As transport support policies are so diverse, focusing on the outcome is a good way of studying a global sample and making more generalizable inferences about EV (policy) diffusion.

As I investigate the overall outcome in terms of market takeoff, I cannot disentangle local and national policies. EVs receive support at different governance levels. Typical policy instruments include a wide variety of approaches such as public procurement, financial incentives to reduce purchasing (e.g., tax exemptions or credits) and operating costs (e.g., free parking, access to bus lanes), as well as various regulatory measures (IEA, 2016). Most recently, announcements of sales bans for diesel- and gasoline-powered passenger vehicles have been added. Potential EV adopters vary in their preferences for policy incentives, underscoring the current heterogeneous approaches (Priessner et al., 2018). However, national policies are deemed more powerful, and most monetary benefits, which have also shown to be most closely linked to EVs diffusion, are granted at the national level (Rietmann and Lieven, 2019).

Identifying the takeoff threshold for the dependent variable has to balance the need i) to be followed by the growth phase, and ii) to be as early as possible to include a maximum of data points. The approach of Tellis et al. (2003) to defining takeoff for cross-category and cross-country analyses takes the Golder and Tellis (1997) threshold

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[2] See https://www.r-project.org/.

based on units and growth in sales and translates it to market penetration. In this approach, takeoff curves that can be related to a 1% market share are empirically derived for consumer goods and used in the analysis as the threshold for takeoff proxy, marking the end of the formative phase (Bergek et al., 2008). I thus operationalize takeoff as the first year EVs reach 1% of market share in new car sales/registrations in a country. This binary dummy variable (yes = 1/no = 0) is coded reflecting data from a consulting firm based in Sweden (EV Volumes, 2019). Other market share thresholds were tested. The threshold of 1% has high predictive power related to takeoff year and market share and has been crossed by a sufficient number of countries (Appendix A). The sensitivity analysis (Appendix H) confirmed the results for different takeoff thresholds.

As passenger car markets vary significantly in size across countries, total numbers would have been misleading (Mersky et al., 2016; Münzel et al., 2019). A relative threshold can easily be crossed by smaller countries, induced by singular events. This was observed in Estonia and Sri Lanka (i.e., public procurement schemes) and Denmark (i.e., subsidy abolition with a surge in sales and subsequent market crash). Sales shares in all countries were studied to make sure that crossing the threshold did result in sustained growth,. This was also reflected in the coding of the dependent variable. Countries where this was not the case (i.e., Estonia and Denmark) were coded as not having taken off in the year they reached 1% EV market share for the first time.

4.3. Independent variables and hypotheses

When selecting variables in the literature that might explain why countries have reached takeoff, I applied the following criteria: i) availability for the country sample in the observation period (2010–2017), and ii) simplicity, focusing on avoiding duplication.

Variables can be relevant for several processes at different layers identified in the theoretical framework (section 3). In the following I present the hypotheses and chosen variables. Tables C1–C4 in Appendix C present exemplary supporting literature, the variable that operationalized each hypothesis, the data source, structure, effect, and any transformation, if applicable, for the different levels. In many cases, other operationalization and additional variables are thinkable (Appendix E).

4.3.1. Population characteristics

H1.1: The gross tertiary enrollment rate is used to reflect environmental awareness and innovativeness, which is related to a more highly educated population. Although the indicator does not say anything about the completion of tertiary education, it is the closest available reflecting post-secondary education across countries.

H1.2: Income levels have a positive effect on the likelihood of takeoff. GDP, GDP per capita and World Bank (WB) income groups are used to reflect the wealth of a country and the purchasing power of its population. Wealth is also connected to a state's capacity, so this variable is repeated below.

Fuel and electricity prices (below) are also connected to the affordability and purchasing decisions of EVs. They are grouped under national strategic objectives, as they are subject to taxes and subsidies that are often instruments of national policy objectives, thus being partly entangled with the objective to measure the outcome of policy support.

H1.3: Low population density has a negative influence on takeoff. Longer travel distances will make switching to EVs tougher until they have longer ranges. At the same time, the development of the charging infrastructure is less attractive in less densely populated countries.

H1.4: The urbanization rate is positively related to the uptake of EVs. Peri-urban populations tend to be among early EV adopters. Urban areas are initially more attractive for EV ownership because of the available charging infrastructure and the issue of range.

Hypotheses H1.3 and H1.4 are also related to national impediments (see below), as they not only pertain to individuals and their uptake based on their living conditions but possibly also to charging infrastructure development at the national level.

