Papers in Innovation Studies

Paper no. 2015/42

Explaining differences in electric vehicle policies across countries: innovation vs. environmental policy rationale

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This is a pre-print version of a paper that has been submitted for publication to a journal.

This version: November 2015

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Content and statistical analyses show that national PEV policies differed drastically across countries in intensity and orientation, ranging from a focus on supply-side innovation policy to a focus on demand-side environmental policy. The government's role across national political economies only explain differences in PEV infrastructure investments, while the government's EV diffusion targets for 2020 surprisingly do not correlate with any PEV policy. Economic interest in the car industry shows and explains why car countries focus their policy on technology development, and non-car countries on technology diffusion. These findings enhance the understanding of national policies in transitions.

JEL codes: Q58, H23, H31, O38, O25

Keywords: innovation policy; demand-side policy; geography of transition; industry support; varieties of capitalism; 2020 target

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Transition studies' understanding of differences in public policy is limited due to its tendency to focus on single-country cases. This paper assesses differences in plug-in electric vehicle (PEV) policies expenditures, comprising RD&D subsidies, infrastructure investments and sales incentives, across 13 countries over the period 2008-2014. I explore three conditions that may influence these policy expenditures.

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Highlights

- National PEV policies strongly differ in intensity and range from supporting technology development to technology diffusion
- Accordingly, policy rationales range from innovation (support domestic industry) to environmental policy (reduce emissions)
- Economic interest in the car industry stimulates supply-side innovation policy, but hampers demand-side environmental policy
- Varieties of capitalism only show that statist governments provide significantly stronger infrastructure investments
- More ambitious 2020 PEV diffusion targets surprisingly do not correlate with higher expenditures in any type of PEV policy

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1. Introduction

Transition studies have made significant contributions to understanding the complex, multidimensional processes of change from one socio-technical system to another. Such transitions entail co-evolution between industry, technology, markets, policy, culture, infrastructure and civil society (Geels, 2012). An example is the decarbonization of the transport sector. Transition studies have however recently received criticism for having an underdeveloped spatial perspective (Bergek et al., 2015; Markard et al., 2015; Truffer and Battistini, 2015; Truffer and Coenen, 2012; Quitzow et al., 2014). Both within the approaches of Technological Innovation Systems (TIS) and the Multi-Level Perspective (MLP), the geographical context has received little attention (Coenen et al., 2012).

Within TIS studies, national boundaries tend to be used as starting point of the analysis, "without making explicit why these boundaries were chosen and how they affect the findings and the generalizability of the results" (Markard et al., 2012, p.962). The Multi-Level Perspective equally fails to incorporate the spatial differences in a systematic way, sometimes conflating the conceptual levels of structuration with territorial levels (Coenen et al., 2012). Although various contributions to incorporate the spatial dimensions in transition studies have recently been made (Coenen et al., 2012; Murphy, 2015), more empirical research is needed that explains how spatial context matters in transition processes (Hansen and Coenen, 2014).

Public policy is an important means of organizing the innovation system and influencing transition processes (Borrás and Edquist, 2013; Schot and Geels, 2008; Rotmans et al., 2001; Coenen et al., 2010). Particularly environmental innovations that support sustainability transitions are strongly dependent on public policy support (Stern, 2006; Geels, 2011). Truffer and Battistini (2015, p.2) argue that because many policies supporting innovation and transition processes are formulated at the country level, most transition studies assumed that relevant transition processes would also take place within national boundaries. Such national policies may however differ significantly between countries. Because transition studies have mostly focused on cases in a small number of European countries (Markard et al., 2012), the extent of differences in policy support for innovation between countries has been understudied and perhaps underestimated. To assess these differences in public policy and to reflect on the generalizability of single-country transition studies, this paper analyzes policies supporting environmental innovation across a broader set of countries.

