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Exploring car manufacturers' responses to technology-forcing regulation: The case of California's ZEV mandate

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ABSTRACT

The ability of firms to influence environmental regulation has largely been overlooked in transition studies. We study how car manufacturers combine and change their innovation and political influence strategies in response to a technology-forcing regulation. We apply a conceptual framework on corporate responses to public innovation policy to the case of the zero emission vehicle mandate over the period 1990–2013. We use patent and sales data to operationalize the R&D and commercialization aspects of innovation strategies, while using corporate political activities data to operationalize political influence strategies. We find that first, car manufacturers used specific combinations of innovation and political influence strategies, depending on their value maintaining or value creating nature. Second, manufacturers changed their strategies and became more value creating over time, which supported socio-technical change. Third, we refine the available strategy typology by identifying subclasses in defensive (opposition and slowdown) and proactive strategies (shaping, support and progressive).

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1. Introduction

Our society faces many sustainability problems and a transition toward a more sustainable society is imperative (EC, 2012; WCED, 1987; Van den Bergh et al., 2011). The diffusion of new, more sustainable technologies will make an important contribution to making our society more sustainable. This will not only involve the development of novel technologies, but also requires changes in the socio-economic and institutional contexts that facilitate the diffusion of these new technologies. Many 'transition studies' papers have described possible pathways in which new technologies emerge in niches and may become part of a socio-technical regime—i.e. a stable configuration of interacting dimensions, including technology, markets, politics, culture, and science (Geels, 2002, 2011; Kemp et al., 1998; Grin et al., 2010). Policy interventions are an important means of facilitating transitions, by supporting technological niches or by opening up the regime for novel technologies (Schot and Geels, 2008; Raven, 2004; Loorbach, 2010; Rotmans et al., 2001).

Public innovation policy is frequently used to trigger or even force firms to engage in innovations that contribute to a more sustainable society. Examples of such innovation policies include tax incentives, R&D subsidies and technology-forcing regulations. Technology-forcing regulations – e.g. fuel or energy efficiency standards for cars, appliances and buildings, or sustainable energy obligations in the electricity mix – force firms to develop and introduce novel sustainable technologies. Some of such sustainable technologies are radical and competence-destroying in nature (Tushman and Anderson, 1986) and may require changes in the system that surrounds the technology, e.g. infrastructure, supply chain and consumer behavior (Hekkert et al., 2005). The competence-destroying and systemic nature of a technology reduces the ability and incentive to innovate, particularly for incumbent firms (Christensen, 1997; Wesseling et al., in press; Chandy and Tellis, 2000). Without public innovation policy, firms would invest less in these technologies, also because the (environmental) benefits of clean technologies do not fully accrue to the firms that develop them (Rennings, 2000; Van den Bergh et al., 2011; Geels, 2011).

When firms are confronted with regulatory pressure to innovate, they will not simply comply by engaging in the mandated innovation; they may also try to actively prevent or influence the regulation through corporate political activities (CPAs). CPAs are defined as "corporate attempts to shape government policy in ways favorable to the firm" (Hillman et al., 2004, p. 838; Baysinger, 1984). Particularly incumbent firms that are unwilling to innovate may leverage their powerful resource base to oppose policy interventions mandating radical innovation. This way they attempt to maintain their existing position which is more profitable than it would be with the radical innovation. With their unwillingness to innovate and potential influence on policy interventions, powerful incumbents may pose a significant barrier to socio-technical transitions.

However, the ability of firms to influence regulations has largely been overlooked in the innovation management and transition studies literature, but is the focal point of the CPA literature (Hillman et al., 2004; Lawton and Rajwani, 2011). The CPA literature has developed largely independently from the literature on innovation strategies; recent CPA review studies do not even mention the words 'innovation' or 'technology' (e.g. Lawton et al., 2013; Lux et al., 2011; Mathur and Singh, 2011).

In this paper we therefore develop a conceptual framework that combines corporate innovation and political influence strategies, thereby bringing together two previously separate bodies of literature. Building on the work of Oliver and Holzinger (2008) and the innovation management literature, the framework not only distinguishes between innovation and political influence, but also between value maintenance and value creation. Where value maintenance refers to the exploitation and preservation of the status quo, value creation relates to exploiting early mover advantages under a firm's changing environment. This framework allows us to longitudinally study how incumbents combine and change their innovation and political influence strategies over time, in response to innovation policy. By doing so, we provide insights into the role incumbents play in the socio-technical transition to a more sustainable society.

The type of public innovation policy we focus on in this case study is technology-forcing regulation, because it mandates innovation and triggers political influence by incumbent firms. In the context of the need for a more sustainable society, we focus on the car industry, as road transport accounted for 28% of the CO_2 emissions from fossil fuel combustion in the US in 2012 (EPA, 2014a). More specifically,

we study the case of how car manufacturers responded to the Californian Zero Emission Vehicle (ZEV) mandate over the timeframe 1990–2013. This mandate forces clean vehicle technologies onto the market, including radically new and systemic innovations, with the goal of making our currently unsustainable transportation system more sustainable (Sperling and Gordon, 2009; Collantes and Sperling, 2008). The ZEV mandate was issued in 1990 by the California Air Resources Board (CARB) and, in response to car manufacturers' political activities, has been continuously adapted since that date. This makes it possible to study strategic changes in the context of our conceptual framework. Moreover, the mandate has been very influential, as it is adopted by California, one of the largest car markets in world, and by nine other US states (CARB, 2012a). Consequently, the ZEV mandate provides a good case to longitudinally study the interrelation and possible change of corporate innovation and political influence strategies in response to influential technology-forcing policy.

The remainder of this paper is structured as follows. Section 2 discusses our conceptual framework on corporate response strategies to public innovation policies. The Methods are discussed next, followed by a brief description of the ZEV mandate in Section 4, and the Analysis in Section 5. To conclude, we summarize the findings of this paper and we reflect on how this study has benefited the field of transition studies by providing more insights in the innovation and political influence strategies of incumbent firms through which they affect transition processes.

2. Theoretical background

2.1. Political influence strategies

The corporate political activities (CPA) literature argues that in strongly regulated environments, firms may strengthen their competitive advantage by engaging in political influence strategies (Hillman and Hitt, 1999). Political influence strategies comprise a timed sequence of consistent CPAs to influence public policy in a particular way. CPAs that underpin these strategies include for example lobbying, litigation, constituency building and political action committee contributions. The CPA literature perceives the political environment not just as a set of government-imposed constraints that impose costs on firms, but also as an opportunity set within which firms can exert influence to maintain their value or create new value (Hillman and Hitt, 1999; Lux et al., 2011; Oliver and Holzinger, 2008).

Oliver and Holzinger (2008) differentiate between the value maintaining and the value creating nature of political influence strategies. They refer to value maintenance as "the preservation of those firm assets and competencies that constitute the foundation of firm rents", and to value creation as "the invention or reconfiguration of firm assets or competencies that constitute an original or unique addition to firm rents" (, p. 497).