4.3.2. National characteristics

4.3.2.1. Strategic objectives. The endogenous problem perceptions of a country shapes its strategic objectives (Tews et al., 2003). With the transport sector being dominated by fossil fuels, most transport policies tackle energy objectives dealing with energy security and competitiveness. Transport policies can contribute to reducing import dependence, air pollution and greenhouse gas emissions and supporting local industries.

H2.1: Oil importers are more likely to take off as they want to reduce their import dependence. The share of net crude oil imports over primary oil consumption is taken to assess this.

H2.2: Major oil producers are less likely to take off as they have no incentive to electrify their fleet early. I select a threshold of 30% of total energy exports of total primary energy supply for a country to be a major oil producer, which is coded with a binary variable.

H2.3: The fuel price is positively correlated with EV takeoff. This might be a policy action itself, as fuel price taxation acts as a disincentive for EVs. Yet, as examples have shown, affordability is a key criterion for EV adoption. The weighted average fuel price according to national fuel mix (dieselization) is taken.[3]

H2.4: Growth in the transport sector (energy demand) has a positive effect on the likelihood of takeoff, to mitigate future import dependence or impacts on trade balances. The annual growth rate in transport energy demand is used.

H2.5: Electricity exporters are more likely to take off, as they have abundant electricity supply which can cover part of their domestic transport energy demand. Electricity importers might be hesitant to switch to EVs because of energy security issues. Net electricity exports are taken to look into this.

H2.6: Countries with lower CO_2 intensity in electricity are more likely to take off, as this indicates that a switch in fuel will support climate change mitigation.

H2.7: High air pollution levels lead to takeoff. Population-weighted exposure levels to PM2.5 are used. Air pollution and its related negative effects on human health and the environment due to ICEV has received major attention.

H2.8: Countries with a larger automotive industry are less likely to take off early, as incumbents will defend their market position, lobbying against policy change (Geels, 2014). The automotive industry has large leverage within national economies, given its importance for the industrial sector and labor market, and influenced as it is by state–business relations and how industry actors are organized (Bakker et al., 2014; Meckling and Nahm, 2018). It is thus

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[3] Further details available upon request.

an important policy field itself (Thun, 2006), and as EVs move out of the niche, they enter industrial policy competition where the state also guides technological visions (Meckling and Nahm, 2019). I believe, however, that in the early stage this might still be more of an obstacle for EVs. Governments, depending on their national industry's role in the global car value chain, have different motivations for supporting EVs (Wesseling, 2016). I use both the production of passenger cars (continuous) and a binary variable (the country is a producer or not) to test this.

H2.9: The electricity price has a negative effect on the likelihood of transport policy adoption.[4]

4.3.2.2. *Capacities (socioeconomic & institutional).*

H1.2. = H2.10: Income levels have a positive effect on the likelihood of takeoff. GDP/GDP per capita and WB income groups are used to reflect a state's capacity to adopt innovations. Wealthy countries can pay the costs of a technology, adopt novel technologies more quickly (Jewell, 2011), and introduce and promote environmental protection policies (Schmidt and Fleig, 2018; Stadelmann and Castro, 2014; Tews et al., 2003).

H2.10: The size of the population and the size of the car stock have a positive effect on the likelihood of takeoff. Larger markets have more leverage to introduce standards that manufacturers have to comply with.

H2.11: The motorization rate of a country has a positive effect on the likelihood of takeoff. This also relates to wealth, as motorization and GDP levels are correlated.

H2.12: The level of democracy has a positive effect on takeoff. I use a combined polity score assessing countries' autocratic and democratic characteristics. Countries need to have the institutional/political capacity to implement novel policies. While this is partly related to economic capacities (financial and human resources needed to develop and implement novel policies), it also covers the notion of a country being able to introduce policies in favor of the citizens (Lockwood et al., 2017). Democratic countries, for example, have been shown to perform better on these criteria.

H2.13: Federalist countries are more likely to adopt transport policies, as policy learning can occur on a sub-national level. I use different variable codings to assess federalism.

4.3.2.3. Impediments. To cover geographic challenges in providing infrastructure for EVs, urbanization and population density are also taken as relevant for this category (see above), H2.14 = H1.3, and H2.15 = H.1.4. The size or availability of a car industry (H2.8) could turn out to be an impediment.