Policy making is a highly political process and influenced by various economic and political conditions that affect the legitimacy of public policy as well as its orientation towards supply or demand side measures (Borrás and Edquist, 2013; Schmidt, 2002; Weber and Rohracher, 2012). In the context of sustainability transitions it is relevant to distinguish between innovation policy, which aims to enhance economic growth by stimulating the innovative performance of new and existing domestic industries (Alkemade et al., 2011), and long-term environmental policy, which aims to reduce global and local emissions by for example facilitating the adoption of new, cleaner technologies[1] (Sandén and Azar, 2005). These issues have for a long time been addressed by separate policy regimes (Foxon and Pearson, 2008). Innovation policy focuses on overcoming market failures that relate mostly to the supply-side, through supply-side measures like R&D subsidies (Weber and Rohracher, 2012; Foxon and Pearson, 2008). Environmental policy, on the other hand, focuses on overcoming the

[1] Long-term environmental policy in this sense resembles that of transitions policy in the context of sustainability transitions, although transitions policy is less applied by policy makers and may be more multi-facetted (Alkemade et al., 2011).

demand-side market failure of negative externalities, like unpriced environmental impacts. To internalize these externalities, environmental policy tends to focus on demand-side measures like taxes, sales incentives and standards (*Ibid*.). In sum, effective and legitimate policy support for environmental innovations with high-growth potential yield both economic and environmental benefits; these double benefits may be enhanced by including both supply (innovation) and demand-side (environmental) policy measures (Weber and Rohracher, 2012; Foxon and Pearson, 2008; Alkemade et al., 2011).

Transition studies and particularly the TIS literature however do not adequately address the conditions that are influential to policy making (Bergek et al., 2015; Markard et al., 2015), how it affects a focus on innovation or environmental policy, and consequently what the consequences are for technology development and diffusion. To better understand the geographical component of transition processes, I follow the recommendations of Kern (2015) and Markard et al (2015) in exploring, across countries, how underlying economic and political conditions influence national policy support measures for environmental innovations with a high growth potential.

As discussed in the following Section, the conditions studied in this paper include, first, the effect of the political economic context and how this shapes perceptions about the role of government in terms of the extent and types of policy support measures that are legitimate to apply (Schmidt, 2002; Borrás and Edquist, 2013). Second, it includes how economic interest resulting from the relative size of an industry shapes innovation policy support. Third, it includes how political commitment to sustainability targets affects environmental public policy support. I quantitatively and qualitatively analyze the role of these economic and political conditions in relation to different types of supply and demand side policy support measures and explore potential other relevant conditions.

Finally, this paper also contributes to the literature on demand-based policy that argues that demand-side policy support measures are underutilized in innovation policy (Edler and Georghiou, 2007; Hommen and Rolfstam, 2009; Edquist and Zabala, 2012), by analyzing how and why supply and demand side policy support measures differ across countries.

The focus of this study is on public policy measures that support plug-in electric vehicles (PEVs). PEVs are radically different from conventional vehicles due to their reliance on a different drivetrain and infrastructure (Wesseling et al., 2014a). They also constitute an important solution for the long-term sustainability of the automotive industry (Uherek et al., 2010). Since EVs may replace part of the demand for conventional cars, the EV and related industries (such as battery manufacturing, infrastructure development and services) have the potential for high-growth. PEV policy support is therefore legitimized from both an innovation and environmental policy perspective. Finally, the automotive industry has been a global industry for decades, underlining the importance of an international, preferably global, perspective. The timeframe of study is 2008-2014 because during this period the first PEVs became available on the mass market (Wesseling et al., 2013), which coincides with the effectuation of policy support for not only PEV development, but also for PEV diffusion (Zhang et al., 2014). Studying the differences in national PEV-support policies and the underlying causes of these differences, thus provides a good case to learn more about the national policy dimension in sustainability transitions.

2. Theoretical framework

2.1 Role of the government in PEV policy support

The varieties of capitalism literature is identified as a useful complement to "incorporate political dimensions into TIS analysis", and to gain a better understanding of particularly the national institutions (Kern, 2015, p.2; Bergek et al., 2015; Markard et al., 2015). Embedded within the comparative capitalisms literature, the varieties of capitalism concept argues that, at the national level, different political economic systems can be identified based on the relations between businesses, governments, employees and financiers (Hall and Soskice, 2001; Jackson and Deeg, 2008). The unique configurations of these political economic systems constitute their comparative institutional advantage; institutional path dependence prevents radical shifts in these configurations (Jackson and Deeg, 2008). The framework has so far found little application in the field of transition studies and the associated policy perspectives specifically.