Oliver and Holzinger (2008) label value maintaining political influence strategies as defensive strategies. Firms engage in these strategies to oppose regulations that threaten the value of their assets and to protect the favorable status quo (Oliver and Holzinger, 2008; Shaffer and Hillman, 2000; Stenzel and Frenzel, 2008; Hillman et al., 2004; Carroll, 1979). Tobacco companies for example, are famous for their defensive strategies, illustrated by their many attempts to thwart restrictive regulations on tobacco. Oliver and Holzinger (2008) label value creating political influence strategies as proactive strategies. These strategies are intended to shape regulations in ways that support value creation for the firm (Carroll, 1979; Buysse and Verbeke, 2003; Oliver and Holzinger, 2008). Through political influence of public innovation policy, firms may increase their success in obtaining government subsidies or winning government tenders, or they may attempt to shape technology-forcing regulations in ways that involve low compliance cost for themselves, but that raise compliance costs for competitors disproportionately (Oliver and Holzinger, 2008).

2.2. Innovation strategies of incumbents

Public innovation policies trigger or even mandate firms to engage in innovation. Hence, firms – even incumbents with vested interests – generally respond to such policies through innovation strategies. Building on previous work, we define an innovation strategy as a timed sequence of internally

consistent resource allocations to the development and commercialization of technologies that are new to the firm itself and/or its markets, to achieve long-term profitability (Adams et al., 2006; Dyer and Singh, 1998; Lieberman and Montgomery, 1998).

We conceptualize innovation strategies as having an R&D and a commercialization component. Diverse R&D activities retain the firm's flexibility, allowing it to explore and move into different technologies (March, 1991; O'Reilly and Tushman, 2008). Intense R&D investments are required to engage and lead in technological development (Freeman and Soete, 1997). Commercialization involves mass sales of the technology and requires significant investments in production facilities and marketing.

Applying Oliver and Holzinger's (2008) distinction between value maintaining and value creating strategies, we adopt the innovation management's dichotomy of what can be characterized as laggards and early movers (Lieberman and Montgomery, 1998, 1988; Freeman and Soete, 1997). Value creating 'early movers' employ stronger innovation strategies to exploit early mover advantages, like capturing early markets and establishing lead time (Lieberman and Montgomery, 1998, 1988). Early movers invest heavily in R&D, which enables them to move to the market when the market is emerging. Regarding the timing of market-entry, we distinguish 'first movers' that pioneer in commercialization and 'quick followers' that aim to quickly follow first movers to the market to prevent the costly mistakes of pioneers (Lieberman and Montgomery, 1998; Freeman and Soete, 1997). Exploiting public innovation policies can be an important means to enhance the profitability of the early mover innovation strategy.

Value maintaining firms aim to exploit the status quo, often because they lack innovative capabilities. These firms employ laggard innovation strategies that minimize costs by investing little in R&D and entering the market late (Lieberman and Montgomery, 1998; Freeman and Soete, 1997).

In some instances public innovation policy fails to make firms commit strongly to new technology development and commercialization. In such cases, firms may not seek to gain long-term profit through innovation, but may – in the case of technology-forcing regulations – instead pursue cost-efficient compliance strategies. Such strategies constitute a low cost alternative that is preferential to incurring the penalty of non-compliance, and which may involve the exploitation of regulatory loopholes (Ford, 2008; Anderson and Sallee, 2011). Because such strategies also aim to continue exploiting the status quo with minimal innovation, we group them under laggard innovation strategies.

Because of the high costs of innovation and firms' limited resources, firms may not be able to afford strong innovation in many different technologies. Therefore, innovation strategies are often technology specific (Teece et al., 1997) and differ per type of innovation. Innovations may be typified according to the technological (incremental vs. radical or competence-destroying) and the socio-economic (modular vs. systemic) changes they bring about (Hekkert et al., 2005; Garcia and Calantone, 2002). Radical and/or competence-destroying innovations are harder to exploit by incumbents because they require new capabilities (Tushman and Anderson, 1986). Systemic innovations are more difficult to commercialize successfully because they require change by all actors affecting the technology, including consumers, policy makers, suppliers and infrastructure providers (Hekkert et al., 2007).

2.3. Conceptual framework

Table 1 displays our conceptual framework that combines innovation and political influence strategies of firms in response to public innovation policy. The upper quadrants of the two-by-two matrix differ in the nature of the innovation strategy (laggard and early mover) and the lower quadrants differ in the nature of the political influence strategy (defensive and proactive). Oliver and Holzinger (2008) suggest that firms may exploit synergies in combining different types of strategies, i.e. innovation and political influence strategies, something we will explore in Section 5.

3. Methods

3.1. Case study design

To study how incumbents respond through innovation and political influence strategies to technology-forcing regulation, we conduct a longitudinal case study of the innovation and political

Table 1
Corporate response strategies to public innovation policy, comprising innovation and political influence strategies.

		Value perspective	
		Value maintenance	Value creation
Strategic orientation	Innovation (compliance)	Laggard strategy Exploit the status quo and minimize R&D to cost-efficiently comply with public innovation policy	Early mover strategy Invest heavily in R&D to capture and maintain early market for innovation and exploit public innovation policy
	Political influence	Defensive strategy Engage in political influence to oppose public policy that threatens the status quo	Proactive strategy Engage in political influence to shape public innovation policy in ways beneficial to the firm

influence strategies of car manufacturers regarding the ZEV mandate. To study the interaction between corporate innovation and political influence strategies, we mapped their respective indicators over the timeframe 1990–2013 and qualitatively analyzed their interaction. The timeframe of study is split up in three periods describing the trends in innovation and political influence strategies, including period 1 (1990–1999), period 2 (2000–2006), and period 3 (2007–2013). As we discuss in Section 4, each of these periods includes two amendments to the ZEV mandate on which car manufacturers could exert influence, providing a balanced selection of periods.

For innovation strategies we focus on the R&D and commercialization activities, and for political influence strategies on the corporate political activities (CPAs); see the operationalization scheme in Table 2 on which we elaborate in the following subsections. R&D and commercialization activities measure different aspects of the innovation process, as R&D indicates the extent to which firms are exploring and further developing new technologies, while commercialization activities refer to the stage of (mass) market introduction. Innovation strategies relate to a specific technology and the technologies under study include: clean internal combustion engine vehicles (ICEVs), Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Neighborhood Electric Vehicles (NEVs), Electric Vehicles (EVs) and Hydrogen Fuel Cell Vehicles (HFCVs). Ranging from competence-enhancing to competence-destroying, these technologies are listed and described in Table 3.

Our study focuses on the six 'large volume' car manufacturers that sold more than 60,000 vehicles in California annually. These manufacturers were consistently subject to the full requirements of the ZEV mandate, as opposed to the 'intermediary volume' manufacturers that were subject to less stringent requirements. These six large car manufacturers are General Motors, Chrysler, Ford, Toyota, Honda and Nissan (CARB, 2012b). Although the analysis centered on these six firms, Chrysler's merger partners Daimler (1998–2007) and Fiat (2014-now) were also taken into account in the analysis because they may have influenced Chrysler's strategy.

Table 2
Indicators of R&D, commercialization and political influence activities.