4.3.3. *International mechanisms*

Disentangling the different mechanisms of international diffusion is not always clear-cut. Regarding this, I look into coercion, learning, and geographic proximity.

H3.1: Membership of the European Union (EU) and the European Free Trade Association (EFTA) has a positive effect on the adoption of transport policies, as EU strategies related to energy and transport are translated into national objectives (coercion), harmonization and standardization is pushed, and learning from peers is facilitated. I use two variables, one discriminating between EU/EFTA and non-EU/EFTA member states, and one where EU members states are split into new (joined since 2003) and old.

H3.2: Membership of the Organisation for Economic Co-operation and Development (OECD) has a positive effect on the adoption of transport policies. As the Electric Vehicle Initiative (EVI),[5] for example, was set up through the IEA within the framework of the OECD, learning can take place through this exchange.

H3.3: Adoption of a transport policy is more likely if neighboring countries have already adopted such policies, following the reasoning of spillover effects through geographic proximity. Other types of proximity studied are cognitive, organizational, social, and institutional. Geographical proximity is neither sufficient nor necessary for the transfer of innovations (Fadly and Fontes, 2019). Empirical diffusion studies have emphasized geographical proximity for the intensity and speed of adoption (Comin et al., 2012; Comin and Hobijn, 2004; Fadly and Fontes, 2019; Grubler, 1991). I use a binary variable if at least one neighbor has reached takeoff in the previous year. Following other literature (Pickel et al., 2009), land borders are used with the following exceptions: Iceland and Denmark are treated as a neighbors to Norway and Sweden; Pakistan and India are not treated as neighbors to China, as exchange via those borders is limited and the capitals are far from each other. The United Kingdom is treated as a neighbor to France and the Netherlands. These assumptions are also checked in a sensitivity analysis by using alternative coding.

H.3.4: The likelihood of EV takeoff increases with time. A time trend is representative of global technological learning. Learning happens with increasing experience and cumulative output over time. Technological learning is described through experience curves that delineate the reduction in unit costs at a certain rate. Time alone is not sufficient; also needed is the accumulated knowledge through cumulative experience in form of units produced. Still, here, time can be used to represent the global trend in technological learning which leads to EVs becoming more accessible to adopters with lower capacities, lower income, and less policy support. Granular technologies with large output numbers tend to have faster learning rates (Wilson et al., 2020).

4.4. *Timeframe*

In the literature, 2010 is identified as the first year when commercial manufacturers offered EVs to the broader consumer market with the first full EV 5-door "family" car[6] becoming available (Figenbaum and Kolbenstvedt, 2013; Sierzchula et al., 2014). The analysis thus starts in 2010. Norway was the first country to reach 1% in 2011. The last year included in the analysis is 2017, as the majority of data for the independent variables are only available till 2017. Also, the share of EVs in new sales globally reached the takeoff of 1% for the first time in 2016 (or 2017 for battery electric vehicles [BEV] only). The analysis thus covers the very early phase of the commercial diffusion of this technology, when it was strongly reliant on policy support.

4.5. *Sample*

The country sample (Fig. 3, Annex D) covers 60 countries 18 of which had reached EV sales of >1% of new annual vehicle sales by

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[4] Only available for IEA members.

[5] https://www.iea.org/programmes/electric-vehicles-initiative. EVI has had fluctuating membership. Currently 13 countries are members, all of which are part of the analysis.

[6] The Nissan Leaf was introduced in December 2010 in Japan and the USA. Mitsubishi iMIEV was available in April 2010. Tesla started delivery to customers in 2008 but Teslas are high-end EVs.