Schmidt (2002) deviates from Hall and Soskice's (2001) dichotomy of capitalisms, arguing that, based on the role of the state, three ideal-type capitalisms can be identified. The role of liberal governments is "creating a fair playing field but otherwise maintaining a hands-off approach", which is based on the belief that firms avoid highly regulated markets (Schmidt, 2002, p.133). The managed "state's greater involvement in the functioning of the economic system than in ideal-typical market capitalism may … mak[e] the economic system run more smoothly" (p.87); their role can be characterized as an "enabling facilitator". The statist government's role can be characterized as an "interventionist director" that directs innovation through public investment (Schmidt, 2003, p.529), "by way of industrial policy" (p.137). Where funding for innovation comes primarily from the government in statist capitalism, it tends to come from (risk averse) banks in managed capitalisms and from risk-taking venture capitalists in liberal capitalisms (Hall and Soskice, 2001). Although statist countries have over time become more liberal, institutional path dependence has prevented radical institutional change; they can therefore still be characterized as at least "state-enhanced" capitalisms (Schmidt, 2002, p.141). Hence, statist governments engage in stronger policy intervention, in this case PEV support policies, than managed governments, which again intervene more strongly than liberal governments, see Proposition 1[2].

Although no studies have compared the varieties of capitalism typology with innovation or environmental policies in a comprehensive set of countries, studies on the USA have indicated that its apparently liberal government has engaged in strong industrial policy (Lazonick, 2011; Block, 2008). Lundvall and Borrás (2006, p.609) remark that "it is a paradox that in the country having the most massive public intervention in terms of technology policy (the US), most of the policy has been motivated by non-commercial arguments and the discourse has been anti-state". By analyzing whether this apparent contradiction is unique or whether similar patterns can be found across captitalisms, this paper explores whether the varieties of capitalism typology can be extended to explain differences in public policy for environmental innovations.

Proposition 1: *"If countries' policy approaches are characterized as "interventionist director", then they will engage in stronger PEV policy support than countries whose approaches are characterized as "enabling facilitator"; if countries' policy approaches are*

[2] Mazzucato (2014, p.12) labels these respective policy approaches as "market fixing", "creating conditions" and "entrepreneurial".

characterized as "enabling facilitator", then they will engage in stronger PEV policy support than countries whose approaches are characterized as "hands-off"".

2.2 Economic interests and innovation policy

Innovation policies aim to improve the innovative capabilities of domestic firms to enhance their competitive advantage and foster economic growth (Foxon and Pearson, 2008), mostly through supply-side measures such as R&D subsidies (Edquist and Zabala, 2012; Edler and Geogrhiou, 2007). Innovation policy support tends to discriminate in favor of actors that are located within the nation state, which is labelled economic nationalism (Clift and Woll, 2012). Such public policy investments serve to create or safeguard jobs and may partially be earned back (ECC, 2013). Although state aid regulations generally prohibit economic nationalistic policies, innovation policies are permissible under European competition law (*Ibid*.). Countries have used extensive fiscal policies to stimulate their domestic industries, particularly those that are important to their national economies (Clift and Woll, 2012).

New industries and technologies have however also been targeted by nationalist innovation policies, particularly emergent high-tech fields such as aviation, internet and nuclear technologies (Lazonick, 2011; Ruttan, 2006; Mazzucato, 2014) and, more recently, for wind power (Lewis and Wiser, 2007). Through early public investments in these fields, governments hope to develop or attract potentially high-growth industries in their country. The competitive pressures between countries, arising from increasing globalization, may stimulate nationalist innovation policies (D'Costa, 2009).

Overall, innovation policy support is expected to be stronger in industries that are crucial to a nation's economy, not only to safeguard a higher number of jobs, but also because of the political power of the industry. Large industries with economic weight tend to have better organized and more powerful industry associations, enabling a more effective lobby for policy support (Hillman and Hitt, 1999). Wesseling et al. (2014b; 2015) show this for car manufacturers, whose interrelated innovation and political influence strategies strongly affected how clean vehicle policy is formulated. Hence, the expectation is that:

Proposition 2: *"If the automotive industry is more important to the national economy, then the government will issue stronger PEV innovation policy support that can be appropriated by that industry"*

2.3 Innovation diffusion aspirations and environmental policy

Long-term environmental policy aims to overcome the market failures associated with sustainability to reduce local and global emissions (Sandén and Azar, 2005; Foxon and Pearson, 2008). Besides internalizing negative externalities, environmental policy is also warranted because new, sustainable technologies are initially often outperformed by established technologies, and because incumbents that dominate the car industry and other polluting industries have little or no incentive to change by themselves (Geels, 2011; Wesseling et al., 2013).