Concept:	Indicator:	Database (per technology and firm)
R&D	Patent applications	Global Patent Index program from European Patent Office
Commercialization	Sales; fuel economy	US (and EU) production/sales figures for alternative vehicle technologies; CAFE
Corporate political activities	Arguments, litigation, compliance	ZEV mandate database: public hearing transcripts, public documents, letters to CARB and EPA, interviews, complementary sources

Table 3
Acronyms and descriptions of the sustainable automotive technologies included in this study, ranging from competence-enhancing (top) to competence-destroying (bottom).

	Technology	Description
Increasing competence-destruction	clean ICEV	Competence-enhancing, incremental innovations to reduce emissions and increase fuel economy of the Internal Combustion Engine Vehicle, e.g. start-stop systems and catalytic converts. Requires no infrastructural change
	HEV	Relatively competence-enhancing innovation that combines ICEV technology with energy recuperation and storage to support partial (mild-HEV) or full (full-HEV) electric driving without requiring infrastructural changes
	PHEV/EREV	Plug-in hybrids and extended range electric vehicles have a plug for external charging that enables diverging all-electric-driving-ranges before the ICEV takes over propulsion (with PHEV) or starts generating electricity (with EREV). Benefits from but is less dependent on recharging infrastructure
	NEV	Neighborhood Electric Vehicles are low speed, low performance EVs that resemble enhanced golf carts that require recharging infrastructure but can easily utilize home charging
	EV	Electric Vehicles are fully battery powered vehicles that require an external recharging infrastructure for operation
	HFCV	Hydrogen Fuel Cell Vehicles use fuel cell technology to power their full electric drivetrain which provide them with a larger action radius that EVs and require a hydrogen refueling infrastructure

3.2. Operationalization of R&D

Laggards do little R&D, whereas early movers invest heavily in R&D. To measure car manufacturers' R&D in each technology, we used patent application data, as patents are a good indicator for R&D activities (Archibugi and Pianta, 1996). Patents, as opposed to other indicators for R&D activities like media statements and prototypes, are used more for protecting valuable knowledge than for influencing stakeholders (Van den Hoed, 2005; Bakker, 2010). Moreover, as opposed to firms' R&D expenditures per technology which are often kept secret, patents are easily available over long time series enabling longitudinal analysis. A major drawback of patents as indicator for R&D activities is that tendencies to patent may differ over time and between countries, industries, firms and technologies (Oltra and Saint Jean, 2009; Van den Hoed, 2005; Archibugi and Pianta, 1996). Because of the drawbacks involved in patent analyses, our findings should be interpreted with caution. For example, interpretation should focus particularly on a combination of analyzing portfolio differences between firms, large differences in patent applications, patent fluctuations over time within one technology and firm, and differences between firms of similar cultural background.

Patent application data were obtained through the European Patent Office's Global Patent Index program which contains worldwide patent data (EPO, 2014). We applied the HEV, EV and HFCV queries from Wesseling et al. (2014a). For the PHEV query's basis we combined 'hybrid' with 'plug-in' and 'range-exten*', and the NEV query's basis comprised 'neighborhood electric', 'low-speed electric*' and 'low speed battery'. These basic queries were combined with the keywords combination '(vehicle OR car OR automobile)' within a two word proximity. No patents were found for the low performance NEVs. To identify the patent applications of innovations related to emission reduction and/or fuel economy improvement of clean ICEVs, we first reviewed the literature on such innovations (e.g. Alkidas, 2007; Taylor, 2008). Keywords representing these innovations were used in a newly established search query, in addition to more general keywords related to fuel economy and emissions and engine-related concepts. Car manufacturers' subsidiaries were included in the search queries.

We reduced the drawback of a time lag between invention and the patent by using the date the patent was filed for instead of the date the patent was granted. Because a significant number of patent

documents do not provide information on granting at the time of indexing (European Patent Office, 2013) patent applications were used instead of patent grants. We applied a publication level filter to ensure relevant patent applications. To prevent overlap in patent applications between technologies, we added mutually exclusive search strings to the basic search queries. Because patents covering different technological fields cannot be related to commercialization, which is always linked to one technology, and because the focus of this paper is on analyzing the interrelatedness of innovation and political influence strategies in different technological fields, patent applications belonging to more than one technological field were omitted from the analysis. Obtained patent applications were read to check for relevance to the technology category. For a more elaborate discussion on the search query formation, see Wesseling et al. (2014a).

3.3. Operationalization of commercialization

Where early movers are the first to commercialize innovations, while laggards lag behind and focus on cheap compliance options to prevent non-compliance penalties. The commercialization of alternative sustainable automotive technologies was measured using global vehicle sales data. Global data were used since there are large differences in the sales of these different technologies amongst countries and regions (IEA, 2013). Worldwide sales were obtained from the Marklines database (Marklines, 2014) and complemented with additional sources (e.g. ICCT, 2013; AFDC, 2013; Cole, 2014; PIA, 2006) to enhance the timeframe and increase accuracy of low volume sales data (<1,000).

To measure the commercialization of clean ICEVs, we did not use vehicle sales, because sales data do not account for the differences in environmental friendliness between cars. To better approach differences in the environmental friendliness of cars, we used Corporate Average Fuel Economy (CAFE) data of each manufacturer's car fleet. We controlled for the weight conform EPA and Ricardo measures (EPA, 2014b; Blanco, 2009) to remove weight-induced fuel efficiency bias. These data were obtained from the EPA (EPA, 2013). A disadvantage of using CAFE standards as a proxy is that they only represent the fuel economy in the US, where car manufacturers may sell different models with different fuel economies than in other regions. Hence, the CAFE standards may not be generalizable to the global level as our global sales data for the other technologies are. Additionally, fuel economy can be perceived as an imperfect measure for sustainability as it does not include tailpipe innovations that reduce emissions, like catalytic converters. A reflection on the drawbacks of this indicator is warranted when interpreting our findings.

3.4. Operationalization of corporate political activities (CPAs)

CPA data were collected by studying the comments car manufacturers used to influence the ZEV mandate over the period 1990–2013. Car manufacturers used these comments in different types of CPAs, such as (direct) lobbying, commissioning studies, having experts testify and in law suits. The comments were obtained from a database comprising 5 public hearing transcripts; 61 letters to CARB and 22 to letters EPA; 263 policy documents that include, amongst others, data on litigation. Complementary interviews with policy makers (7), car manufacturer representatives (7), and ZEV advocates (2) were used to contextualize the CPAs. For a more comprehensive overview see Wesseling et al. (2014b). We counted and aggregated all the car manufacturers' comments from each of these data sources and omitted any double counts. When these data sources did not provide sufficient information, additional sources were consulted including websites, literature and other documents.

Using content analysis on our comments database, we identified the various CPAs and attributed them to strategy categories. We used a priori coding (Weber, 1990) because our theoretical framework provided categorical guidelines. This framework suggests that defensive CPAs are comments aimed at opposing the ZEV mandate, while proactive CPAs are comments aimed at actively shaping the mandate. This coding approach still leaves room to slightly revise and tighten up these categories (Weber, 1990), and thus to identify potential subcategories. We checked for inter-coder reliability by having two independent researchers check our coding scheme. Our Krippendorff's alpha of 0.866 indicates the three coders have interpreted the data similarly (Krippendorf, 2004). The number of

comments was also used as a proxy for the strength of a political influence strategy, i.e. firms providing more comments are expected to try to exert more influence.