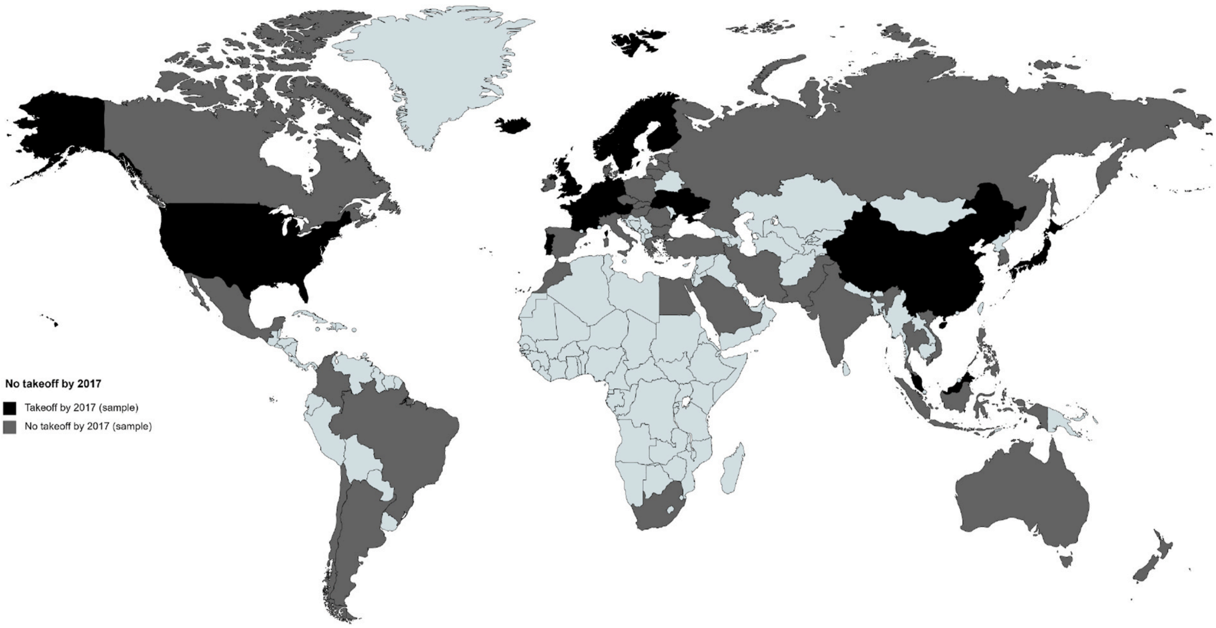

Fig. 3. Geographic spread of sample covering >90% of global new car sales. Countries in black have experienced takeoff by 2017; countries in dark grey have not. Countries in light grey are not part of the sample.

2017.[7] The sample represents 5.6 billion people: 75% of the world population and 89% of global GDP in 2017. The sample represents >90% of annual new car sales and practically the total global EV market during the period 2010 to 2017. It covers all OECD and high-income countries as well as emerging economies with annual passenger car sales greater than 150,000 in 2017 or previous years,[8] namely, the size of the total car market of Norway in 2017. Industrial countries have historically large car markets with high penetration rates, while emerging economies experience strong demand growth. The sample captures the world's largest car markets. Several of the new EU member states are relatively small car markets; however, given their EU membership, EV penetration is expected in those markets before other markets, which merits their inclusion.

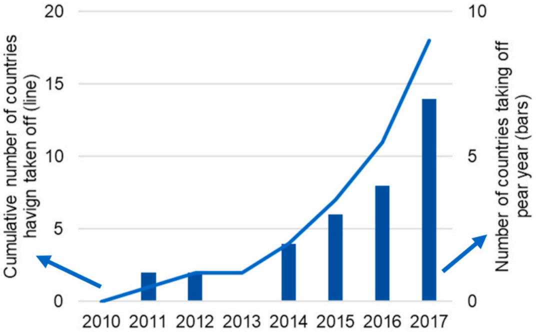

Fig. 4. Cumulative number of countries (lines) and number of countries taking off per year (bars) (>1% EV market share).

5. Results

This section presents the results for the sample (descriptive statistics in Appendix F) which covers 60 countries and 453 observations (n), with 18 countries experiencing takeoff during the study period 2010–2017 (Fig. 4). Each observation is a country-year pair. Countries are dropped after they experience takeoff.

Starting with a univariate analysis (Appendix Table G.1), different hypothesis are tested in multivariable regressions. GDP per capita, which is positively correlated with the likelihood of taking off, is controlled for. Overall, correlation is moderate across independent variables (Appendix Table G.2). Several of the hypotheses of explanatory variables were confirmed (Table 1): A lower grid emission factor is strongly related to takeoff, hinting at a decarbonization objective. In contrast to the hypothesis, the absolute or relative size of a local automotive industry is positively correlated with EV diffusion, as is the size of the local car market. Old EU/EFTA members are leading EV takeoff which is also reflected in a proximity effect of neighboring countries when not accounting for EU-EFTA membership. Fuelprice stays significant, when controlling for income. It is linked to policies directly through, e.g. taxation, and is thus quite close to the outcome variable to be useful in explaining what characteristics are related to differences in policy adoption across countries. Other exploratory variables did not turn out to be statistically significant (i.e., EU-EFTA or OECD membership in general, federalism, democracy, variables related to energy security and living/geographic conditions – density and urbanization rate, air pollution, and education level). A time trend turned out to be highly statistically significant in all logistic regression models, hinting at technological learning with increased output of EVs and experience with the technology worldwide. Both methods returned very similar results. Table 2 summarizes the findings for all variables.