With the adoption of the UNFCCC in 1994 which currently counts 195 member countries, annual global negotiations on climate targets have contributed to increasing climate pressures at the country level. These pressures will only increase as the 2015 COP21 aims to establish legally binding emission targets (COP21, 2015). Countries are free in how they meet their emission targets and tend to target the most polluting industries, such as energy and transportation. To reduce emissions, governments have issued a plethora of regulations, financial policies and soft institutions that penalize established polluting technologies, or that support environmental innovations.

Because in the automotive industry long-term emission targets cannot be met with established car technologies, countries are also setting targets for the diffusion of radically new, environmental innovations, like PEVs. Such diffusion targets for environmental innovations articulate to what extent the government intends to meet international emission targets, or overcome local issues such as criteria air pollutants, through these specific environmental innovations. Hence the following proposition:

Proposition 3: *"If countries adopt more ambitious PEV diffusion targets, then they will adopt stronger policy to support the diffusion of PEVs to help meet these targets"*

3. Methods

3.1 Research design

This study employs a mixed methods approach that combines quantitative and qualitative methods of analysis (Creswell, 2003). The quantitative approach assesses statistically if, and to what extent, national PEV policies differ across a set of industrialized countries, and analyses if these differences are influenced by the independent variables of role of the government, economic interests and innovation diffusion aspirations. The qualitative approach entails a content analysis of the rationales behind PEV policies, to verify the relation between these variables and to establish whether there are any other conditions that may influence how PEV policy support is drafted. Combining these quantitative and qualitative approaches may provide a deeper understanding of to what extent and why PEV policy support differs across countries.

The study focuses on industrialized countries, because data from developing countries is not always available and is less reliable. The sample of industrialized countries is presented in Table A.1 in the Appendix. These countries encompass both the world's most important as well as less important car manufacturing sites (OICA, 2015).

3.2 Operationalization and data collection

3.2.1 PEV policies

Governments may issue a range of policies to support the development and diffusion of PEVs. This study focuses on financial support instruments because they are easily quantified and extensively used by national governments, facilitating a quantitative comparison amongst a broader sample of countries. Standards may (indirectly) support PEVs, but are often established at the European level which hampers the comparison of EU countries. Soft institutions are less frequently used by national governments and often in a more complementary way (Borrás and Edquist, 2013). The dependent variable is labeled "PEV policy expenditures" and constitutes the total expenditures on national RD&D subsidies, on public investments in charging infrastructure and on sales incentives. This range of PEV policies covers both technology development and diffusion, and comprises both supply-side innovation policy (RD&D) and demand-side environmental policy (sales incentives and infrastructure investments).

The database builds on data from the IEA. To complement missing values and to triangulate the data, I contacted policy makers in the studied countries and conducted targeted research using policy documents, literature, the IEA's annual reports on hybrid and electric vehicles (IA-HEV, 2009-2015) and data from the ICCT. Despite these methods of triangulation, there may still be a gap between the estimates used and what has actually been spent, which poses a drawback to this study.

Because comprehensive data were not available at the local and regional level for the broad sample of countries, these levels fall outside the scope of this paper. This means that actual public policy expenditures per country may be higher and that tendencies to establish PEV policies at the local and regional as opposed to the national level may affect the findings. Typical regional and local PEV policies, such as access to high-occupancy-vehicle and public transport lanes, toll-free driving, public procurement and free public parking were therefore omitted from the analysis. Due to this drawback, the results of this study should be interpreted with care.

The database comprises government expenditures on PEV policies instead of announcements of public funding, because preliminary analysis indicated that much of the PEV funding announced by governments is actually not spend (see for example SPD, 2009). For sales incentives, the advantage of using actually spent data is that incentives are not biased by volatile or recently introduced policy incentives. Policy expenditures on RD&D, infrastructure and sales incentives are presented as percentage of GDP to account for differences in country size. GDP averages for 2010-2014 were obtained from the World Bank (World Bank, 2015).

The complementary qualitative analysis of the rationales behind the PEV policies of each country is based on national policy documents, on the IEA's annual reports about hybrid and electric vehicles (IA-HEV, 2009 through 2015) and on media statements by policy makers.

3.2.2 Role of the government

Differences in perception on the role of government were derived from Schmidt's (2002) typology of varieties of capitalism. Differentiating between liberal, managed and state capitalism, Schmidt characterizes the policy approaches of each of the countries studied as depicted in Table A.1 in the Appendix.