Since limited data were available over the 1990–1999 timeframe, analysis of the 1990s relies mostly on secondary data.

4. The ZEV mandate in the period 1990–2013

In this section we provide a short summary of the emergence and subsequent adaptations of the ZEV mandate. This summary is by no means exhaustive and more information might be found in for example Doyle (2000), Kemp (2005) and the documents cited in this section. The ZEV mandate was first issued in 1990 and mandated large volume car manufacturers to sell 2% of their fleet as ZEVs by 1998, 5% by 2001 and 10% by 2003. Strong political influence and infeasibility of the mandate resulted in 1996 in relaxation of the mandate, eliminating the temporary 'ramp up' years of 1998 and 2001, while maintaining the 2003 standard. Car manufacturers signed a memorandum of agreement to place a total of 3.750 demonstration EVs in the marketplace by 2001 (CARB, 1998). Further opposition resulted in the 1998 amendments that allowed clean ICEVs to comply with part of the mandate (CARB, 2000).

The 2001 amendments further relaxed the mandate, as CARB agreed with car manufacturers to include provisions (i.e. additional regulatory language) in the mandate that allowed HEVs to comply with part of the mandate and that raised credits for other technologies and vehicle types in different ways (CARB, 2001). A series of lawsuits led by GM and DaimlerChrysler resulted in the 2003 amendments. These amendments delayed the ZEV requirements by 2 years, offered further credit multipliers for different technologies and attempted to stop compliance through the relatively cheap NEVs, which policy makers believed did not contribute to technological and market development of ZEVs and were therefore perceived as a loophole (NRDC et al., 2008). Additionally, the amendments included an alternative compliance path that required only a limited amount of HFCVs instead of numerous EVs to comply with the mandate—making HFCV technology a relatively cheap compliance option (CARB, 2004) or loophole according to some (NRDC et al., 2008).

The 2008 amendments enabled EVs to also comply with the less stringent, alternative compliance path for HFCVs and included a special category for PHEVs in the ZEV mandate (CARB, 2008). The ZEV requirements were raised for the first time during the 2012 amendments. These amendments provided new credit categories; allowed car manufacturers over-complying with the greenhouse gas emissions requirements in the Clean Cars program to offset part of their ZEV requirement, but eliminated the clean ICEV category; discontinued the 'travel provision' for EVs by 2018, whereby car manufacturers could sell EVs in non-California states and earn credit toward the California ZEV requirements, effectively doubling the EV sales mandated. Under the political influence of car manufacturers and perceived as infeasible, the ZEV mandate has thus been continuously postponed, relaxed and shaped to fit multiple technologies.

5. Analysis

5.1. Introduction

Sections 5.2–5.5 discuss the responses of individual car manufacturers to the ZEV mandate in terms of their innovation and political influence strategies, structured along the periods 1 (1990–1999), 2 (2000–2006) and 3 (2007–2013). We analyzed the strategies of all six large volume manufacturers, but to avoid repetition of similar results, we describe only the four most distinct response strategies, which are those of Nissan, Toyota, GM and Chrysler. R&D strategies as first part of the innovation strategies are depicted in Figs. 2–5 that present per car manufacturer the absolute number of patent applications for each technology. Commercialization strategies as second part of the innovation strategies are depicted for ICEV technology in Fig. 1. This figure presents for the industry average, and per manufacturer, the weight controlled two-year moving average of corporate average fuel economy (CAFE) of passenger cars.

Through our iterative labelling of the data, we find that a lot of information is lost by maintaining the simple distinction in defensive/proactive influence comments by Oliver and Holzinger (2008).

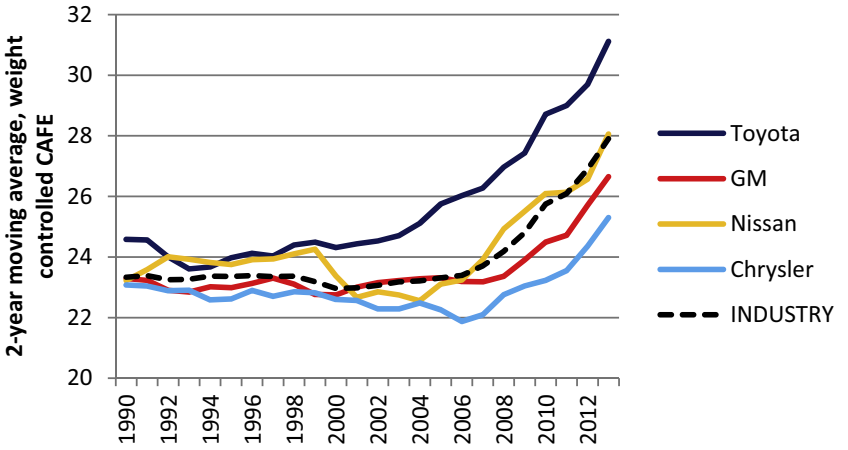

Fig. 1. 2-years moving average, weight controlled CAFE of General Motors, Chrysler, Toyota and Nissan, over the period 1990–2013 (*Source*: EPA, 2014c).

Instead, our qualitative analysis suggests a distinction between four types of comments in our dataset: (1) defensive comments to oppose the mandate; (2) defensive comments to slowdown and relax the mandate; (3) proactive comments to shape the mandate to benefit the firm's or disadvantage rivals' technology-specific compliance and innovation strategies; (4) proactive comments in support of the mandate. We apply this newly found typology throughout the remainder of this section. Table 4 provides an overview of the types of comments that we collected over the period 2000–2013 for each manufacturer, indicating how influential companies tried to be (i.e. how many comments they submitted) and what political influence comments were most dominant for each firm (underlined). Because no company-specific comments were available for period 1, this period has been omitted from Table 4 but is incorporated in the following subsections.

Table 4
Political influence comments on the ZEV mandate during the periods 2000–2006 and 2007–2013, categorized per type of strategy.