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[7] The only country to have passed 1% market share and that is not covered by the sample is Sri Lanka, where overall car sales increased from 2,600 to 26,000 in the period and where the 1% threshold translates to less than 300 cars which are mainly related to a public procurement scheme.

[8] Taiwan would also fall into this category but had to be excluded because of missing data.

Table 1

Hypothesis testing: results of event history analysis ($n = 453$), logistics regression including time (more model combinations and Cox regression results in Appendix G). Note: The best fit combination is reported for each hypothesis group, coefficient estimates with standard errors in parenthesis; *$p < 0.05$, **$p < 0.01$, ***$p < 0.00$. Goodness of Fit: Concordance (i.e., a value of 0.5 denotes a random guess; the higher the value, the better). Akaike Information Criterion (AIC) – smaller AIC value indicates better model quality, AIC rewards model parsimony (limiting independent variables); Multicollinearity: Variance Inflation Factor (VIF).

Variable/Model	A.Combined	A.Combined	B.Geography/ Living Condition	C.Energy	D.Environ-ment	E.Industry	F.Market size	E. Instit. Capacity/ Characteristics	F. Internat. Mechanisms
	COMBO1	COMBO2	GEO1	ENE1	ENV3-2	IND1	MARKET1	INST1	IM1
intercept	−8.99 (1.55)***	−8.71 (1.48)***	−6.60 (1.03)***	−8.46 (1.38)***	−8.16 (1.37)***	−6.70 (1.06)***	−6.62 (1.04)***	−7.21 (1.47)***	−7.99 (1.29)**
carsproduced_scaled	0.67 (0.20)***					0.45 (0.17)**			
carsinuse_scaled		0.55 (0.19)**					0.34 (0.17)*		
density_scaled								0.67 (1.12)	
electricityco2_scaledˆ3	−0.78 (0.19)***	−0.77 (0.19)***			−0.63 (0.17)***				
eueftacat1									2.01 (0.64)**
eueftacat2									−16.68 (1561.78)
federalism3-1								0.40 (0.65)	
fuelprice_scaled				0.92 (0.41)*					
gdpcaplog_scaled	1.11 (0.45)*	0.83 (0.41)*	0.91 (0.40)*	0.87 (0.41)*	0.90 (0.40)*	1.22 (0.38)**	1.05 (0.36)**	1.03 (0.38)**	0.49 (0.37)
roadenergygrowthscaled				−0.76 (0.40).					
urbanpop_scaled			0.33 (0.38)						
year	0.81 (0.20)***	0.79 (0.19)***	0.55 (0.15)***	0.85 (0.20)***	0.74 (0.18)***	0.55 (0.15)***	0.55 (0.15)***	0.55 (0.15)***	0.71 (0.17)***
Concordance	0.91	0.91	0.85	0.88	0.89	0.85	0.85	0.84	0.92
AIC	106.58	108.61	128.73	122.25	113.75	124.34	125.95	130.56	110.70
VIF	gdpcap 1.20 electricityco2 1.72 carsproduced 1.39 year 1.49	gdpcap 1.06 electricityco2 1.65 carsinuse 1.20 year 1.44	gdpcap 1.23 urbanpop 1.23 year 1.01	gdpcap 1.05 roadenergy-growth 1.25 fuelprice 1.55 year 1.78	gdpcap 1.05 electricityco2 1.38 year 1.39	gdpcap 1.13 carsproduced 1.13 year 1.00	gdpcap 1.01 carsinuse 1.01 year 1.01	gdpcap 1.06 federalism3 1.10 democracy 1.04 year 1.01	gdpcap 1.18 eueftacat1 1.27 eueftacat2 1.0 year 1.10

Table 2
Summary of findings. Note: partly confirmed relates to the model specifications and variable levels.