3.2.3 Economic interest

Economic interest, approached by the importance of the car industry to the national economy, was measured by the automotive industry's turnover, divided by the country's GDP. Industry turnover data were obtained from the OICA (OICA, 2015) and GDP data from the World Bank (World Bank, 2015). Because the OICA only provides turnover data for 2005, the 2005 GDP data were also used. Although this proxy dates back three years before the timeframe of study, it gives a good idea of the car industry's national economic importance before the economic crisis and thus of the actual stakes that require protecting during times of economic and technological uncertainty.

3.2.4 Innovation diffusion aspirations

Innovation diffusion aspirations were measured through the 2020 targets for PEVs on the road, as many countries set PEV diffusion targets to contribute to reducing their national emission targets. Broader sustainability targets, such as CO_2 emissions from transportation, do not specify whether these reductions are to be made through PEVs or other technologies. National PEV target data were obtained by triangulating data from IEA reports (IA-HEV, 2009 through 2015; IEA, 2011), contact with policy makers and online searches. To control for differences in car fleets, the stock data were taken as a percentage of the OICA's annual "personal cars on the road" data (OICA, 2013).

3.3 Data analysis

Because of this study's small sample size, which is characteristic to studying national policies, it is impossible to do multivariate analysis. Instead, separate bivariate analyses were conducted. Because the dependent variables are not normally distributed, non-parametric analyses were administered. Analyses were done for PEV policies' RD&D, infrastructure and sales incentives as well as for their totals. Spearman correlations were applied to identify the relation between PEV policies and the quantitative independent variables "economic interest" and "diffusion aspirations". Mann-Whitney U tests were administered to assess whether and which varieties of capitalisms had higher PEV policy expenditures. No significant correlations or differences were found amongst the independent variables.

For the qualitative part, content analysis of policy rationales was conducted, to deepen the understanding of the economic and political conditions that shaped PEV policy making and to identify additional conditions.

4. Results

Table A.1 in the Appendix provides an overview of the countries included in this study as well as the values for each independent variable. Figure 4.1 provides an overview of the national policy expenditures per country. In total, these countries have spent 12.9 billion USD on PEV policies over the period 2008-2014, which may not be much with respect to the 4.9 trillion USD (which is 6.5% of global GDP) spent worldwide on energy subsidies in 2013 (Coady et al., 2015). The USA accounts for one third of the total PEV policy expenditures. On average, countries annually spent 0.0063% of their GDP on PEV policies, of which 50% goes to RD&D, 12% to infrastructure and 38% to sales incentives. The data show that the level of these public expenditures differ extensively per country, with Norway and the Netherlands having spent by far the most of their GDP on PEV policies, due to their very high sales incentives. To illustrate, Norwegian and Danish relative PEV expenditures differ by a factor 12. Also the focus in PEV policies differs extensively per country; particularly Germany is quite extreme in providing no sales incentives and spending 88% of their policy expenditures on RD&D, whereas Norway's RD&D support (2.1% of policy expenditures) is negligible in comparison to its expenditures on sales incentives (96%).