		Comments period 2 (2000–2006)	Comments period 3 (2007–2013)
GM	**Total # of comments**	**90**	**28**
	% Defensive (oppose)	84%	18%
	% Defensive (slowdown)	4%	25%
	% Proactive (shape)	10%	47%
	% Proactive (support)	0%	11%
Chrysler	**Total # of comments**	**45**	**39**
	% Defensive (oppose)	49%	17%
	% Defensive (relax)	15%	26%
	% Proactive (shape)	34%	46%
	% Proactive (support)	2%	11%
Toyota	**Total # of comments**	**55**	**54**
	% Defensive (oppose)	49%	19%
	% Defensive (slowdown)	22%	11%
	% Proactive (shape)	26%	21%
	% Proactive (support)	4%	50%
Nissan	**Total # of comments**	**6**	**31**
	% Defensive (oppose)	17%	0%
	% Defensive (slowdown)	33%	0%
	% Proactive (+shape tech)	33%	3%
	% Proactive (support)	17%	97%

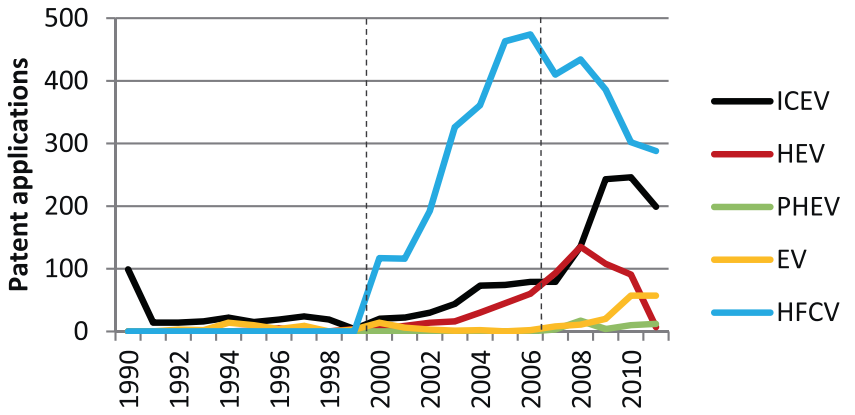

Fig. 2. General Motors' patent applications over 1990–2012.

In reflection, ranging from value maintenance to value creation it would be possible to identify an even more extreme value creating subclass of proactive political influence strategies, namely not just supporting but progressing the stringency of the regulation. Looking outside the scope of our firm selection, we found that Tesla Motors, a startup that builds only EVs, adopted this progressive strategy. Tesla sells its EV credits to rival car manufacturers so that they may comply with the regulation; a more stringent standard implies higher demand for EV credits and thus more profit for Tesla.

5.2. Innovation and political influence by General Motors

During period 1, GM believed that EVs might play a role in the future, and in 1990 tried to attain a first mover advantage by introducing an EV concept car and announcing production plans for the car (Hoogma, 2000; Kemp, 2005). However, when CARB issued the ZEV mandate that same year, GM's perspective on EV strategy quickly changed. During the 1990s General Motors had abandoned its original early mover EV strategy and changed to cost-efficient compliance; they would produce no more than 842 compliance EVs and they used their 'inability' to sell more as an argument to oppose the mandate (Boschert, 2006). Fig. 2 shows that in relation to later years GM was also doing little R&D, which focused mostly on clean ICEV technology. GM's fleet was also less fuel efficient than the industry average of the US' 10 largest car manufacturers, see Fig. 1. Instead of doing clean vehicle innovation, GM relied mostly on strong CPAs to oppose the regulation, using lobbying and, in a coordinated effort with Ford and Chrysler, litigation (Boschert, 2006; Fern, 1997). Hence, GM employed an opposition-oriented political influence strategy to complement its innovation strategy that failed in pioneering commercialization, and were subsequently limited to minor R&D.

During period 2, GM increased its innovative activities by intensifying and diversifying its sustainable R&D portfolio, while postponing mass commercialization. GM started focusing strongly on HFCVs and increased patenting in clean ICEVs and HEVs. Despite this R&D, GM did not improve its fleet's fuel economy past 1990 levels, see Fig. 1, nor did they sell any low emission vehicles (Marklines, 2014). As indicated by Table 4, GM continued its strong opposition-oriented political strategy using litigation and lobbying. GM employed two cheap short-term compliance strategies, leasing 5.000 NEVs for free and re-leasing previously built EVs, which they strongly supported through proactive lobbying. Trying to shape the mandate, GM also lobbied in favor of HFCVs, which supported their strongly HFCV-oriented R&D strategy, and lobbied against favorable HEV conditions, a technology in which they were lagging behind. In sum, during period 2 GM combined a mainly opposition-oriented political influence strategy to protect its vested interests, with innovation strategies limited to R&D and preventing non-compliance penalties.

GM became more innovative during period 3, increasing its sustainable R&D and moving first in commercialization of PHEVs, having sold over 70,000 units worldwide between 2011 and January 2014

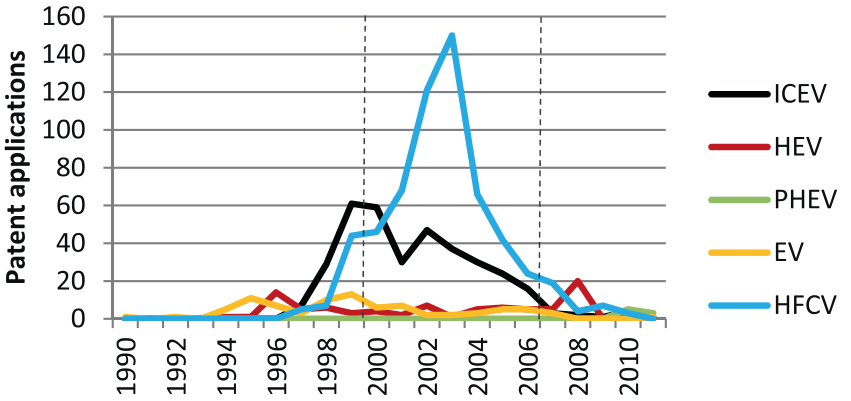

Fig. 3. Chrysler's patent applications over 1990–2012.

(Cobb, 2014). GM's HEV sales were less successful and averaged 1.300 units annually (*Ibid.*). GM's R&D in clean ICEVs peaked in 2010 and resulted in a 3-miles-per-gallon improvement of its CAFE, which is still below the industry average (Fig. 1). To comply with the mandate, GM not only sold numerous PHEVs, but also launched a fleet of 119 highly credited HFCVs (Duffer, 2014) and bought numerous EV and HEV credits from Tesla, and Toyota and Honda respectively (CARB, 2013). Table 4 shows that in period 3 GM dropped its opposition-oriented influence strategy and focused more on lobbying to relax and shape the mandate to gain regulatory support for their PHEV. GM no longer lobbied for HFCV support in 2012 when HFCV patent applications dropped heavily, which may indicate that GM is abandoning its HFCV strategy. Because of its below-industry-average CAFE, GM opposed the over-compliance option in the 2012 amendments, which would benefit its more fuel efficient competitors. To conclude, as GM became more innovative and started successfully commercializing PHEVs, they reduced their opposition-oriented political influence and focused on shaping the mandate in favor of their early mover PHEV strategy.

5.3. *Innovation and political influence by Chrysler*

Fig. 3 shows that Chrysler started their limited R&D in clean vehicles in 1995, focusing initially on EVs and HEVs; then switching to ICEV and HFCV technology by the late 1990s. Chrysler also lagged behind in fuel efficiency, see Fig. 1. To comply with the ZEV mandate, they leased 207 converted EVs (PIA, 2006). Daimler's plans to sell EVs were cancelled when they merged with Chrysler in 1999 (Boschert, 2006). Chrysler adopted an opposition-oriented political strategy during period 1, using lobbying and litigation to influence the mandate (Boschert, 2006; Collantes, 2006). Overall, like GM in period 1, Chrysler engaged in opposition-oriented political influence to protect its very weak, R&D-oriented innovation strategy that focused on preventing non-compliance penalties.