Hypothesis		Operationalization	Results
Population Characteristics			
1.1	A high level of educational attainment has a positive influence on takeoff.	Gross tertiary enrollment ratio (%)	Not confirmed
Wealth (1.1): see below for income indicators (2.10); Living conditions (1.3): see below for density (2.15) and urbanization (2.16)			
National Characteristics			
National Strategic Objectives			
2.1	Oil importers are more likely to take off.	Net oil products imports as share of primary oil consumption (%)	Not confirmed
2.2	Major oil producers are less likely to take off.	Total energy exports >30% of TPES (yes = 1/no = 0)	Not confirmed
2.3	Fuel prices have a positive effect on takeoff.	Fuel price (USD/liter)	Partly confirmed
2.4	Growth in transport sector has a positive effect on the likelihood of takeoff.	Annual growth in road transport energy demand (%)	Partly opposite confirmed (GDP)
		Annual growth in car sales (%)	Not confirmed
2.5	Electricity exporters are more likely to take off.	Net electricity exports (total GWh)	Not confirmed
		Net electricity exports (share (%) over consumption)	Not confirmed
2.6	Lower CO_2 intensity of electricity is linked to takeoff.	Electricity grid CO_2 emission factor (gCO_2/kWh)	Confirmed
2.7	High air pollution levels lead to takeoff.	Population-weighted exposure levels to PM2.5	Not confirmed
2.8	A larger automotive industry is negatively linked to takeoff.	Cars produced (units)	Opposite confirmed
		Cars produced per capita (units)	
		Local car production (yes = 1/no = 0)	Not confirmed
2.9	The electricity price is negatively linked to takeoff.	Household electricity prices, PPP (USD/kWh) (233 missing values)	Not confirmed
Capacity: Socioeconomic & Market			
2.10	Income levels have a positive effect on the likelihood of takeoff. (equals 1.2)	GDP/cap PPP (2011 international USD) (log)	Confirmed
		GDP, PPP (2011 international USD) (log)	Not confirmed
		WB income groups (1 = L, 2 = LM, 3 = UM, 4 = H)	Not confirmed
2.11	The size of population has a positive effect on the likelihood of takeoff.	Total population (log) on January 1 of each year	Confirmed
2.12	The motorization rate has a positive effect on the likelihood of takeoff.	Cars per 1000 inhabitants	Not confirmed
		Total number of cars in use	Confirmed
Capacity: Institutional			
2.13	The level of democracy has a positive effect on takeoff.	"Polity" score on democracy (normalized)	Not confirmed
2.14	Federalist countries are more likely to take off.	Federalism (no = 0/weak = 1/strong = 2)	Not confirmed
		Federalism 2 (yes = 1/no = 0)	Not confirmed
		Federalism3 (strong = 1/weak and no = 0)	Not confirmed
Impediments/Geography			
2.15	Low population density has a negative influence on takeoff. (equals 1.3)	Population density (people per km^2)	Not confirmed
2.16	High urbanization rates have a positive influence on takeoff. (equals 1.4)	Population share living in urban areas (%)	Not confirmed
International mechanisms			
3.1	EU/EFTA membership has a positive effect on takeoff.	EU (and EFTA) membership (yes = 1/no = 0)	Not confirmed
		No/old/new EU (and EFTA) members (no = 0/old = 1/new = 2)	Partly confirmed
3.2	OECD membership has a positive effect on takeoff.	OECD and OECD-HI/EU membership (yes = 1/no = 0)	Not confirmed
3.3	Takeoff is more likely if neighboring countries have already adopted.	At least one neighbor reached takeoff in prior year (yes = 1/no = 0)	Confirmed
3.4	Time has a positive effect on takeoff.	Years	Confirmed

5.1. Sensitivity analysis

Several aspects that contribute to the robustness of the results have been considered:

First, many hypotheses were covered by several variables (e.g., GDP, EU/EFTA membership, and federalism) which sometimes also included different coding (e.g., proximity and federalism) to cover ambiguities and provide greater detail. This showed that "old-EU member" states was a significant characteristic while a binary EU membership variable did not support the hypothesis.

Second, the purposeful selection of variables and the iterative model-building process contributed to checking for all kinds of variable combinations and interactions in testing the hypothesis. In the univariate analyses (see Appendix G), many variables turned out to be statistically significant on their own. Variables that were significant at the $p < 0.25$ level and their interactions were also tested to check for confounding elements but only a few remained significant in the multivariate models (see Appendix G.3).

Third, models were tested with different levels of takeoff thresholds (Appendix H), showing that they performed well when takeoff was considered at 0.5% and 1.5% market share, respectively.