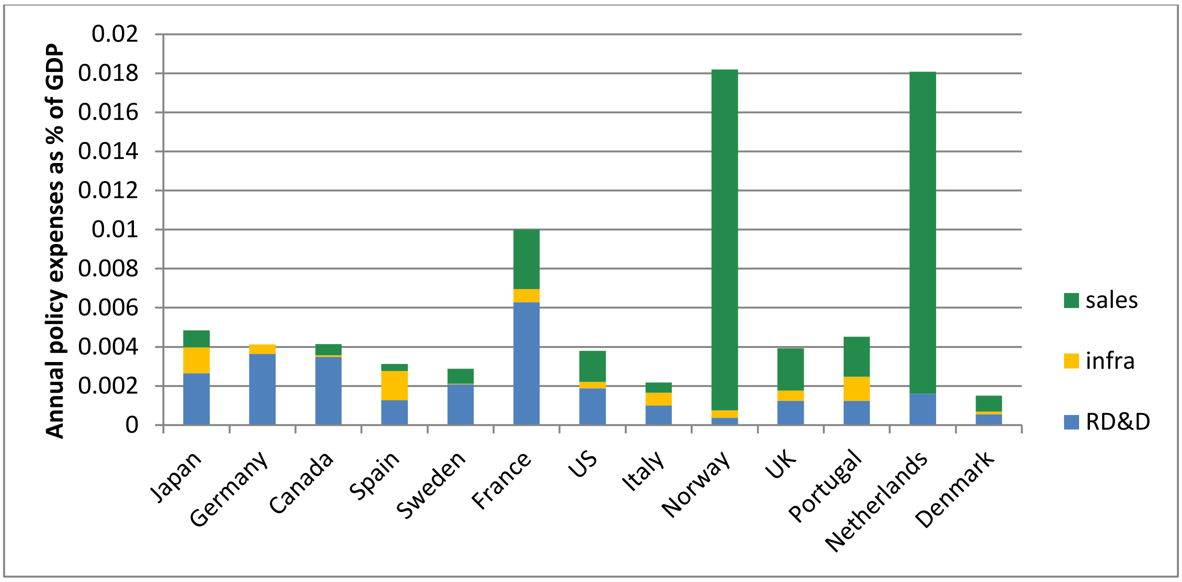

Figure 4.1, Countries' annual policy expenditures as a % of GDP on PEV RD&D, infrastructure and sales incentives. The graph is structured, from left to right, by decreasing domestic economic importance of the car industry.

Analysis of policy documents shows that all policy makers justified their expenditures by emphasizing the environmental benefits of PEV policy, regardless of the focus on technology development or diffusion, and that almost all policy makers emphasized the economic benefit for domestic industries. For environmental benefits they underlined the reduction of local air pollutants and global greenhouse gas emissions; for economic benefits they emphasized boosting the domestic PEV-related industries and sometimes also reducing the dependence on foreign oil. Industry support ambitions ranged across countries, from supporting their industry in gaining a lead in PEVs, to supporting their industry's survival, to forming new industries, to having no clear ambitions.

4.1 Role of the government

Table 4.1 presents the findings of the Mann-Whitney between groups comparisons for varieties of capitalisms on different types of PEV policies. The table shows that there are no significant differences between the varieties of capitalism for RD&D subsidies, sales incentives or the totals of PEV policy expenditures. Contrary to what was expected, it is the managed governments instead of the statist governments that on average have spent the most on total PEV policies. The only significant difference found is that of statist governments, which invest significantly more in PEV infrastructure than other governments ($p<0.05$, Mann-Whitney $U = 11.00$). This indicates that statist governments perceive investments in infrastructure development more strongly as a government responsibility.

Table 4.1, Results of the Mann-Whitney U comparisons between varieties of capitalisms, for different types of PEV policy expenditures.

Dependen t variables	N	RD&D subsidies Mean ranks	RD&D subsidies U and z value	Infra investments Mean ranks	Infra investments U and z value	Sales incentives Mean ranks	Sales incentives U and z value	Totals Mean ranks	Totals U and z value
Liberal	3	8.00	12.000;	5.33	10.000;	7.33	14.000;	6.33	13.000;
others	10	6.70	-0.507	7.50	-0.845	6.90	-0.169	7.20	-0.338
Managed	6	6.83	20.000;	5.33	11.000;	7.33	19.000;	7.67	17.000;
others	7	7.14	-0.143	8.43	-1.429	6.71	-0.286	6.43	-0.571
Statist	4	6.50	16.000;	**10.75**	**3.000;**	6.25	15.000;	6.50	16.000;
others	9	7.22	-0.309	**5.33**	**-2.315***	7.33	-0.463	7.22	-0.309

* Significant at the 0.05 level (2-tailed)

Although market failure arguments could legitimize PEV policy support for any capitalism, the PEV policy statements identified through the content analysis go beyond fixing such failures and instead are framed in an interventionist way; even by liberal capitalisms. To illustrate, in the neo-liberal UK the Transport Secretary justified the UK PEV policy by stating that "government must direct and support this, through what I call new industrial activism" (DFT, 2010). Similarly, the neo-liberal USA's PEV strategy is framed as "ensuring that America leads in the growing electric vehicle manufacturing industry" (DOE, 2011, p.2).

Hence, the quantitative and qualitative analyses suggest that the varieties of capitalism typology cannot be applied 1-on-1 to PEV policy and that Proposition 1 *"If countries' policy approaches are characterized as "interventionist director", then they will engage in stronger PEV policy support than countries whose approaches are characterized as "enabling facilitator"; if countries' policy approaches are characterized as "enabling facilitator", then they will engage in stronger PEV policy support than countries whose approaches are characterized as "hands-off"",* is not valid. Instead, only statist governments invested significantly more in PEV infrastructure than governments in other market economies.