During period 2, Chrysler's R&D peaked, focusing mainly on HFCVs and clean ICEVs, see Fig. 3. Chrysler's weight-controlled CAFE started lagging further behind on the industry average (Fig. 1) and as various interviewees indicated, commercialization was limited to Chrysler's NEV-oriented short-term compliance strategy of selling thousands of NEVs produced in collaboration with NEV manufacturer GEM. For compliance Chrysler also relied on its partner Daimler's HFCV credits (Sperling, 2001). While complying, Chrysler was opposing and trying to relax the ZEV mandate through lobbying, see Table 4, and litigation (CARB, 2004). In addition to this mandate-wide defensive strategy, Chrysler was also trying to shape the mandate at the technology-specific level by lobbying to support their NEV-oriented short-term compliance strategy and their clean ICEV and HFCV-oriented R&D strategies[1] (CARB, 2001,

[1] Both the compliance through NEVs and low-volume HFCVs were perceived as loopholes by some organizations (NRDC et al., 2008).

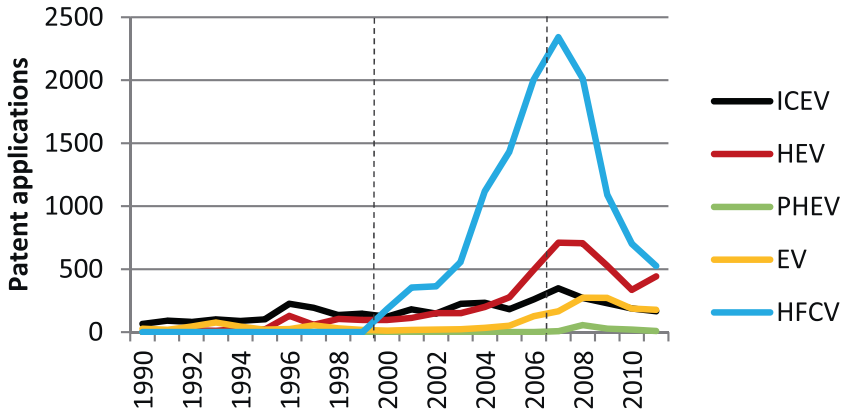

Fig. 4. Toyota's patent applications over 1990–2012.

2004). They also lobbied against regulatory provisions that disproportionally benefitted their competitors, like the early phase-in multipliers for re-leased EVs and the HEV category (CARB, 2001, 2004). Chrysler thus continued their mainly opposition-oriented political influence strategy in period 2 to protect their interests, and enhanced its shaping-oriented influence strategy to support their laggard strategy of minimal R&D and preventing non-compliance penalties.

Chrysler's clean vehicle R&D dropped drastically during period 3, see Fig. 3, and Chrysler's CAFE continued to fall farther behind on its competitors' (Fig. 1). In 2007 Chrysler split from Daimler and after filing for bankruptcy in 2009 was slowly bought up by Fiat until wholly owned in 2014 (Flak, 2014). Having introduced no clean vehicles under the Chrysler brand other than ICEVs and NEVs (Marklines, 2014), Chrysler relied on the EV credits it bought from Tesla and got from Fiat (Voelcker, 2014; CARB, 2013). Despite its lack of innovation, Chrysler lessened its political opposition, lobbying instead to slowdown and relax the mandate (CARB, 2012a). Chrysler tried to shape the mandate by lobbying to protect its NEV credits and lobbying in favor of HFCVs and plug-in technologies, although Chrysler never introduced more than 109 PHEVs (Chrysler, 2012). Chrysler also lobbied against the over-compliance option that would disproportionally benefit its competitors with a better CAFE (CARB, 2012a). Hence, throughout the timeframe 1990–2013, Chrysler's political influence strategy has focused increasingly on shaping the mandate to support their continued laggard innovation strategy.

5.4. Innovation and political influence by Toyota

During period 1, Toyota steadily increased its clean vehicle R&D, focusing on ICEVs, a little on EVs and later also HEVs. Resulting from its mainly clean-ICEV-oriented R&D strategy, Toyota had a fairly fuel efficient vehicle fleet, see Figs. 1 and 4. To comply with the mandate, Toyota marketed 320 RAV4 EVs and would not meet the reportedly higher demand (Hoogma, 2000, p. 267). They also moved first in HEV commercialization, launching its Prius HEV in Japan and in the US in 1997 and 2000, respectively (Toyoland, 2014). Toyota did not try to shape the mandate by lobbying for HEV credits until the 2001 ZEV amendments (CARB, 2001). Instead, they lobbied defensively against the ZEV mandate during period 1 (Hoogma, 2000, p. 266; Collantes, 2006). Toyota thus combined a compliance EV strategy and early mover clean-ICEV and HEV innovation strategies with a defensive political influence strategy against a mandate that required ZEVs, because Toyota did not perceive ZEVs as profitable.

Toyota increased its R&D in clean ICEV, HEV and particularly HFCV technology in period 2, see Fig. 4. Toyota's annual HEV sales averaged over 80,000 during this time (Marklines, 2014), while their CAFE continued to improve more strongly than the industry average (Fig. 1). As of 2001, Toyota accumulated ZEV credits using various generations of HFCV test fleets (Toyota, 2007). Politically, Toyota maintained a defensive, particularly opposition-oriented, political influence strategy in period 2, see

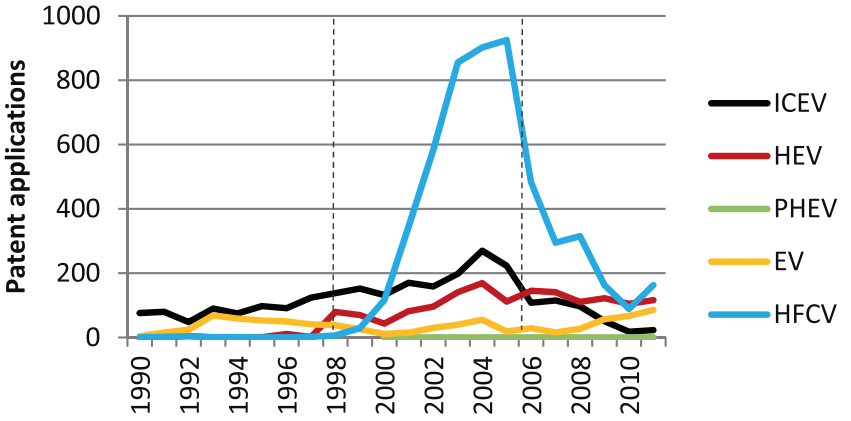

Fig. 5. Nissan's patent applications over 1990–2012 (excluding those of Renault).

Table 4. Toyota also tried to shape the mandate by lobbying in favor of (1) HEVs to support its first mover HEV strategy; (2) HFCVs to support its strong R&D and compliance strategy; (3) clean ICEVs to support their lead in clean ICEVs (CARB, 2001, 2004). During period 2, Toyota thus became more innovative in the fields of clean ICEVS, HEVs and HFCVs which is reflected in their shaping strategy oriented at supporting these early mover strategies. Other than that, Toyota's political influence strategy remained predominantly defensive.