Fourth, to account for unobserved heterogeneity, the models were checked via frailty models. The introduced frailty term was not statistically significant and was zero indicating that the model explains the variation across country without any unobserved heterogeneity.

6. Limitations and future research

6.1. Limitations

The results of this study come with some limitations:

First, the study confines itself to national-level data. Sub-national entities are often quicker to introduce policies in support of innovations or are responsible for local transport policies (e.g., free parking, access to high-occupancy vehicle lanes, public procurement, toll-free driving). In a study on EV adoption in Austria, Priessner et al. (2018) found that early adopters live in regions with EV policy incentives. Actions at regional or city level then influence local adoption and national-level policies. Variation in policies across different scales (i.e., city, state, and national policies) influences EV diffusion (Stokes and Breetz, 2018). Because of data availability and the global scope, I restricted myself to a national-level analysis. Although this study reflects on the existence of federalism, it does not go further to operationalize sub-national decision-making for which individual country studies are more suitable. The results of this study should thus be interpreted with care. The majority of financial support policies that have the widest impact for uptake beyond innovators and that are needed for takeoff in the formative phase, are, however, provided at the national level.

Second, by looking at overall policy outcomes, this analysis does not cover explicitly the intensity, stringency or timing of individual policies. Policies could be strengthened or weakened or stay the same, which is also subject to different determinants and diffusion mechanisms (Biesenbender and Tosun, 2014). Case studies on policymaking across countries can provide insights on these processes. As some variables might be linked to policy themselves (e.g., fuel price as a disincentive through taxation) the discrimination is not as clear-cut.

Third, this study looked only at the formative phase of EV policy diffusion by focusing on EV market takeoff which was operationalized with a proxy. No insights on the mechanisms of the growth or even saturation phases (which have not yet been reached) can be derived from this research, as these different stages of the technology life cycle are shaped by distinct mechanisms which can vary from phase to phase (Grubler et al., 1999; Wilson et al., 2013). Separate studies would be needed as EVs mature.

Fourth, models aim to simplify complex interconnections between systems. Any operationalization in a single variable risks sidelining or masking important information, while others cannot be captured. Examples would be the international nature of the automotive industry, the different technological capabilities of national automotive and related industries, and the industries' political power and strategies. Parts of this can be captured by variables (e.g., the existence of an industry), as also done in this study; other characteristics or processes related to these actors need other analytical approaches, such as case studies. According to Altenburg et al. (2015) (p.474), the "complex dialectic relationship between global carmakers' strategies and country-specific conditions" cannot be captured.

Fifth and final, as with any econometric model, this research faces the challenges of correlation that could be mistaken for causality. The specification of covariates does not imply causal impacts on the outcome variable, though their selection is grounded in theory. Thus, the models must be interpreted primarily as descriptive models of the factors associated with takeoff.

6.2. *Future research*

The insights and limitations of this research provide a basis for further research. Some examples would include updating the analysis to include more countries and years as data become available, and also going beyond the formative phase. The same applies for more sub-national analyses on takeoff diffusion covering states (e.g. U.S. states), provinces, or municipalities, and interaction between local and federal policy.

In same markets (e.g. Netherlands) policy support lead to strong EV uptake in company fleets with a large share of overall sales (Santos and Davies, 2019). Corporate decision making is subject to different criteria (e.g. company policy, tax-optimization) that is not adequately reflected by the choice in variables. An analysis of the impact of policy on corporate purchasing and individual EV uptake, differences across countries in how they are trying to bring EVs into the market through different channels and the role of second-hand EV market merits further research.

The analysis could also be expanded by an historical perspective on transport policies targeted at reducing the fossil fuel dependence of existing technologies (e.g., fuel economy standards or biofuel blending mandates).

The approach used in this study could also be applied to other policy realms relevant to sustainable development, such as energy access (electrification and clean cooking), or energy efficiency in households, buildings, or industry. For example, Vinichenko (2018) looked at takeoff of solar and wind power through event history analysis.

This study does not consider a systemic view on the entire integrated transport system. Individual motorized passenger transport with privately owned vehicles may not the be the future. It would be of interest to study how multiple technology and policy innovations influence the transport system as a whole (Geels et al., 2015, 2018).

7. Policy implications

Transformations toward sustainable development are seen as a political challenge. The majority of studies are targeted at policymakers, providing science for policy (Geels et al., 2017, 2018). However, analysis of policies (or politics) and how they come about is also needed to achieve transformative change. Geels et al. (2018) stress various origins for transition policies that go beyond the idea that introduction of transformative policies are the results of sheer political will, (e.g., crises or shocks) (Delina and Diesendorf, 2013; Sovacool, 2016) or pressure from the public or industry (Kern et al., 2015; Raven et al., 2016).