4.2 Economic interest

The results of the Spearman test, presented in Table 4.2, show that economic interest in the car industry does not correlate with public PEV infrastructure investments. There is however a positive correlation between economic interest ($p<0.01$) and RD&D subsidies and a negative correlation between economic interest and sales incentives ($p<0.05$). This suggests that RD&D subsidies may compete with sales incentives for limited public funding for PEVs, even though the rationales for supply and demand-side policies differ.

Table 4.2, Results of the Spearman correlation of PEV policies and economic interest in the car industry and innovation diffusion aspirations

		PEV policy expenditures:			
		RD&D	*Infra*	*Sales*	*Total*
Economic interest	Correlation Coefficient	,741**	,297	-,555*	,044
	Sig. (1-tailed)	,003	,162	,025	,443
Innovation diffusion aspirations	Correlation Coefficient	,407	,225	-,110	-,132
	Sig. (1-tailed)	,084	,230	,360	,334

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

The content analysis confirms that strong car countries favor RD&D subsidies to enhance the development of PEV capabilities by the domestic industry, whereas non-car countries favor sales incentives to facilitate PEV diffusion. Automotive countries push each other to support their domestic industries through increasingly strong interventionist innovation policy. As indicated by a German policy document to legitimize a 500 million euro RD&D program: “Germany must position itself in good time to the global competition if not to fall behind. Other countries such as the USA and Japan, but also China support their industries and research community already with extensive programs on electric mobility: China funds 1 billion euro … the USA funds $2 billion and $25 billion in loans … Japan $200 million” (BMWi et al., 2009, p.2, translated from German). Indeed, the car countries Germany, Japan, USA and France account for 82% of the total 6.4 billion USD spent on RD&D over the period 2008-2014 by the 13 countries studied.

Besides strong automotive contenders, some countries with weaker car industries indicate they also see “a real potential” in the global PEV transformation of the automotive industry; in the UK case to “take a lead in this sector” (HM government, 2009, p.3) or, in the Dutch situation, to create new opportunities for their entrepreneurs (IA-HEV, 2015). These countries spent however less of their GDP on RD&D subsidies.

From an innovation policy perspective, strong PEV sales incentives are easier to maintain in countries where the domestic car industry may profit from these incentives. This may be one of the reasons why Germany did not implement any sales policy: initially, the public money would have gone to foreign manufacturers since German brands were relatively late to introduce their PEVs (Wesseling et al., 2013). Furthermore, the sales-incentive oriented Norwegian PEV policy has been criticized for not providing sufficient economic opportunities for domestic industries and instead benefitting only foreign manufacturers (Valle, 2015). To reduce their costs, Norway decided to cut back its successful PEV diffusion policy (The Telegraph, 2015). The French case illustrates however that sales incentives may also yield economic benefits. Minister Montebourg justified the increased sales incentives for PEVs by indicating that French manufacturers have received over 80% of these incentives (Holtz, 2013).

The quantitative and qualitative findings support Proposition 2*: "If the automotive industry is more important to the national economy, then the government will issue stronger PEV innovation policy support that can be appropriated by that industry"*, noting that RD&D subsidies can be appropriated by the domestic industry more easily than sales incentives and public infrastructure investments can.

4.3 Innovation diffusion aspirations

The Spearman correlation in Table 4.2 shows that countries' targets for PEVs on the road by 2020 do not correlate with any of the PEV policies, not even with demand-side policy. This is surprising, because sales incentives and public charging have been proven to stimulate PEV diffusion (Jin et al., 2014; Sierzchula et al., 2014) and governments with more ambitious PEV targets would be expected to also provide the support to meet these targets. The differences in 2020 targets can perhaps be better explained by differences in expectations and in forecasting capabilities. It turns out that many of the PEV targets seem too ambitious; most of the 2015 PEV targets will not be met and a complementary analysis of the number of PEVs on the road shows that of this study's sample only Denmark, Japan, the Netherlands, Norway and the USA had by, the end of 2014, met just more than 5% of their 2020 target.

This argument is supported by the content analysis which shows that the Netherlands and Norway aspired to lead (a succeeded to) in PEV diffusion through strong sales incentives (IA-HEV, 2011; 2015), while having relatively modest or, hence more precisely, not overly ambitious 2020 diffusion targets (see Table A.1). Germany's target is equal to that of the Netherlands, and even though it had met only 2.6% of its 2020 target by the end of 2014, it is still not providing any sales incentives for PEVs. Germany instead argues that its R&D-dominated PEV policy will help meet its target, postulating that further technology development is necessary before "electric cars have a real environmental advantage" (BMUB, 2011, p.4).