Toyota's R&D efforts peaked in 2007–2008, see Fig. 4, while its commercialization efforts continued to increase and became more diverse. Toyota continued to lead in HEVs, with global annual sales exceeding 1,100,000 in 2012 (Marklines, 2014). Additionally, Toyota adopted a quick follower PHEV strategy, launching its PHEV Prius in 2012 (two years after GM) and selling over 20,000 units that year (Marklines, 2014). Also in terms of CAFE, Toyota continued to outperform its rivals (Fig. 1). They also started selling their compliance RAV4 EV in 2012, built in collaboration with EV startup Tesla, although sales have been far below the 2.800 unit target (Crowe, 2013). During period 3, Toyota became more supportive of the ZEV mandate, see Table 4. Toyota tried to shape the mandate by lobbying in support of its quick follower PHEV strategy and its HFCV R&D and compliance-oriented strategy. In sum, Toyota's trend of increasing innovativeness coincides with a trend away from a defensive and toward a proactive, mainly supportive, political influence strategy.

5.5. *Innovation and political influence of Nissan*

Fig. 5 shows that during period 1, Nissan was already engaging in R&D in clean ICEV, EV and, as of 1997, also HEV technology. Nissan also had an above average CAFE, see Fig. 1. To comply with the memorandum of agreement, they marketed approximately 210 compliance EVs in 1998 (Nissan, 2009; PIA, 2006). Already investing strongly in clean vehicle technologies, Nissan lobbied only moderately defensively against the ZEV mandate in 1996, leaving the stronger opposition to its competitors (Hoogma, 2000, p. 266). Hence, Nissan combined relatively strong R&D strategies (idiosyncratic to early movers) with a mildly defensive political influence strategy during the first period.

During period 2, Nissan further increased its R&D in clean ICEV, HEV and particularly HFCV technology, at the costs of EV technology—see Fig. 5. Nissan's CAFE actually dropped significantly during this time to below the industry average (Fig. 1). Not having moved into mass commercialization yet, Nissan complied with the mandate through re-lease of EVs and testing of HFCVs (Nissan, 2002). Table 4 shows that Nissan provided only 6 comments to influence the ZEV mandate, indicating they adopted a weak political influence strategy in period 2. Nissan did try to shape the mandate by lobbying in favor of HEV credits (although their HEV sales never really took off) and in favor of their EV compliance strategy (CARB, 2001, 2004). Overall, although particularly R&D oriented, Nissan did become more innovative and adopted a less influential political strategy.

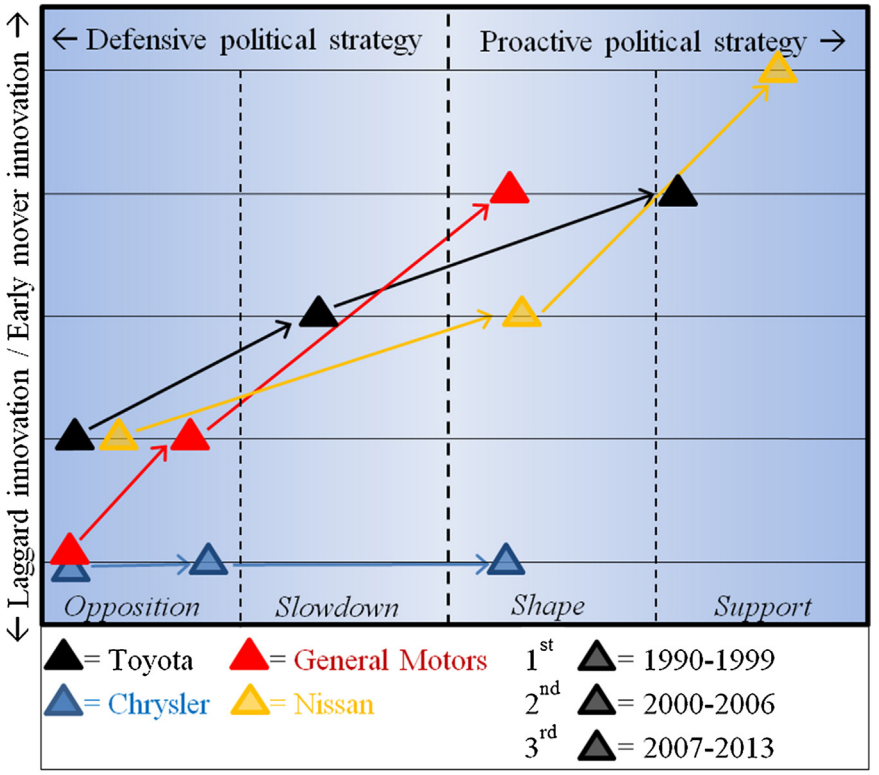

Fig. 6. Changes in the innovation and political influence strategies of the car manufacturers in response to the ZEV mandate over the periods 1990s, 2000–2006 and 2007–2013.

Nissan reduced its R&D activities in period 3, although they increased EV patenting. Nissan adopted a first mover EV strategy, mass commercializing the first purpose build EV, the Leaf, by late 2010 and becoming EV market leader by selling 100,000 units by January 2014 (Cobb, 2014). Nissan's CAFE has been slightly above average during this period and their annual HEV sales increased to 35,000 in 2012. During this period, Nissan's first mover EV innovation strategy, enabling long-term compliance, is reflected in their political strategy, which was very supportive of the ZEV mandate and included lobbying in favor of EVs, see Table 4. Throughout the timeframe 1990–2013 Nissan became increasingly innovative and its initially defensive political influence strategy became strongly oriented toward support for the mandate.

5.6. Reflecting on the conceptual framework

Sections 5.2–5.5 show that car manufacturers indeed use different strategies at the same time. Fig. 6 inventories the different strategies used by each car manufacturer over the three periods, placing the innovation strategy on the *y*-axis and political influence strategy on the *x*-axis. The figure shows that car manufacturers initially combined laggard innovation and defensive political influence strategies and adopted steadily more early mover innovation and proactive political influence strategies over time (hence the diagonal development). In other words, in response to the technology-forcing regulation under study, car manufacturers combine innovation and political influence strategies of either value maintenance (laggard and defensive) nature or value creation (early mover and proactive) nature. Over time, their strategies changed from value maintenance to value creation.

Only Chrysler deviates from this trend as their political influence strategy became less defensive over time, without becoming more innovative. Chrysler's lack in innovation may be explained by their financial struggles and their dependency for innovation on take-over partners Daimler and Fiat (Flak, 2014), which may have prevented the company from making the necessary large investments in ZEV technologies. The fact that Chrysler became politically less defensive over time may be explained by their increased government-dependence, created through their bail-out in this period.

Through our detailed analysis of car manufacturers' political influence comments we also refined Oliver and Holzinger's (2008) typology of political influence strategies. Ranging from value maintenance to value creation, we identified subclasses of defensive (opposition and slow down) and proactive influence strategies (shape and support) which are still very different and provide more thorough insights in corporate strategies. Our analysis of the individual car manufacturers showed this is a useful refinement of the strategy typology and that specific combinations with innovation strategies can be identified. The following is a reflection on these subclasses of political influence strategies and their relation to corporate innovation strategies.