Support policies are a critical and powerful lever for steering and possibly accelerating the adoption of EVs in the formative phase. Policymakers aim to tackle different national strategic objectives when allocating scarce public resources. The decarbonization of the transport fuel mix through a low grid emission factor, which turned out to be one of the most significant variables, is hinting at climate objectives of policymakers in supporting EVs. In this study, most of the energy-sector-related hypotheses (i.e., energy security, major oil producers, grid oversupply) could not be confirmed, suggesting a stronger role of industry policy in this realm. This is supported by the fact that the existence and size of a local automotive industry also had a positive connection to takeoff. The idea of regime resistance of the incumbent industry could thus not be confirmed, but rather the industry policy motivation. Countries that are leading in terms of EV diffusion do have higher fuel prices for end-users. Within the broad policy options to support EVs, disincentives for ICEV use is one route countries can take.

With regards to capacity in terms of which characteristics and initial conditions countries share that experience takeoff earlier, wealth (GDP per capita) turned out to be significant and strong. One has to be able to afford EVs and EV support policies. The study has shown that the form of governance (i.e. level of democracy) and level of federalism does not have a significant impact on the timing of EV takeoff, as illustrated in recent history by the rapid spread of EVs in countries as diverse as Norway, France, China or the US. Membership in EU/EFTA and OECD also did not impact the timing, except for old EU/EFTA members who have many early adopters. Policy learning, imitation or coercion through such a membership could not be reliably detected, while there is indication for geographic proximity. Disentangling and operationalizing these mechanisms remains a challenge.

The analysis shows that the probability of EV takeoff increases with time, as expected. Increased diffusion over time is a result of global technological learning, where industry plays an important role. Cumulative output grows which leads to improvements in performance, reductions of costs (e.g., design, materials, and components of EVs and charging infrastructure) and growing availability of charging infrastructure. Thus, EVs become more attractive and affordable. This is demonstrated by the sequence of takeoff where countries with less capacity start taking off with time as economic and technological barriers decrease and policy support to overcome remaining barriers becomes less crucial and challenging.

8. Main contributions

This study has tried to contribute to a better understanding of the conditions at play supporting transition policies (as called for by

Figueres et al., 2017; Geels et al., 2018; Meadowcroft, 2009) for one potentially transformative transport technology - EVs. The diffusion of EVs, like other transformative technologies, is an outcome of socio-technical, economic, and political factors (Cherp et al., 2018). The analysis advances understanding of the role of global and national contexts in the formative stage of EVs. There is little empirical evidence about policy diffusion in this realm.

Such empirical evidence could help to identify some barriers to policy evolution, thus i) improving guidance for policymakers on the design of national transport and development strategies; and ii) improving modeling of the energy and transport transition via better forecasting of technology diffusion (i.e., by improving the predictions of which new policy or technology countries will adopt next and what the diffusion patterns look like) (Jewell and Cherp, 2020). With these insights, coarse assumptions used in energy and transport modeling, can be refined to keep up with real-world diffusion rates needed for a sustainability transformation (Zimm et al., 2019).

The paper combines literature on technology and policy diffusion with empirical literature quantifying the socio-economic, political and international variables associated with technology adoption. It is the first quantitative study to apply event history analysis to EV diffusion and related policies to look at the explanatory variables for EV takeoff in the formative phase (2010–2017). Event history analysis has not been used to study EV deployment which is a continuous and not a single or recurring event. The theoretical contribution of this paper is the conceptualization of technology diffusion as an outcome of policy diffusion based on population and national characteristics, and international mechanisms. The year of "EV sales takeoff" (the year when EV market share exceeds the threshold of 1% for the first time) is used as the outcome. Such a variable has never been used in a cross-country analysis of EV adoption but it has been used elsewhere in the literature for other technologies (e.g., energy technologies (Bento et al., 2018; Vinichenko, 2018)).

While previous research has focused mainly on high-income countries, this study covered 60 countries worldwide (>90% of the global car market), including middle-income and developing countries. The empirical contribution of the study lies in identifying and validating socioeconomic and political factors and the international mechanisms that influence the position of a country on the diffusion curve.

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Author contribution

n.a.

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Supplementary data

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