These findings falsify Proposition 3: *"If countries adopt more ambitious PEV diffusion targets, then they will adopt stronger policy to support the diffusion of PEVs to help meet these targets",* because differences in diffusion targets are more likely to be explained through differences in forecasting capabilities and because some countries do not feel the urge for stronger demand-side policy.

5. Conclusions and discussion

This study shows that over the period 2008-2014, national PEV policies differed drastically across countries in intensity and ranging in focus from supply-side innovation policy to demand-side environmental policy. Accordingly, policy goals ranged from boosting the innovative performance of domestic industries to achieving environmental benefits. Hence, some countries focus more on supporting technology development, and others more on supporting early niche market formation, implying that the policy dimension of socio-technical transitions develops differently across countries. To understand these differences in PEV policies, the study explored economic and political conditions of potential influence.

Contrary to the literature, no significant differences in PEV policies were found across varieties of capitalism's different perceptions about what the government's policy approach should be; with exception only of statist governments investing significantly more in PEV infrastructure. Even the most liberal countries framed their strong innovation policies in an interventionist way, actively supporting domestic industries. Further research should look into the causes for this trend towards interventionist policy. Interventionist policy may for example have been legitimated due to the recent economic crisis (Clift and Woll, 2012), or may be affected by the trend towards challenge-driven policies across all political economies in Europe, including the mission-oriented policies in the USA (Mazzucato, 2014).

Differences in PEV policies can however be better explained by the importance of the car industry to the national economy, which correlated positively with RD&D subsidies and negatively with sales incentives. Content analysis indicates that car countries trigger each other in boosting their car industries with strong innovation policies. Non-car countries instead are led more by environmental policy and focus on sales incentives to facilitate PEV diffusion. This understanding of why some countries focus their policy on technology development and others on technology diffusion underlines the importance of developing a transitions framework that links different national supply and demand-side developments into a well-functioning, international or even global socio-technical system (Truffer and Battistini, 2015). Such a framework will help overcome the often criticized tendency of TIS studies to recommend all system functions should take place within one country (Markard et al., 2015).

Finally, although countries justified their PEV policies as a way of meeting their PEV diffusion and broader environmental ambitions, PEV diffusion targets for 2020 did not correlate with any type of PEV policy. This discrepancy questions the validity of such targets, and suggests that the height of PEV targets is either subject to strong differences in expectations about the pace of PEV diffusion, or that PEV targets may have been used as a political tool.

To identify a strong balance between supply and demand-side policies has been an important venue for further research (Borrás and Edquist, 2013; Edler and Georghiou, 2007; Edquist and Zabala, 2012). This paper however shows that such a balance is strongly influenced by political and particularly economic conditions that should be taken into account when formulating policy recommendations. Consideration of these conditions helps prevent making technocratic, one-size-fits-all policy recommendations.

An important drawback of this paper is the lack of data on regional and local PEV policies, which may be influential in infrastructure development and particularly in PEV diffusion (Van Rijnsoever et al., 2013). Research on geographical differences in public policy would profit from the inclusion of regional and local innovation and environmental policies, which may differ within and between countries. Such data would also enable the comparison of policies at different geographical levels, creating opportunities to develop a truly spatial perspective on public policies that affect socio-technical transition.

Acknowledgements

I want to thank the IEA, the ICCT and the policy makers of the different countries for their assistance in the data collection. I thank Lars Coenen and Frank van Rijnsoever for their comprehensive comments on earlier versions of the paper. Financial support from Nordic Energy Research through the TOP-NEST project is gratefully acknowledged.

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Appendix A

Table A.1, Overview of countries under study and their independent variable scores

	Role of government (policy approach)	**Economic interest** (turnover car industry / GDP)	**Diffusion aspiration** (PEV target 2020)
Canada	Hands-off	7,4%	3,5%
Denmark	Enabling facilitator	0,5%	1,8%
France	Interventionist director	5,7%	6,0%
Germany	Enabling facilitator	8,9%	2,4%
Italy	Interventionist director	3,3%	1,8%
Japan	Enabling facilitator	10,6%	3,3%
Netherlands	Enabling facilitator	0,5%	2,3%
Norway	Enabling facilitator	2,8%	6,7%
Portugal	Interventionist director	2,5%	10,5%
Spain	Interventionist director	7,2%	10,5%
Sweden	Enabling facilitator	7,1%	12,5%
UK	Hands-off	2,7%	4,6%
US	Hands-off	3,6%	4,9%