We found that the least innovative firms used 'opposition influence strategies' on technology-forcing policy intervention to maintain the value of their core technology investments, prevent themselves from being forced to innovate and reduce the competitive disadvantage resulting from a lack of innovation. GM and Chrysler for example challenged the ZEV mandate in court to protect their interests. The other way around, laggard innovation strategies also supported credible defensive political influence strategies, as car manufacturers used the inability to innovate as an argument to oppose the regulation, i.e. 'fact based lobbying'.

When firms are unable to prevent regulatory change, they may employ 'slowdown influence strategies' to slowdown and/or relax regulatory change, allowing the firm to maintain value for as long as possible while buying time for their innovation strategies to create new value. To illustrate, various car manufacturers advocated less stringent and slower ramp-up of ZEV standards, and compliance through less radical and less systemic technologies.

More innovative firms already betting on certain technologies to comply with the regulation tended to employ 'shaping influence strategies' to shape the regulation in ways that benefit their technology-specific innovation strategies. General Motors for example lobbied for higher PHEV credits to support its early mover PHEV innovation strategy. A shaping strategy can however also be used to try and maintain or create loopholes in the mandate, to support cheap compliance through laggard innovation strategies. Chrysler for example lobbied to maintain the NEV credit category.

Still more innovative firms that have no trouble complying with the technology-forcing regulation and therefore require no further shaping of the regulation, may employ a 'support political influence strategy' to support the successful implementation of the regulation. An incentive for supporting the regulation is to increase the cost of compliance for their rivals, generating an indirect competitive advantage[2]. During the 2012 ZEV amendments, Nissan for example supported the mandate as a whole because it was moving first in commercializing ZEVs.

6. Conclusion and discussion

In this paper, we have designed and applied a new conceptual framework on corporate innovation and political influence strategies in response to public innovation policy. We did this for a case of technology-forcing regulation in the automotive industry. In doing so, this case study provides some new insights and contributions to the literature. First, we show that firms combine innovation and political influence strategies to exploit strategic synergies. More specifically, they combine value maintaining innovation and political influence strategies, and they combine value creating innovation and political influence strategies. This finding adds to the strategy framework of Oliver and Holzinger (2008), who positioned different types of strategies as independent. Second, we find that firms changed their strategies over time, generally from value maintaining strategies to value creating

[2] We perceive statements of support as an influence strategy, because it provides policy makers the legitimacy to push regulation, despite opposition by other firms.

Table 5
Corporate response strategies to public innovation policy, as identified in this case study on technology-forcing regulation.

		Value perspective				
		Value maintenance		Value creation		
Strategic orientation	Innovation (compliance)	Laggard strategy Exploit the status quo and minimize R&D to cost-efficiently comply with public innovation policy		Early mover strategy Invest heavily in R&D to capture and maintain early market for innovation and create a competitive advantage under public innovation policy		
	Political influence	Defensive strategies		Proactive strategies		
		Opposition Oppose public innovation policy to protect incumbent technology	Slowdown Slowdown and/or relax public policy for innovation strategy to 'catch up'	Shaping Shape public innovation policy in favor of innovation strategy	Support Support public innovation policy that is advantageous to the firm	Progressive Increase stringency of public policy that is advantageous to the firm

strategies. Third, we refine Oliver and Holzinger's (2008) typology of political influence strategies by introducing subcategories of the defensive political influence strategies – namely opposition and slowdown strategies – and of the proactive political influence strategies—namely shaping and support strategies. These subclasses of political influence strategies show clear synergies in combination with specific innovation strategies. Table 5 incorporates these subclasses into our conceptual framework on corporate response strategies to public innovation policy.

In reflection on our indicators, we note that using patent applications as an indicator for R&D activities brings about some drawbacks. Differences in tendency to patent between technologies, firms and over time may affect our data. As discussed our use of CAFE as an indicator for the commercialization of clean ICEVs also has some pitfalls, related to limited generalizability to the global level and its imperfect approximation of environmental friendliness. Furthermore, differences between the innovation strategies of globally-oriented car manufacturers may be explained by differences between their most important market regions, in terms of consumer preferences and regulatory frameworks. Hence, we do not suggest that the ZEV mandate was the sole determinant for car manufacturers' innovation strategies. For these reasons, our findings should be interpreted with care.

In order to enhance further studies in this field, it would be fruitful for future research to develop more accurate measures for the R&D activities of firms in different technological fields, i.e. measures that account for differences in tendency to patent. Future research would also benefit from a more accurate and more widely available measure of the environmental friendliness of ICEVs. Examples are emissions measured in grams per kilometer or per kW h, which are used as indicators in for example European public policies. This would be a useful measure if it became available over longer time series and for larger regions.

Our conceptual framework on corporate response strategies to public innovation policy, displayed in Table 1, has in this case study only been tested for a case of technology-forcing regulation. A fruitful area of further research would be to test whether we find similar corporate responses to other types of innovation policy. It is likely that incumbents perceive rewarding policies, like R&D subsidies and tax rebates as less of a threat than the penalizing technology-forcing regulations. Rewarding policies may therefore result in less industry opposition. It would be worthwhile to study whether innovation and political influence strategies also show a similar interrelatedness in other types of public innovation policies that drive sustainability transitions.

Another recommendation for further research would be to study the role of societal (landscape) factors on changes in corporate strategies. Societal factors, like the increasing acknowledgement and importance of the existence of climate change policies throughout society are likely to reduce opposition by firms against public policy on sustainability. Additionally, regional regulatory and market influences other than the Californian ZEV mandate would be a useful complement to future studies aiming to understand how globally-oriented firms respond to public innovation policies.

Other factors, like Tesla showing policy makers that EVs can be made profitable in niche markets, may also have affected car manufacturers' opposition strategies. Eventually the goal is to gain a comprehensive understanding of why incumbents change their strategies.

By studying the interplay between and changes in innovation strategies and political influence strategies this study provides useful insights into the role of incumbents facing socio-technical changes supported by technology-forcing policy interventions. We found that incumbent car manufacturers could significantly slow down the transition to a more sustainable mobility system by opposing technology-forcing regulation and limiting innovation to cheaper compliance options. However, over time these incumbents invested in different, emerging clean vehicle technologies. To support these diverging innovation strategies, their political influence strategies became more proactive and oriented at supporting and shaping the ZEV mandate to the benefit of their individual, technology-specific innovation strategies. As new clean vehicle technologies were developed and car manufacturers engaged in 'shaping' political influence strategies, the mandate transformed to accommodate compliance through these alternative technologies. This transformed policy in turn triggered a new round of industry responses. Hence this case study shows that corporate strategies and regulatory developments may co-evolve. Eventually, the incumbent car manufacturers' innovative activities and increasing regulatory support facilitated the technological, market and regulatory developments needed to transition toward a more sustainable mobility system.

From this case study we find that policy makers may expect initial opposition to technology-forcing regulations. However, as innovations develop and technological competition becomes stronger, incumbents may start to focus on shaping policy interventions instead of opposing them. Decreased opposition, in turn, creates legitimacy for policy makers to ramp up their targets and regulations.

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